Distribution, Abundance and Composition of Zooplankton in the South China Sea, Area II: Sabah, Sarawak and Brunei Darussalam Waters

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ABSTRACT

The samples of 79 stations in Sarawak, Sabah and Brunei Darusalam waters were collected by M.V.SEAFDEC on 4 July - 9 August 1996 and on 25 April - 31 May 1997. Thirty-eight groups of zooplankton were found in this study. Copopoda dominated the zooplankton population, followed by Ostracoda and Chaetognatha in both period. Biomass vary from 0.11-1.54 ml/m^3 (average 0.44±0.25) and 0.09-1.76 ml/m^3 (average 0.45±0.33) in July and May respectively. Abundance vary from 72-681 no/m^3 (average 232±125) and 35-1,383 no/m^3 (average 251±216) in July and May respectively. T-test shows no significant difference of biomass and abundance between July and May.

Key words Zooplankton, biomass, abundance, Sarawak, Sabah, Brunei Darussalam

Introduction

It is generally recognized that zooplankton occupy an important role in the economy in the sea, both as consumer of phytoplankton and as contributors to the next higher trophic levels. Numerous studies have shown that small zooplankton (e.g. copepods, tintinnids, cladocerans, larval molluscs) are important component of larval fish food [Houde & Lovdal (1982)], [Balbontin, *et al.* (1986)], [Anderson (1994)]. Hence, variation in the availability of these organisms has been hypothesized to be related to the larval survival and the subsequent recruitment to the adult population of marine fishes [Cushing (1975)].

Few papers are studied in Sarawak, Sabah and Brunei Darusalam waters. Most of them worked on fisheries [Beales (1982)], [Lee (1982)], [Wong (1982)]. Some investigated on heavy metal in sediment [Imail (1993)]. Thus the distribution and composition of zooplankton in this areas is poorly known. However, there were many papers worked on the seasonal abundance and distribution of zooplankton in the nearby areas such as the Gulf of Thailand [Brinton (1963), [Suvapepun (1977)], [Suwanrumpha (1980)].

The propose of the present investigation is to describe the zooplankton community in Sarawak, Sabah and Brunei Darusalam waters, and provide an estimation of abundance, composition, biomass and their distribution.

Method

The samples of 79 stations in the Sarawak, Sabah and Brunei Darusalam waters were collected by M.V.SEAFDEC on 4 July - 9 August 1996 and on 25 April - 31 May 1997 (Table 1 & Fig. 1). Plankton was collected using 0.03 mm mesh net attached to 60 cm. diameter bongo frames. A flow-meter, attached within the aperture of the net, measured the amount of water filtered. At each station a 30 minutes oblique tow of the bongo net was made with the ship speed was about 2 knots. The depth of the haul was 5 meters above the sea bottom for the station that the depth less than 155 meters and 150 meters for the station that the depth over than 155 meters except in the strong current station, the hauling depth was 120 meters.The samples were preserved in 10 % buffered formalin-seawater immediately. In the laboratory, the displacement volume of total zooplankton was measured after large gelatinous zooplankton had been removed. The samples were subsampled with Falsom Plankton Splitter and then count to taxon. Data on biomass and abundance were standardized per cubic metre.

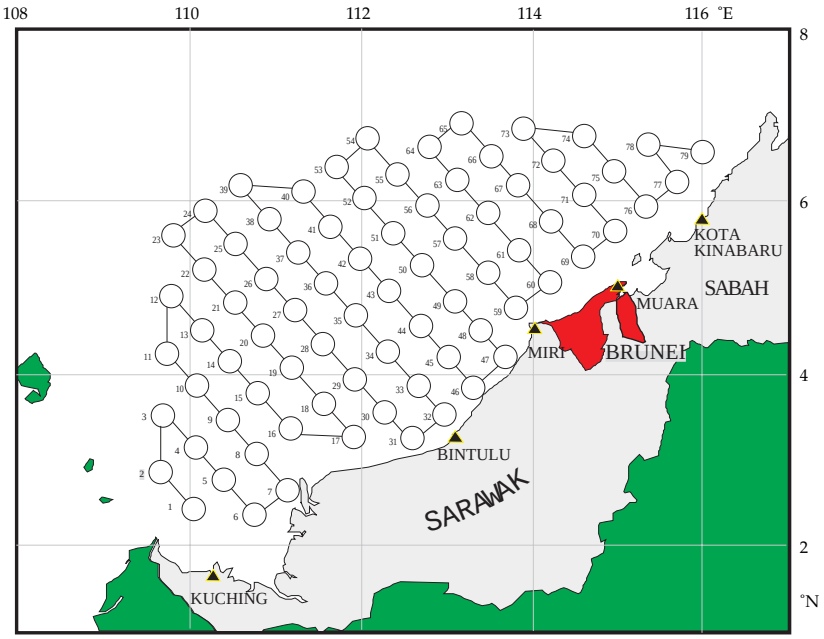

Fig. 1 79 sampling stations off Sarawak, Sabah and Brunei Darussalam

Results

Biomass and abundance of total zooplankton

July period

Biomass and abundance of total zooplankton were showed in Appendix A (Fig. A1 and A2). Biomass vary from 0.11-1.54 ml/m^3 (average 0.44±0.25) that station 31 (near Bintulu) has the highest biomass. Zooplankton biomass quite high in Sarawak's water and near Kota Kinabaru which were neritic zone. Abundance vary from 72-681 no/m^3 (average 232±125) and station 31 (near Bintulu) also has the highest abundance due to high number of siphonophora, medusae, cladocera, salp and thecosomes.

May period

Biomass and abundance of total zooplankton were showed in Appendix A (Fig. A1 and A2). Biomass vary from 0.09-1.76 ml/m^3 (average 0.45±0.33) which station 7 has the highest biomass. Zooplankton biomass quite high in Sarawak's water than in Sabah and Brunei Darusalam water. Abundance vary from 35-1383 no/m^3 (average 251±216) which station 7 has the highest abundance due to high number of siphonophora, medusae, chaetognatha, copepod, *Lucifer* spp. and bivalves larvae.

In May, abundance of zooplankton in Sarawak water was higher than other areas but in July the abundance showed not much difference among 3 areas.

In comparison of plankton biomass collected in July and May, it was found that biomass in May was higher than that in July at 29 stations (36.71 %) which 37 stations (46.84 %) had lower biomass and 13 stations (16.46 %) were not different. The abundance in May was higher than that in July at 32 stations (40.51 %) and zooplankton abundance in May was less than that in July at 37 stations (46.84 %) while 10 stations (12.66 %) was not different (Table 3 and 4). However, T-test of biomass and abundance of zooplankton between July and May indicated that the difference was not significant (Table 5).

Table 1 Information of all survey stations in the Area II

Stn. No.	Date	Time	Date	Time	Position		Depth
					Latitude	Longitude	(m)
1	7/10/96	0606-0638	5/1/97	0555-0625	02-20.0 N	110-00.0 E	36
2	7/10/96	1029-1100	5/1/97	1027-1053	02-42.8 N	109-40.3 E	54
3	7/10/96	1624-1652	5/1/97	1548-1618	03-25.3 N	109-43.3 E	79
4	7/10/96	2040-2108	5/1/97	2035-2100	03-02.5 N	110-03.0 E	66
5	7/11/96	0600-0603	5/2/97	0550-0618	02-39.8 N	110-22.6 E	85
6	7/11/96	1021-1048	5/2/97	1008-1033	02-17.0 N	110-42.3 E	41
7	7/11/96	1447-1506	5/2/97	1404-1432	02-36.8 N	111-04.9 E	35
8	7/11/96	1853-1918	5/2/97	1822-1850	02-59.5 N	110-45.3 E	39
9	7/12/96	0548-0618	5/3/97	0554-0624	03-22.3 N	110-25.6 E	65
10	7/12/96	1013-1043	5/3/97	1015-1045	03-45.1 N	110-05.9 E	85
11	7/12/96	1428-1503	5/3/97	1440-1509	04-07.8 N	109-46.2 E	100
12	7/12/96	2016-2044	5/3/97	2017-2045	04-50.3 N	109-49.2 E	118
13	7/13/96	0539-0607	5/4/97	0550-0616	04-27.6 N	110-08.9 E	115
14	7/13/96	1003-1033	5/4/97	1006-1035	04-04.8 N	110-28.6 E	94
15	7/13/96	1417-1443	5/4/97	1418-1446	03-42.1 N	110-48.3 E	66
16	7/13/96	1836-1901	5/4/97	1837-1906	03-19.3 N	111-07.9 E	62
17	7/14/96	0703-0723	5/5/97	0550-0620	03-16.3 N	111-50.3 E	29
18	7/14/96	1120-1145	5/5/97	1014-1043	03-39.1 N	111-30.6 E	50
19	7/14/96	1559-1626	5/5/97	1420-1448	04-01.8 N	111-10.9 E	70
20	7/14/96	2030-2100	5/5/97	1833-1901	04-24.6 N	110-51.2 E	89
21	7/15/96	0539-0608	5/6/97	0549-0619	04-47.3 N	110-31.5 E	117
22	7/15/96	0957-1025	5/6/97	1006-1034	05-10.1 N	110-11.8 E	145
23	7/15/96	1409-1439	5/6/97	1436-1505	05-32.8 N	109-52.0 E	145
24	7/15/96	1839-1907	5/6/97	1852-1922	05-52.6 N	110-14.8 E	530
25	7/16/96	0537-0605	5/7/97	0545-0615	05-29.9 N	110-34.5 E	207
26	7/16/96	1013-1042	5/7/97	1002-1032	05-07.1 N	110-54.2 E	123
27	7/16/96	1431-1500	5/7/97	1421-1449	04-44.4 N	111-13.9 E	95
28	7/16/96	1852-1921	5/7/97	1835-1905	04-21.6 N	111-33.7 E	80
29	7/17/96	0540-0610	5/8/97	0550-0620	03-58.9 N	111-53.4 E	57
30	7/17/96	1011-1040	5/8/97	1010-1037	03-31.5 N	112-08.0 E	32
31	7/17/96	1910-1936	5/9/97	1924-1950	03-13.4 N	112-32.7 E	22
32	7/19/96	0537-0605	5/10/97	0547-0614	03-33.1 N	112-55.4 E	32
33	7/19/96	1004-1032	5/10/97	0948-1017	03-55.9 N	112-35.7 E	48
34	7/19/96	1423-1451	5/10/97	1410-1440	04-18.6 N	112-16.0 E	71
35	7/19/96	1839-1908	5/10/97	1838-1908	04-41.1 N	111-56.3 E	87
36	7/20/96	0540-0608	5/11/97	0549-0618	05-04.1 N	111-36.6 E	109
37	7/20/96	1018-1047	5/11/97	0957-1027	05-26.9 N	111-16.8 E	446
38	7/20/96	1440-1510	5/11/97	1434-1504	05-49.6 N	110-57.1 E	1063
39	7/20/96	1930-1958	5/11/97	1925-1955	06-12.4 N	110-37.3 E	1234
40	7/21/96	0538-0608	5/12/97	0547-0617	06-09.4 N	111-19.8 E	922
41	7/21/96	1020-1050	5/12/97	1016-1046	05-46.6 N	111-39.6 E	1300
42	7/21/96	1510-1540	5/12/97	1450-1520	05-23.9 N	111-59.3 E	132
43	7/21/96	1923-1953	5/12/97	1857-1925	05-01.1 N	112-19.0 E	105
44	7/22/96	0537-0605	5/13/97	0547-0617	04-38.4 N	112.38.7 E	90
45	7/22/96	1000-1028	5/13/97	0940-1010	04-15.6 N	112-58.5 E	67
46	7/22/96	1422-1442	5/13/97	1344-1412	03-52.9 N	113-18.1 E	22
47	7/22/96	1819-1840	5/13/97	1740-1809	04-12.7 N	113-40.8 E	28
48	7/24/96	0848-0918	5/15/97	1250-1320	04-35.4 N	113-21.1 E	79
49	7/24/96	1258-1328	5/15/97	1705-1734	04-58.2 N	113-01.4 E	105
50	7/24/96	1719-1748	5/15/97	2113-2143	05-20.9 N	112-14.7 E	520
51	7/25/96	0540-0610	5/16/97	0547-0617	05-43.2 N	112-21.0 E	192
52	7/25/96	1002-1032	5/16/97	1004-1034	06-06.4 N	112-02.2 E	1650
53	7/25/96	1519-1592	5/16/97	1504-1534	06-29.2 N	111-42.4 E	1941
54	7/25/96	2054-2123	5/16/97	2021-2051	06-48.9 N	112-05.2 E	2008
55	7/26/96	0542-0612	5/17/97	0546-0616	06-26.2 N	112-24.9 E	1318
56	7/26/96	1026-1056	5/17/97	1030-1100	06-03.4 N	112-44.7 E	1136
57	7/26/96	1500-1529	5/17/97	1504-1534	05-40.7 N	113-04.5 E	2355
58	7/26/96	2009-2038	5/17/97	2047-2117	05-17.9 N	113-24.3 E	1622
59	7/27/96	0538-0607	5/18/97	0549-0619	04-55.2 N	113-43.9 E	95
60	7/27/96	0947-1017	5/18/97	1000-1030	05-15.0 N	114-06.6 E	235
61	7/27/96	1403-1434	5/18/97	1539-1609	05-37.7 N	113-46.9 E	2142
62	7/27/96	1910-1939	5/18/97	2040-2110	06-00.5 N	113-27.1 E	2567
63	7/28/96	0540-0608	5/19/97	0547-0617	06-23.2 N	113-07.4 E	1623
64	7/28/98	1050-1120	5/19/97	1009-1039	06-46.0 N	112-47.6 E	1261
65	7/28/96	1532-1602	5/19/97	1430-1500	07-05.7 N	113-10.4 E	1535
66	7/28/96	2013-2044	5/19/97	1858-1928	06-43.0 N	113-30.1 E	1883
67	7/29/96	0542-0612	5/20/97	0549-0618	06-20.2 N	113-49.9 E	2820
68	7/29/96	1055-1125	5/20/97	1032-1102	05-57.5 N	114-09.7 E	1785
69	7/29/96	1547-1617	5/21/97	2104-2134	05-34.7 N	114-29.4 E	100
70	7/29/96	2014-2044	5/22/97	0548-0618	05-54.5 N	114-52.1 E	125
71	7/31/96	1359-1430	5/22/97	1008-1038	06-17.2 N	114-32.4 E	2078
72	7/31/96	1811-1841	5/22/97	1500-1530	06-40.0 N	114-12.6 E	2867
73	7/31/96	2327-2358	5/22/97	1937-2007	07-02.7 N	113-52.8 E	1836
74	8/1/96	0855-0925	5/23/97	0546-0616	06-59.8 N	114-35.4 E	2893
75	8/1/96	1408-1439	5/23/97	1035-1105	06-37.0 N	114-55.2 E	1751
76	8/1/96	1910-1940	5/23/97	1504-1534	06-14.3 N	115-14.9 E	111
77	8/2/96	0537-0607	5/24/97	0551-0620	06-34.0 N	115-37.7 E	95
78	8/2/96	1006-1037	5/24/97	1006-1036	06-56.8 N	115-17.9 E	1498
79	8/2/96	1616-1647	5/24/97	1545-1612	06-53.8 N	116-00.4 E	42

Table 2 Biomass of zooplankton (ml./m^3) in Sarawak, Sabah and Brunei Darussalam waters

Station	July	May	Station	July	May	Station	July	May
1	0.61	0.88	**28**	0.84	0.71	**55**	0.44	0.31
2	0.94	0.65	**29**	0.91	0.60	**56**	0.25	0.23
3	0.57	0.35	**30**	0.77	0.77	**57**	0.19	0.29
4	0.52	0.76	**31**	1.54	1.38	**58**	0.24	0.18
5	0.92	0.52	**32**	0.71	0.35	**59**	0.34	0.29
6	0.93	0.78	**33**	0.67	0.65	**60**	0.37	0.14
7	0.80	1.76	**34**	0.61	0.73	**61**	0.40	0.09
8	0.57	1.35	**35**	0.48	0.39	**62**	0.27	0.16
9	0.38	1.33	**36**	0.14	0.39	**63**	0.56	0.16
10	0.59	1.24	**37**	0.2	0.17	**64**	0.21	0.16
11	0.28	0.52	**38**	0.25	0.31	**65**	0.38	0.20
12	0.18	0.48	**39**	0.55	0.29	**66**	0.34	0.37
13	0.24	0.23	**40**	0.61	0.29	**67**	0.43	0.28
14	0.20	0.24	**41**	0.22	0.35	**68**	0.28	0.15
15	0.45	0.52	**42**	0.22	0.27	**69**	0.46	0.12
16	0.85	0.58	**43**	0.27	0.52	**70**	0.35	0.18
17	0.69	0.83	**44**	0.53	0.36	**71**	0.28	0.14
18	0.73	0.61	**45**	0.47	0.81	**72**	0.30	0.09
19	0.33	0.41	**46**	0.65	0.55	**73**	0.31	0.17
20	0.23	0.46	**47**	0.32	0.66	**74**	0.42	0.20
21	0.16	0.37	**48**	0.46	0.41	**75**	0.26	0.11
22	0.14	0.18	**49**	0.52	0.44	**76**	0.22	0.53
23	0.17	0.25	**50**	0.31	0.13	**77**	0.66	0.74
24	0.28	0.37	**51**	0.28	0.14	**78**	0.74	0.16
25	0.15	0.25	**52**	0.33	0.40	**79**	0.56	0.27
26	0.11	0.47	**53**	0.22	0.35			
27	0.24	0.94	**54**	0.43	0.32			

Table 3 Total abundance of zooplankton (no/m^3) in Sarawak, Sabah and Brunei Darussalam waters.

Station	July	May	Station	July	May	Station	July	May
1	315	378	**28**	424	533	**55**	215	141
2	363	450	**29**	408	344	**56**	148	125
3	406	172	**30**	306	438	**57**	140	162
4	269	360	**31**	681	888	**58**	108	115
5	623	384	**32**	391	168	**59**	228	177
6	406	735	**33**	223	266	**60**	223	78
7	415	1,383	**34**	265	298	**61**	555	100
8	193	513	**35**	198	230	**62**	138	70
9	193	538	**36**	111	288	**63**	205	57
10	332	607	**37**	159	197	**64**	128	73
11	149	280	**38**	161	114	**65**	231	79
12	157	324	**39**	256	108	**66**	187	88
13	218	153	**40**	193	139	**67**	178	64
14	158	134	**41**	95	162	**68**	138	58
15	384	434	**42**	168	254	**69**	269	87
16	418	297	**43**	219	424	**70**	181	185
17	72	552	**44**	240	193	**71**	208	87
18	341	384	**45**	273	403	**72**	164	39
19	251	203	**46**	85	171	**73**	134	69
20	109	255	**47**	141	219	**74**	163	87
21	92	255	**48**	117	247	**75**	145	35
22	92	98	**49**	263	266	**76**	254	228
23	145	155	**50**	257	114	**77**	288	208
24	175	132	**51**	197	119	**78**	80	66
25	87	140	**52**	209	116	**79**	504	122
26	75	405	**53**	152	122			
27	219	554	**54**	242	130			

Zooplankton Analyses

Thirty-eight groups of zooplankton were found in this study. Major groups found in Sarawak, Sabah and Brunei Darusalam as well as their total numbers and percentages are presented in Table 6. Per cent composition , average abundance and frequency of occurrence of some zooplankton July and May are shown in Table 7-9. Pattern of distribution of the most common forms are shown in Appendix A (Figs. A3 - A18)

Coelenterata

This phylum include Medusae and Siphonophora, comprising together 3.8 % of the total zooplankton population (Table 6). These plankters are major predators in the planktonic food web. In both period, the Medusae found to be very common but in low number. Large number were observed near Bintulu in July (2 no/m^3). While the number increase in May especially in Sarawak water, the highest number was 4 no/m^3. However, most of the medusae found in neritic stations.

Siphonophora also found to be very common and in fare number in both period. In May, their number was high in sarawak water but in July high number was found both in Sarawak and Brunei waters. Furthermore, the number of individual of siphonophora in May was lower than in July. Most of them distributed in neritic stations.

Ctenophora

The ctenophores formed less than 0.1 % of the total zooplankton population. The percent occurrence was only 5 % in July and 11 % in May. The greatest number was 1 no/m^3 in May.

Mollusca

Molluscs were the second most abundant group of zooplankton, forming 8.9 % of the total zooplankton population (Table 6). This group was composed of bivalve and gastropod veligers, the heteropod, the thecosomes (shelled pteropod), the gymnosomes (naked pteropod), nudibranchia (sea slug) and cephalopod larvae. Veliger larvae of gastropod (57.9 %) and bivalve (14.6 %) and the thecosomes (23.4 %) accounted for the majority of the planktonic molluscs.

Bivalve veligers were most abundant in neritic rather than oceanic stations. The amount of them was similar in both period. The highest number occurred in Sarawak water (41 no/m^3) in May.

Gastropod veliger were most abundant in neritic rather than oceanic stations. In May, the amount of them was quite high in Sarawak water while during July the number was lower in the study areas.

The heteropod were very common in this study. Sarawak water showed higher abundance than other areas. The highest number was 1 and 10 no/m^3 in July and May respectively. Most of them dispersed neritic zone for both period.

The thecosomes (shelled pteropod) found to be very common for both period. The highest abundance was found in May (112 no/m^3) which higher than in July especially in Sarawak water.However, in May the thecosomes distributed neritic rather than oceanic stations while in the July the pattern of distribution were similar.

The gymnosomes (naked pteropod) were rare in July (28 % occurrence) but quite common in May (35 % occurrence). Most of them distributed oceanic in Brunei and Sabah waters. They quite rare in Sarawak water. The highest abundance was only 1 no/m^3 in both period.

Nudibranchia were found only in May in low number (1 no/m^3) in one station.

Cephalopod larvae were occasionally present in zooplankton samples. They formed less than 1 % of zooplankton population. The average number for both period was no differences. However, they can be found neritic and oceanic stations.

Cladocera

Cladocera formed only 1.4 % of the total zooplankton population but they were very common in both period. Most of cladoceran distributed at neritic zone in Sarawak water for both period. The average abundance was 3 and 6 no/m^3 in July and May respectively.

Ostracoda

Among the Crustacea, Ostracoda were second to Copepoda in abundance, but they comprised

only 10 % of the total zooplankton population. They observed to be very common but not in large number. In July showed higher abundance (average 29 no/m^3) than in May (average 19 no/m^3). The distribution pattern were similar for both neritic and oceanic stations in July. But most of them dispersed neritic in May.

Copopoda

Copepods were the most abundant in this study area, comprising 52 % of the total zooplankton population. The average number of copepod was 118 and 133 no/m^3 in July and May respectively. They dispersed throughout the study areas.

Cirrepedia

Cirripedia larvae were found to be very common for both period but in low number (average 1 no/m^3). The great number were found neritic in both season especially in Sarawak water and were rarely present at oceanic stations. Anyway, they can be found in Brunei water and Sabah water in great number in July as well. The distribution of larvae reflects that of the adults barnacles which are mostly benthic intertidal animals. This low overall abundance indicates the limited occurrence of barnacles along Sarawak, Sabah and Brunei water.

Lucifer

Lucifer spp. were very common and formed only 0.5 % of the total zooplankton population. The highest number was 19 no/m^3 in May. The average abundance showed no different in both period. Most of *Lucifer* spp. distributed neritic rather than oceanic especially in Sarawak water.

Brachyura

Brachyura larvae were very common but low in number. They found most abundant at the neritic stations (near Bintulu and Kota Kinabaru) in July and near Miri in May. The average abundance of brachyura larvae was similar in both period (1 no/m^3).

Shrimp larvae

Caridea and Penaeidae larvae were regular component in the zooplankton population, constituting 2.1 % of total zooplankton. The abundance was high at neritic stations for both period especially in Sarawak water (28 and 36 no/m^3 in July and May respectively). The average abundant showed no differences between both period.

Phyllosoma

Phyllosoma larvae were occasionally present in zooplankton samples especially neritic stations between Miri and Bintulu and the west of Sarawak water. The average abundance in both period were not difference.

Mysidacea

Mysidacea were very common. They formed 0.4 % of total zooplankton. The most abundant found in July (13 no/m^3) while only 6 no/m^3 in May in Sarawak water. Mysidacea distributed neritic and oceanic stations in both period.

Euphausiacea

Euphausiacea were very rare in this study. They found only 8 % occurrence in July and 10 % occurrence in May.

Anomura larvae

occurred regularly in the zooplankton samples. They found most abundant at neritic stations especially in Sarawak water and along the coast. The largest number was found in May (17 no/m^3). The average abundance showed no differences between both period.

Stomatopod

Stomatopod larvae were very common in July and common in May and occurred in low numbers, forming 0.1 % of total zooplankton. The largest number was found in July (2 no/m^3). The average abundance showed no differences between both period.

Other Crustacea

The remaining crustacea consisted of amphipod, isopod and cumercea. Amphipod were very common while isopod and cumercea were rare for both season. Amphipod dispersed throughout the whole area in both season but in July, high number occurred neritic and oceanic stations while only

Table 4. Differences of total abundance and biomass of zooplankton from Sarawak, Sabah and Brunei Darussalam waters between July and May.

	Abundance		Biomass	
	No. of Station	Percentage	No. of Station	Percentage
Increase	32	40.51	29	36.71
Decrease	37	46.84	37	46.84
Constant	10	12.66	13	16.46

Table 5. Probability (p) of null hypothesis (significant $p < 0.0500$) from t-test for comparing biomass and abundance between July and May.

	P
Biomass	0.7684
Abundance	0.376

Table 6. Total number and percentages of major groups of zooplankton in Sarawak, Sabah and Brunei Darussalam waters at 79 stations

Taxon	Totol	Percentage with in group	Overall percentage
I. Coelenterata	1,464	-	3.83
A. Medusae	92	6.3	0.2
B. Siphonophora	1372	93.7	3.6
II. Ctenophora	1.41	-	<0.1
III. Mollusca	3384.2	-	8.9
A. Bivalvia - veliger	492.9	14.6	1.3
B. Gastropoda			
1. veliger	1960.9	57.9	5.1
2. Heteropod	122.1	3.6	0.3
3. Thecosomata	791.6	23.4	2.1
4. Gymnosomata	13.6	0.4	<0.1
5. Nudibranchia	0.5	<0.1	<0.1
C. Cephalopoda - larvae	2.8	<0.1	<0.1
IV. Arthropoda	27096.8	-	71.1
A. Cladocera	549	2	1.44
B. Ostracoda	3818	14.1	10
C. Copepoda	19816	73.1	52
D. Cirripedia - larvae	123.3	0.5	0.3
E. Amphipoda, Isopoda, Cumercea	1043	3.8	2.7
F. Decapoda			
1. Lucifer spp.	207.4	0.7	0.5
2. Brachyuran	53.7	0.2	0.1
3. Caridea and Penaeidae larvae	791.7	2.9	2.1
4. Phyllosoma larvae	6.9	<0.1	<0.1
5. Anomuran	396.8	1.5	1
G. Stomatopod larvae	34	0.1	0.1
H. Mysidacea	156	0.6	0.4
I. Euphausiacea	101	0.4	0.3
VI. Chaetognatha	2969.2	-	7.8
VII. Chordata	2461.8	-	6.5
A. Thaliacea	914.3	37.1	2.4
B. Lavacea - Oikopleura spp.	1145	46.5	3
C. Pyrosomata	8.8	0.4	<0.1
D. Fish egg and larvae	393.7	16	1
VIII. Invertebrate larvae (Cyphonautes, actinotroch, polychaet larvae, brachiopod, echinodermata, ascidian)	720.9	-	1.9
IX. Other (nemertean, platyhelminthes)	20.9	-	<0.1
Grand total	**38119.4**	**-**	**100**

Table 7. Per cent composition of some zooplankton in Sarawak, Sabah and Brunei Darussalam waters in July and May.

	July		May	
Rank	**Taxon**	**Composition (%)**	**Taxon**	**Composition (%)**
1	Copepoda	50.8	Copepoda	53.1
2	Ostracoda	12.7	Ostracoda	7.6
3	Chaetognatha	9.1	Chaetognatha	6.6
4	Gastropod larvae	4.4	Gastropod larvae	5.9
5	Siphonophora	4.3	Laevacean	4
6	Amphipoda	3.6	shelled Pteropod	3.3
7	Shrimp larvae	2.2	Siphonophora	3
8	Thaliacea	2.1	Thaliacea	2.7
9	Laevacean	1.9	Echinodermata	2.3
10	Anomura larvae	1.4	Cladocera	1.9

Table 8 Taxonomic list of zooplankton found in Sarawak, Sabah and Brunei Darusalam. The average abundance of zooplankton:

+++ = >10 no./m^3
++ = 6-10 no./m^3
+ = 0-5 no./m^3

Taxon	Abundance		Taxon	Abundance	
	July	**May**		**July**	**May**
Medusae	+	+	Anomura larvae	+	+++
Siphonophora	++	++	Brachyura larvae	+	+
Ctenophora	+	+	Stomatopod larvae	+	+
Nemertinea	+	+	Heteropoda	+	+
Cyphonautes larvae	-	+	naked Pteropod	+	+
Actinotroch larvae	+	+	shelled Pteropod	+	+++
Chaetognatha	+++	+++	Nudibranchia		+
Polychaeta	+	+	Cephalopoda	+	+
Cladocera	+	++	Gastropod larvae	+++	+++
Ostracoda	+++	+++	Bivalve larvae	+	++
Copepoda	+++	+++	Echinodermata larvae	+	+
Cirripedia larvae	+	+	Larvacean	+	+++
Amphipoda	++	+	Thaliacea	+	++
Isopoda	+	+	Ascidian larvae	+	-
Mysidacea	+	+	Pyrosomata	-	++
Cumacea	+	+	Brachiopod larvae	+	+
Euphausiacea	+	+	Platyhelminthes	+	+
Lucifer spp.	+	+	Fish eggs	+	+
Phyllosoma larvae	+	+	Fish larvae	+	+
Shrimp larvae	+	+			

neritic stations in May .The average abundance was higher in July (8 no/m^3) than in May (5 no/m^3).

Chaetognatha

Chaetognatha were the third most abundant in this area, forming 7.8 % of total zooplankton. They were observed to be very common in both season. In July, they found great number near Kuching, Brunei and Kota Kinabaru. The highest abundance was 60 no/m^3. While in May, they found great number in Sarawak water which highest abundance was 105 no/m^3. Anyway, the average abundance of chaetognatha was higher in July (21 no/m^3) than May (16 no/m^3). Most of them distributed neritic rather than oceanic for both season.

Chordata

Chordata were the fourth most abundant group of zooplankton, comprising 6.5 % of the total zooplankton population (Table 6). This group was composed of Thaliacea (Salp), Larvacea (Oikopleura

Table 9 Taxonomic list of zooplankton found in Sarawak, Sabah and Brunei Darusalam. Frequency of occurence: R = Rare , C = Common, VC = Very Common.

Taxon	Frequency		Taxon	Frequency	
	July	May		July	May
Medusae	VC	VC	Anomura larvae	VC	VC
Siphonophora	VC	VC	Brachyura larvae	VC	VC
Ctenophora	R	R	Stomatopod larvae	VC	C
Nemertinea	VC	R	Heteropoda	VC	VC
Cyphonautes larvae	-	R	naked Pteropod	R	C
Actinotroch larvae	R	R	shelled Pteropod	VC	VC
Chaetognatha	VC	VC	Nudibranchia	-	C
Polychaeta	VC	VC	Cephalopoda	R	R
Cladocera	VC	VC	Gastropod larvae	VC	VC
Ostracoda	VC	VC	Bivalve larvae	VC	VC
Copepoda	VC	VC	Echinodermata larvae	VC	VC
Cirripedia larvae	VC	VC	Larvacean	VC	VC
Amphipoda	VC	VC	Thaliacea	VC	VC
Isopoda	R	R	Ascidian larvae	R	-
Mysidacea	VC	VC	Pyrosomata	-	C
Cumacea	R	R	Brachiopod larvae	C	R
Euphausiacea	R	R	Platyhelminthes	R	R
Lucifer spp.	VC	VC	Fish eggs	VC	VC
Phyllosoma larvae	R	-	Fish larvae	VC	VC
Shrimp larvae	VC	VC			

spp.) Pyrosomata and fish eggs and larvae.

Thaliacea (Salp) were very common organisms. The highest number was found in July (113 no/m^3) near Bintulu (St. 31). Most of them distributed neritic and oceanic. However, the average abundance in both season showed no differences.

Larvacea (Oikopleura spp.) were the second most abundant group of chordata (46.5 %) and comprised 3 % of total zooplankton. They found to be very common for both season. The highest was found at St. 27 (51 no/m^3) in May. The average abundance of larvacea was higher in May (10 no/m^3) than in July (4 no/m^3). However, the distribution pattern were similar for both neritic and oceanic stations.

Pyrosomata were seldom in this study. They found only in May in fair number. The distribution was scattered throughout the study area.

Fish eggs and larvae were very common but in low number, forming only 1 % of total zooplankton. Except for station 37 which found high number of fish eggs (104 no/m^3). The highest number of fish larvae was 7 no/m^3 at St. 16 in July. Fish eggs and larvae found to be more abundant neritic in both season. The average abundance showed no differences between July and May.

Invertebrate larvae

Invertebrate larvae, comprising 1.9 % of zooplankton population, composed of cyphonautes, actinotroch, polychaet, brachiopod, echinodermata and ascidian.

Cyphoneutes were found only in May while ascidian found only in July in low number. They distributed neritic rather than oceanic.

Actinotroch found only 1 and 3 stations in July and May in low number. Brachyopod were occasionally present but not high in number. Most of them distributed neritic rather than oceanic.

Polychaet larvae were very common organisms but in low number. The highest number was 3 no/m^3 at station 70 in May. The average abundance in both season showed no difference. The distribution was scattered throughout the study area.

Echinodermata larvae consisted of asteroidea (starfish larvae), holothuroidea (sea cucumber larvae), echinoidea (sea urchin larvae) and ophiuroidea (brittle star larvae). They were the regular component in the zooplankton samples but in low number. The average abundant in May (7 no/m^3) was a little bit higher than in July (2 no/m^3). Anyway, the abundance occurred in the neritic stations in both period.

Other

The remaining zooplankton found in the samples comprising of nemertean and platyhelminthes. Both of them formed less than 0.1 % of total zooplankton.

The relationship between fish larvae and their predators

Large carnivorous zooplankters namely, Medusae, Siphonophora, Ctenophora and Chaetognatha are planktonic predators on fish larvae. In this paper will concern only Medusae, Siphonophora and Chaetognatha. The relationship between fish larvae and their predators is shown in Fig. 2-5. The correlation between fish larvae and Medusae, Siphonophora and Chaetognatha was 0.5058, 0.5531 and 0.7204 , respectively, at 95 % confidence. Ctenophora present in small number in the samples so that their relationship with fish larvae was not studied.

The relationship between fish larvae and their prey

The relationship between fish larvae and copepoda is shown in Fig. 6. The correlation of fish larvae and copeoda which were their prey was 0.7132 at 95 % confidence

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Discussion

The biomass and abundance of zooplankton in Sarawak, Sabah and Brunei Darusalam's waters in this investigation was lower than in the Gulf of Thailand and the east coast of Malaysia Peninsular in both period (Jivaluk, in print). The higher biomass were in the areas where the water depth less than 200 m.(neritic zone), mainly in Sarawak water. This result agreed with Santhankumari (1991) who found the standing stock of zooplankton was relatively high in the neritic zone of the west coast of India. Abundance of zooplankton also showed the same phenomenon particularly in May. Fallahi (1993) found that zooplankton in the southern part of the Caspian Sea showed decrease in the abundance from littoral zone to the pelagic zone . It was concluded that Sarawak water is more productive than other area in this study. There were no significant difference of biomass and abundance between May and July.

The result of this investigation indicated that Copepods was the most dominant group followed by Ostracoda and Chaetognatha. Although species composition of Copepods and other groups was not studied. However, geographical diversity gradients obtained in this study, based on the groups at the primary sorting level, will serve to give an idea of geographical distributions of animal communities.

It is obvious that collecting-time affect the zooplankton biomass, abundance and their distribution. In May, many organisms were increase in number such as Medusae, Ctenophora, Cladocera, Copepoda, phyllosoma larvae, brachyura larvae, Thecosomata, Heteropoda, Gastropoda larvae, Appendicularia, Thaliacea and fish eggs. Some organisms were decrease such as Siphonophora, Chaetognatha, Ostracoda, Amphipoda, Gymnosomata. Sribyatta (1996) found higher values of zooplankton in the northeast monsoon and southwest monsoon in the Gulf of Thailand.

Many papers notes that the samples which contained the highest number of organism such as Euphausiacea (Barange, 1989), Mysidacea (Mathew et al. 1990), phyllosoma larvae (Kathirvel, 1990, Kathirvel and James, 1990), stomatopod larvae (Reddy and Shanbhogue, 1990) and cephalopod larvae (Sarvesan and Meiyappan, 1990, Meiyappan et al. 1990) as well as zooplankton biomass (Krishnakumari and Loswami, 1993, Koppelmann and Weikert, 1997) were all collected during night , suggesting that they showed a pronounced diurnal vertical migration(Paulinose and Aravindakshan, 1977).

There are many factors both biotic and abiotic which involve the variations in larval fish survival. Predators and preys are one of the most important biotic causes (Lasker and Smith, 1977). Large carnivorous zooplankters namely, Medusae, Siphonophora, Ctenophora and Chaetognatha are planktonic predators on fish larvae. [Fraser (1969)], [Suwanrunpha (1983[2])]. The consumption of fish larvae by each medusae varying from 50 to 15,000. In this investigation, indicated a high correlation between fish larvae and their predator, especially chaetognatha. Thus their presence in numbers of zooplankton could have a serious effect on the recruitment of larval fish and could be very significant

for the fish stocks and for the fishing industry.

Numerous studies have shown that small zooplankton, particularly copepods, eggs and larval stages of crustaceans, larval molluscs, ciliates and other unicellular organisms, are important components of larval fish food [Houde & Lovdal (1982)], [Balbontin *et al*. (1986)], [Nagasawa (1993)], [Anderson (1994)]. In this investigation found a high correlation between fish larvae and their prey, especially copepods. Positive correlations indicated that fish trend to aggregate where the standing crop of copepods which were their food is greatest. But Sameoto (1972) found no significant correlation between biomass of copepods and the estimated abundance of herring larvae.

Many works point out that zooplankton was influencing on fisheries. Krisshnapillai and Bhat (1981) found that the fish catch/hour was maximum in October which was the most productive month of the zooplankton. Jacob *et al*. (1981) noted that the peak periods in the zooplankton biomass were found to coincide with the peak seasons of pelagic fisheries. Suseelan *et al*.(1985) also found that pelagic fish catch, consisting mostly of anchovies and lesser sardines, showed clear peaks, closely following the primary and secondary peaks of zooplankton. Unfortunately, information about the fisheries in this investigated areas was not available, so that relationship of fish catch and zooplankton abundance was not studied

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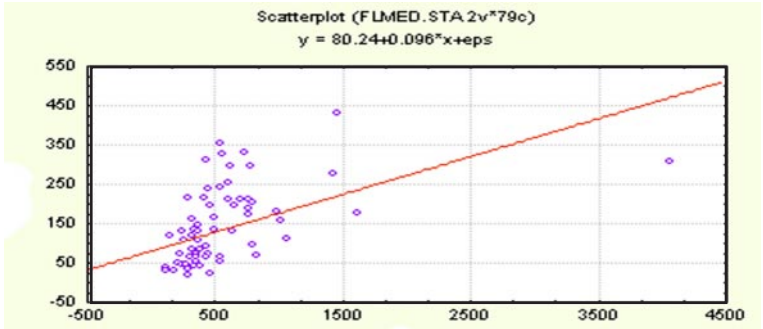


Fig. 2 Relationship between fish larvae (y) and Medusae (x)at 95% confidence

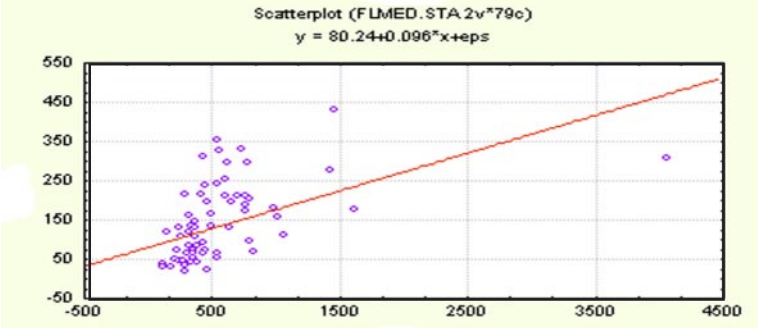


Fig. 3 Relationship between fish larvae (y) and Siphonophora (x) at 95% confidence

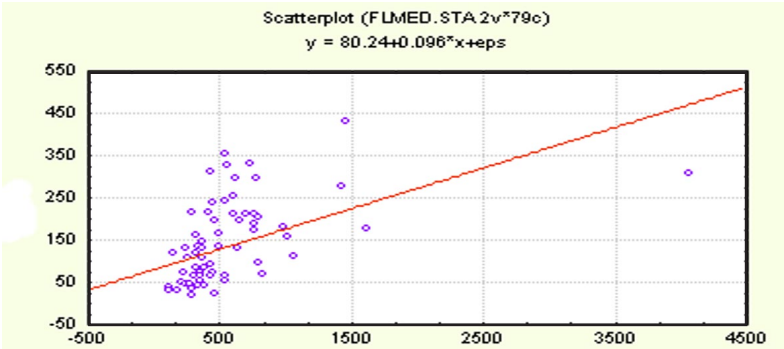


Fig. 4 Relationship between fish larvae (y) and Chaetognatha (x) at 95% confidence

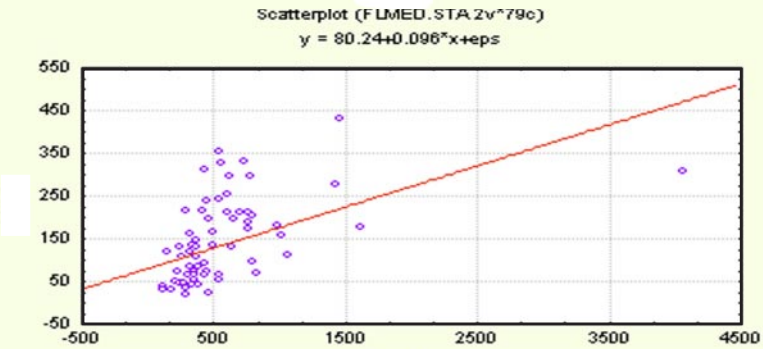


Fig. 5 Relationship between fish larvae (y) and predators (x) (Medusae + Siphonophora+ Chartognatha at 95% confidence

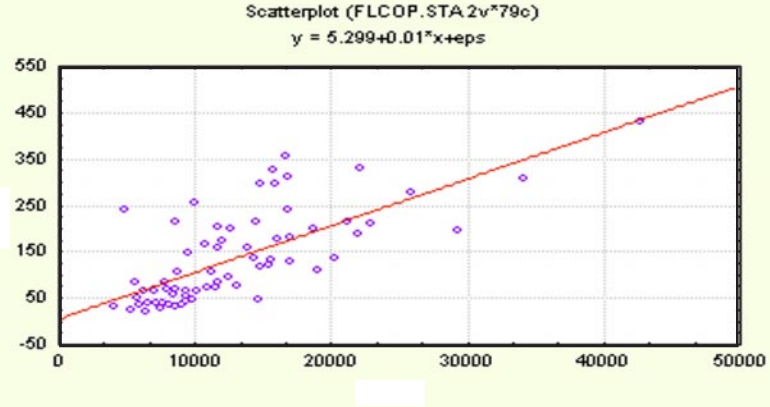


Fig. 5 Relationship between fish larvae (y) and Copepoda (x) at 95% confidence

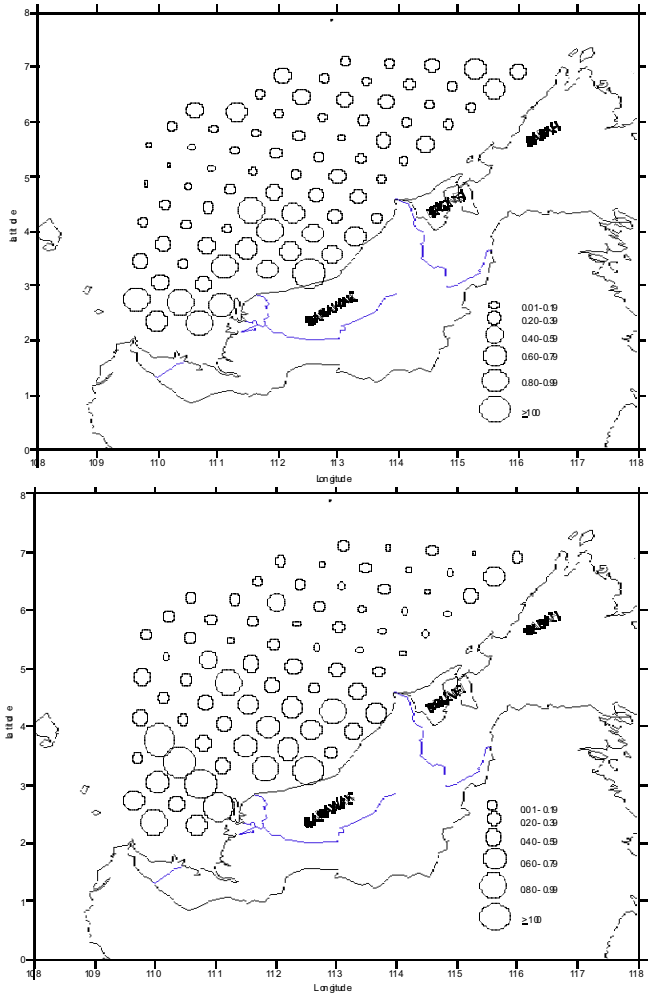


Fig. A1 Biomass of total zooplankton from July-August 1996 and April-May 1997

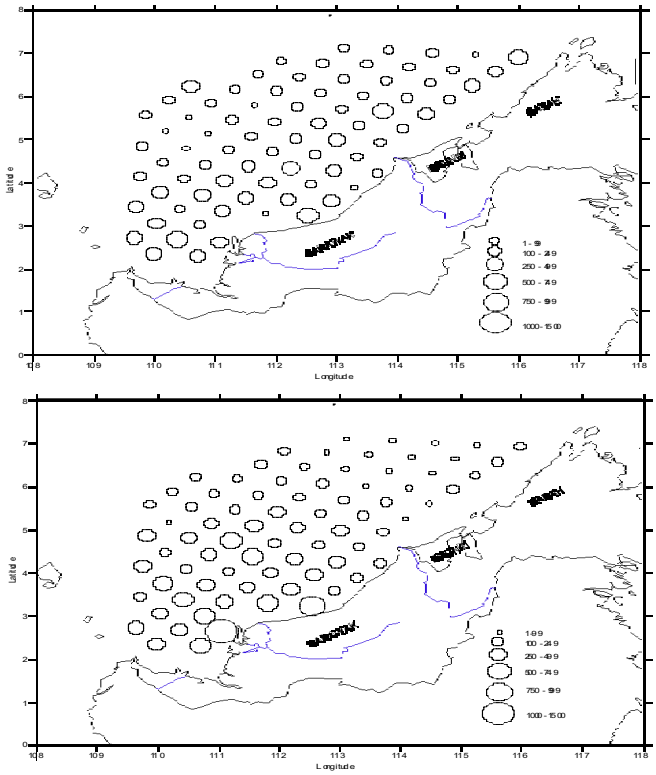
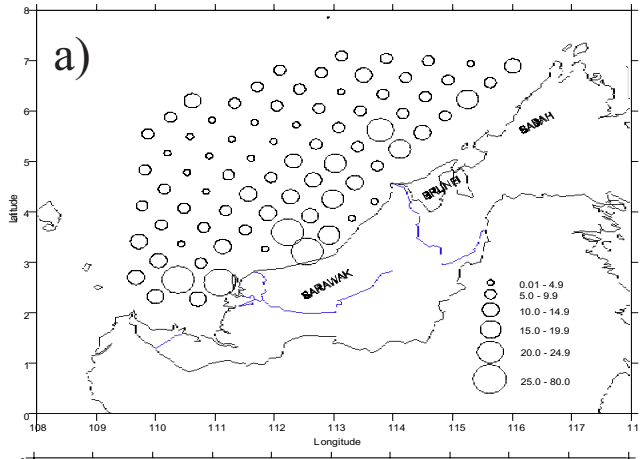


Fig. A2 Abundance of total zooplankton from July-August 1996 and April-May 1997



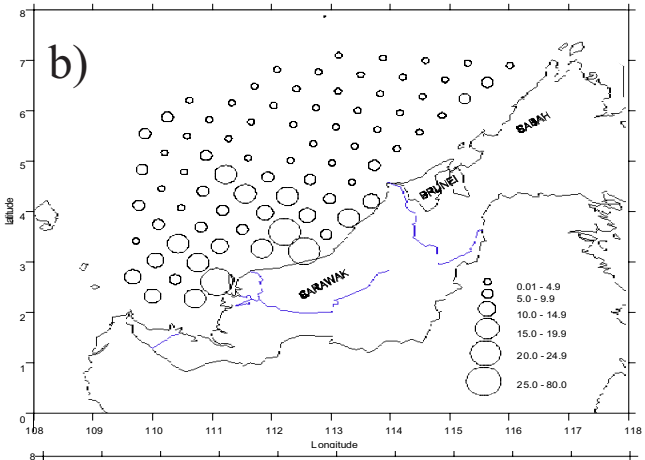
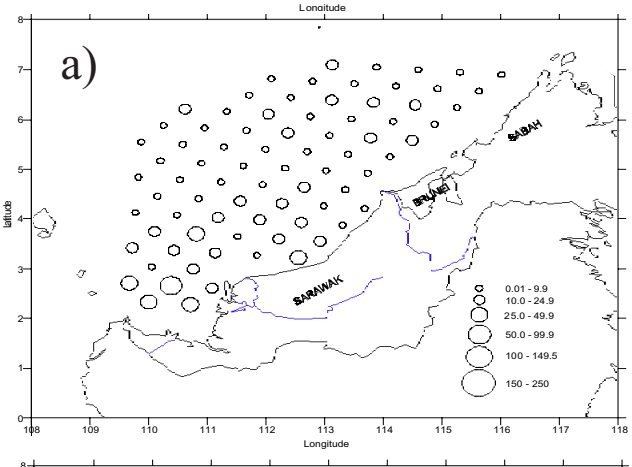


Fig. A3 Distribution and abundance of Siphonphora from July-August 1996 (a) and April-May 1997(b)



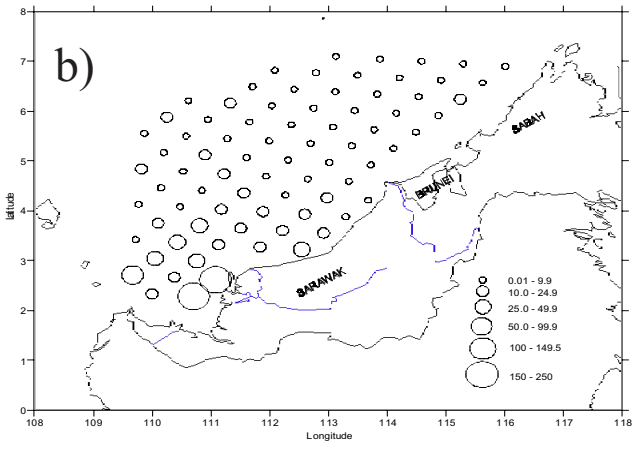
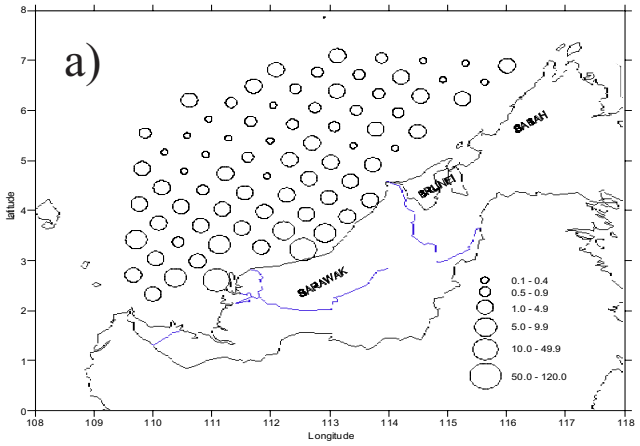


Fig. A4 Distribution and abundance of Gastropod from July-August 1996 (a) and April-May 1997(b)



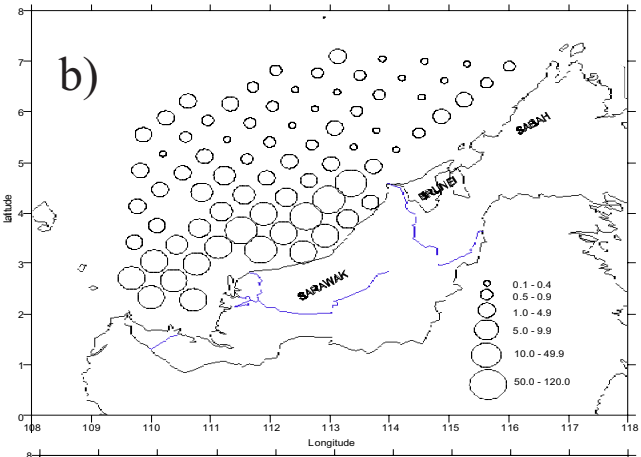
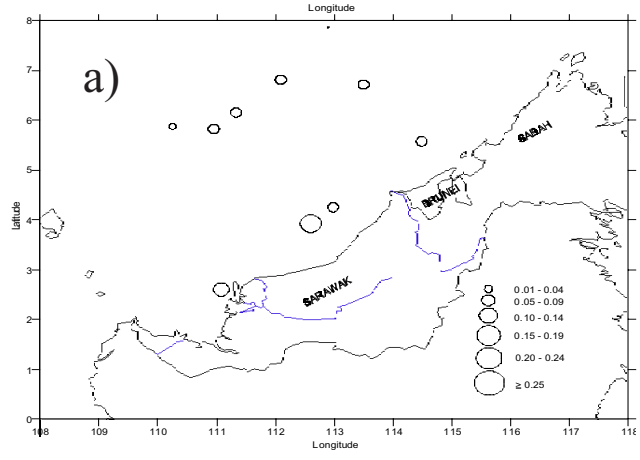


Fig. A5 Distribution and abundance of Thecosomata from July-August 1996 (a) and April-May 1997(b)



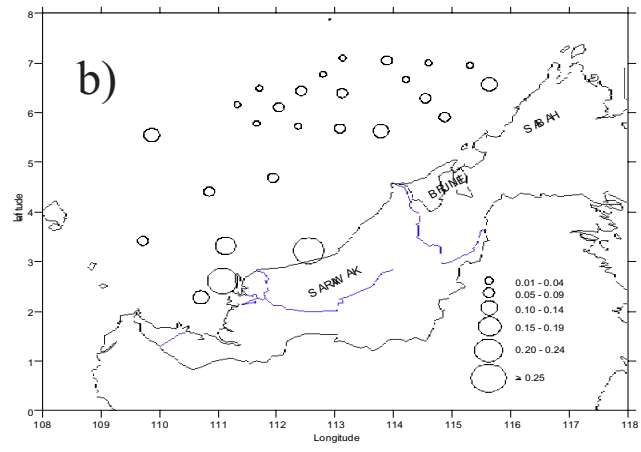
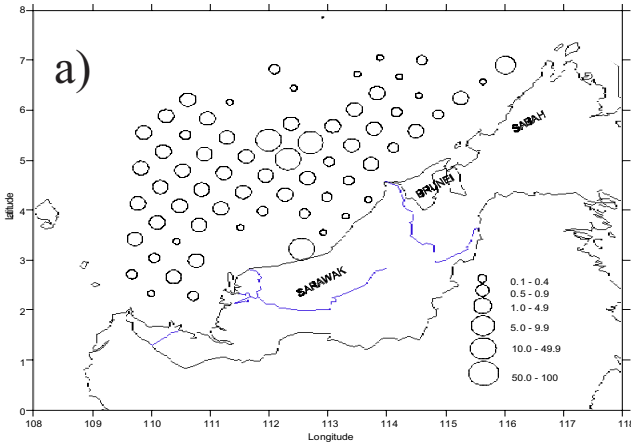


Fig. A6 Distribution and abundance of Cephalopod larvae from July-August 1996 (a) and April-May 1997(b)



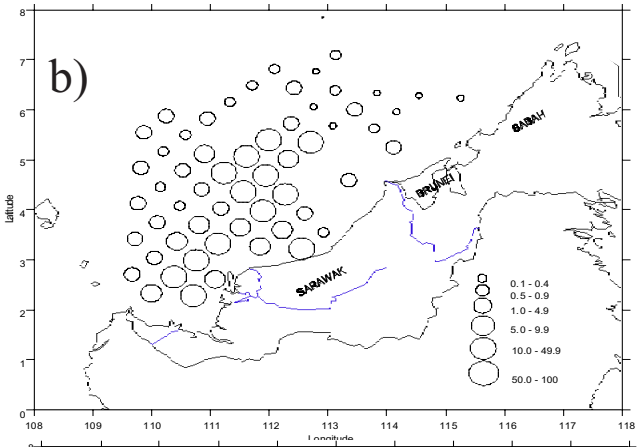
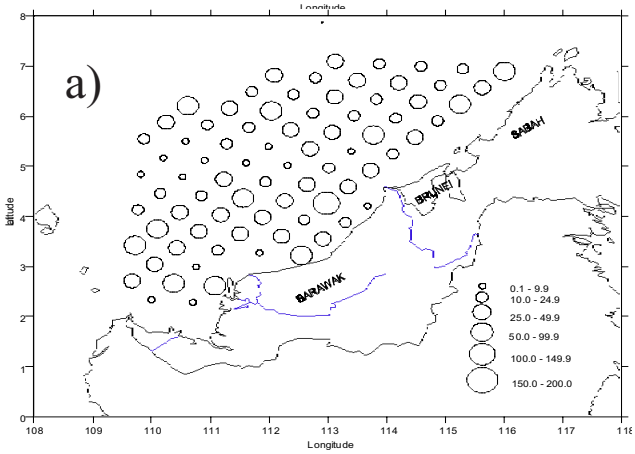


Fig. A7 Distribution and abundance of Cladocera from July-August 1996 (a) and April-May 1997(b)



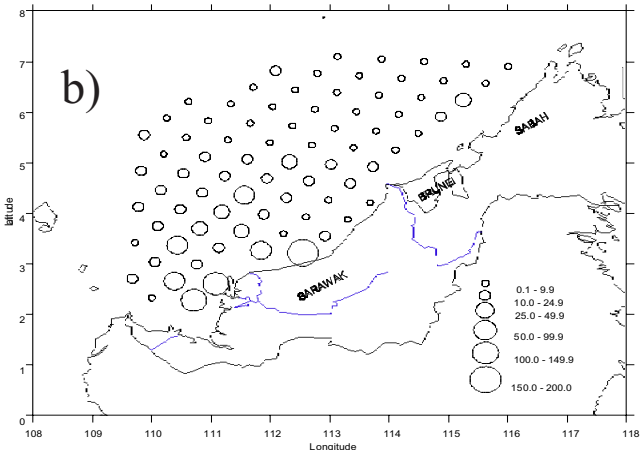
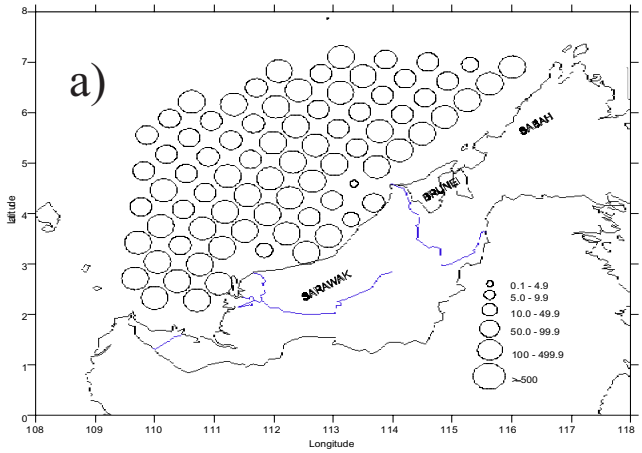


Fig. A8 Distribution and abundance of Ostracoda from July-August 1996 (a) and April-May 1997(b)



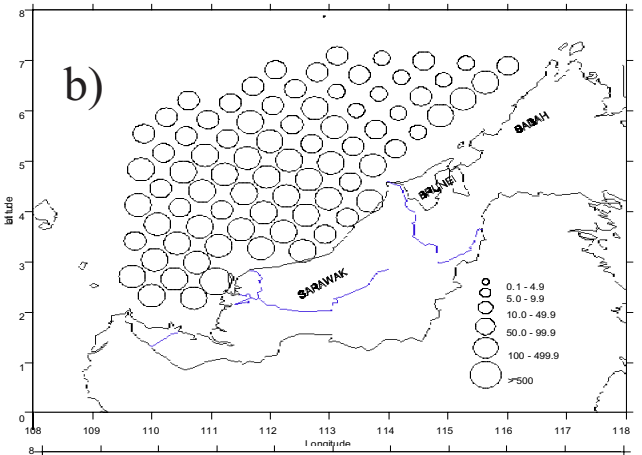
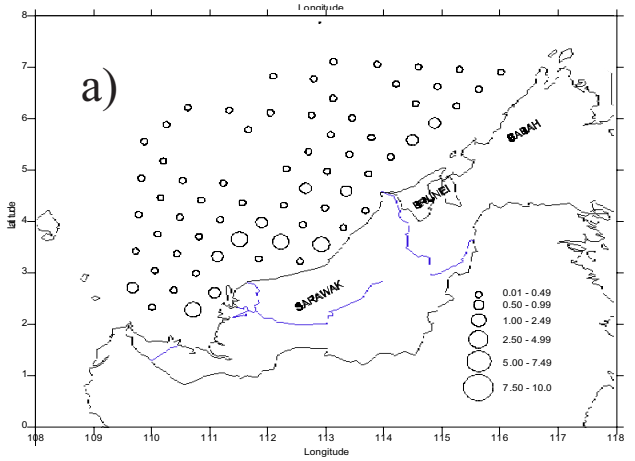


Fig. A9 Distribution and abundance of Copepoda from July-August 1996 (a) and April-May 1997(b)



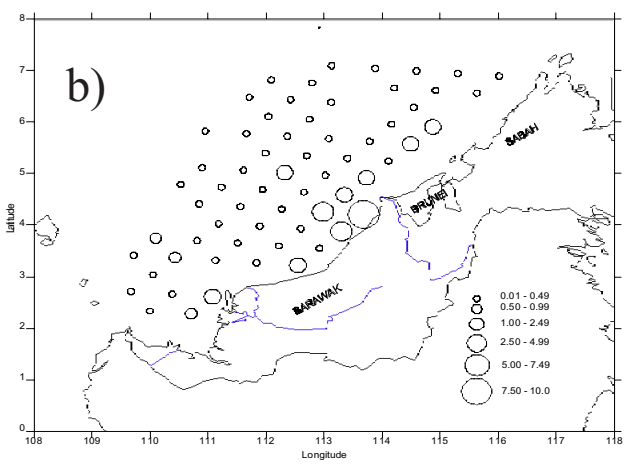


Fig. A10 Distribution and abundance of brachyura from July-August 1996 (a) and April-May 1997(b)

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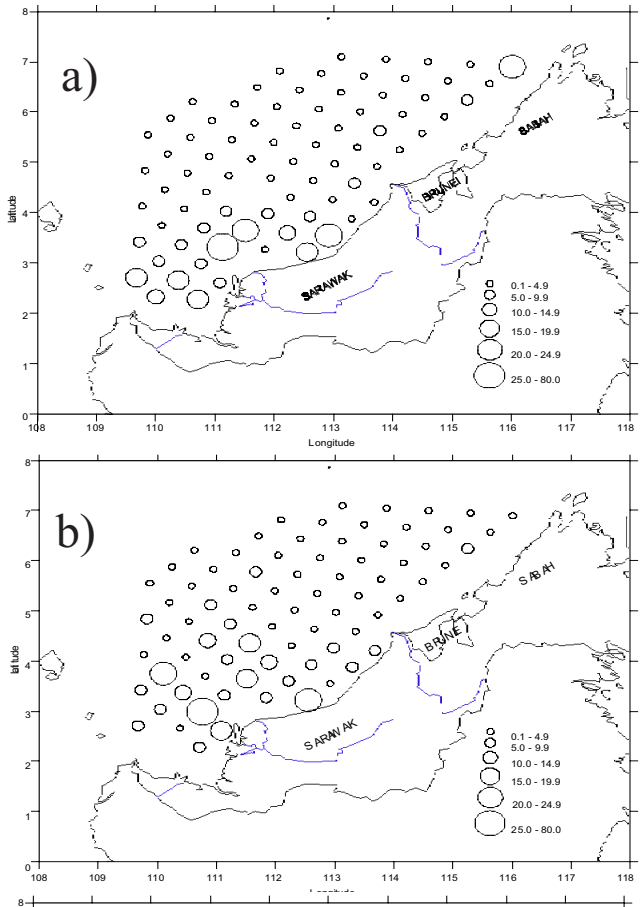


Fig. A11 Distribution and abundance of shrimp larvae from July-August 1996 (a) and April-May 1997(b)

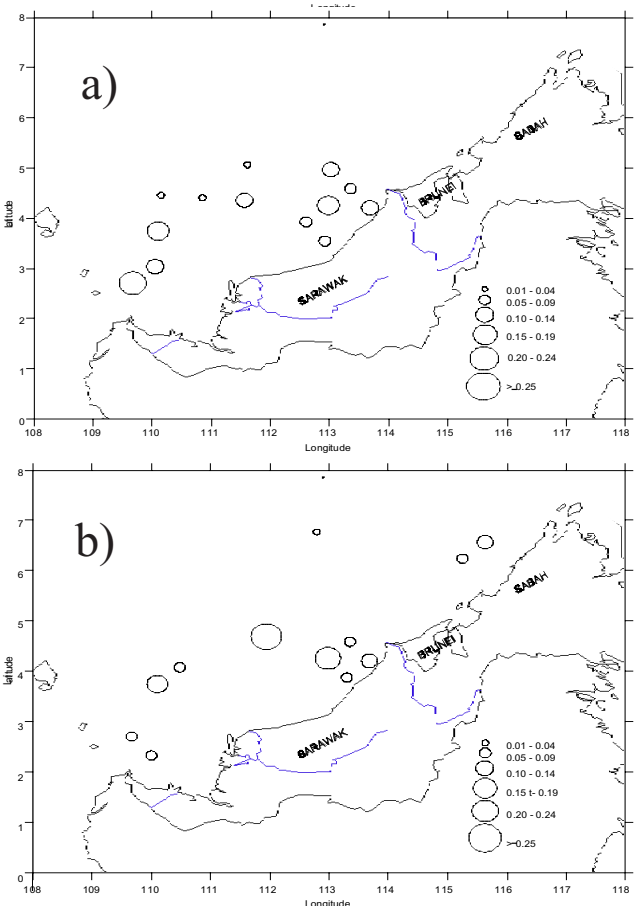
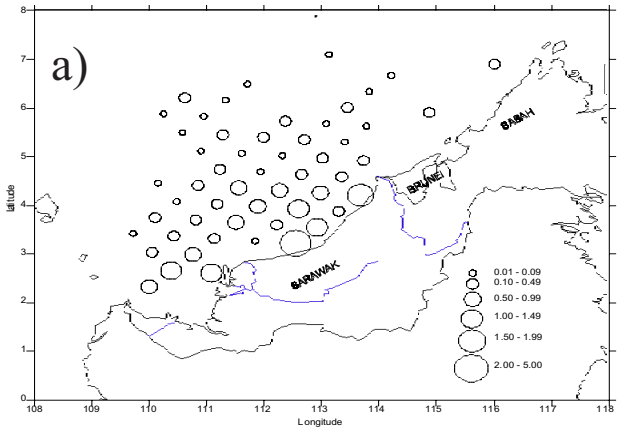


Fig. A12 Distribution and abundance of Phyllosoma larvae from July-August 1996 (a) and April-May 1997(b)



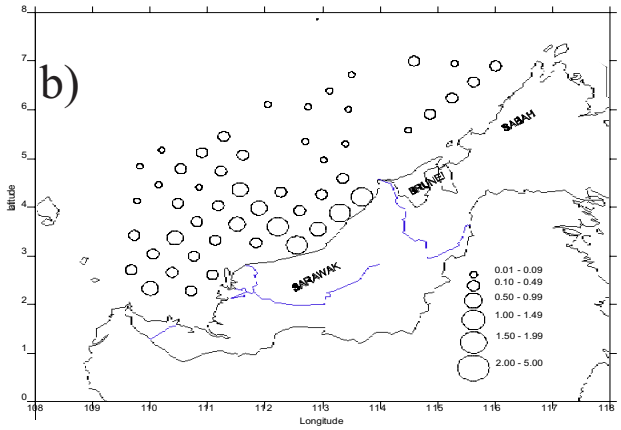
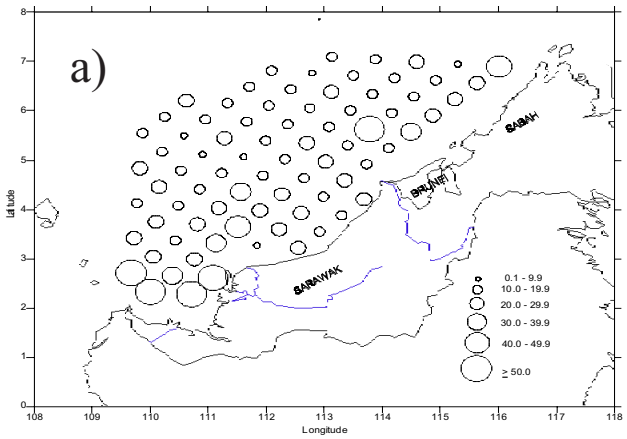


Fig. A13 Distribution and abundance of Stomatopod larvae from July-August 1996 (a) and April-May 1997(b)



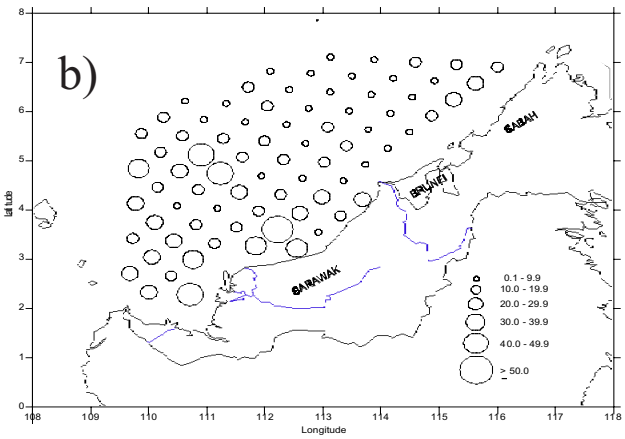
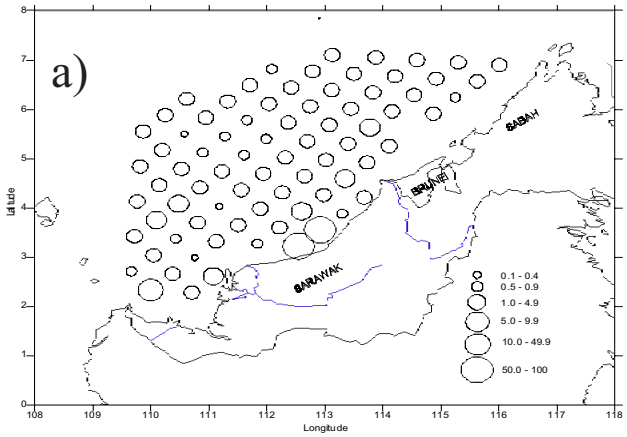


Fig. A14 Distribution and abundance of Chaetognatha from July-August 1996 (a) and April-May 1997(b)



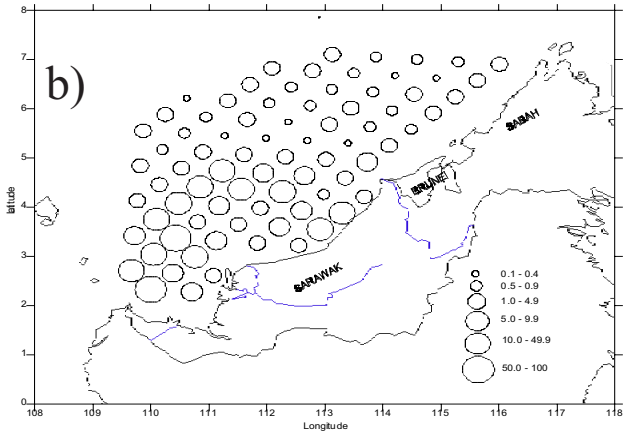
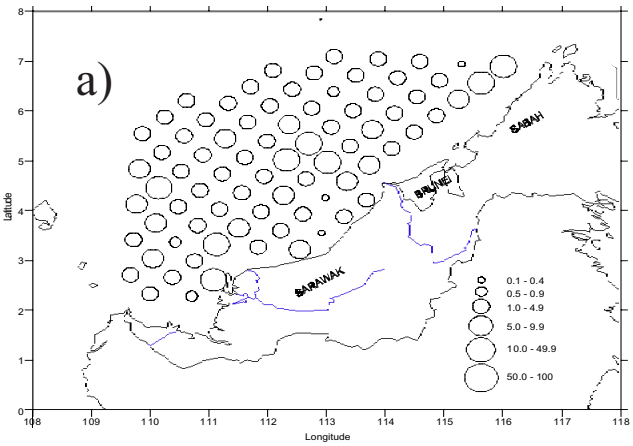


Fig. A15 Distribution and abundance of Thaliacea from July-August 1996 (a) and April-May 1997(b)



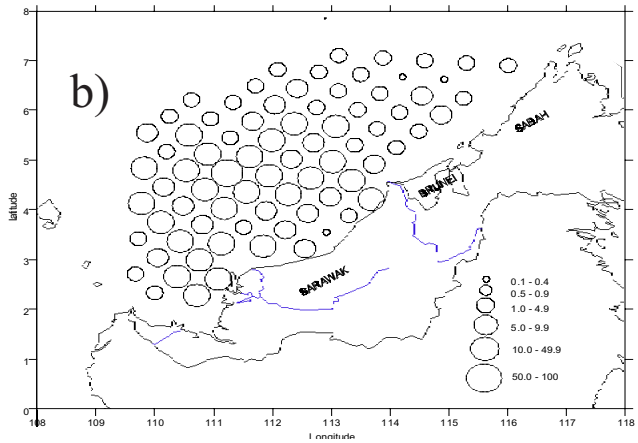
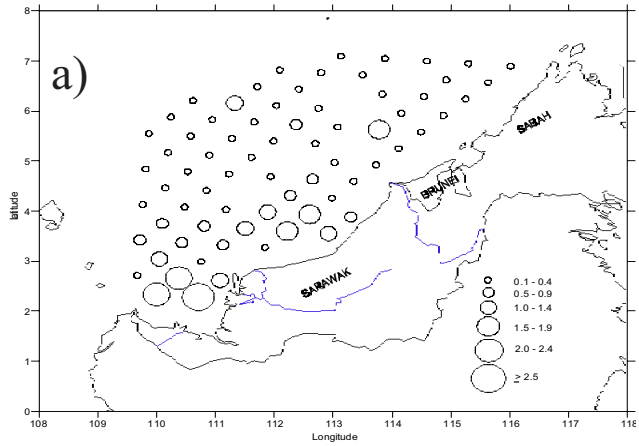


Fig. A16 Distribution and abundance of Larvacea from July-August 1996 (a) and April-May 1997(b)



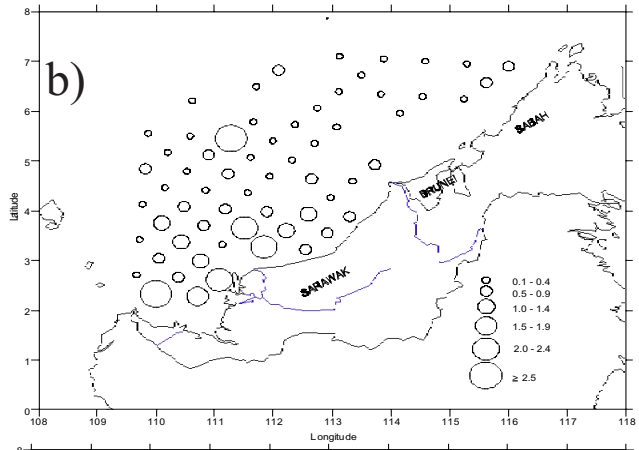
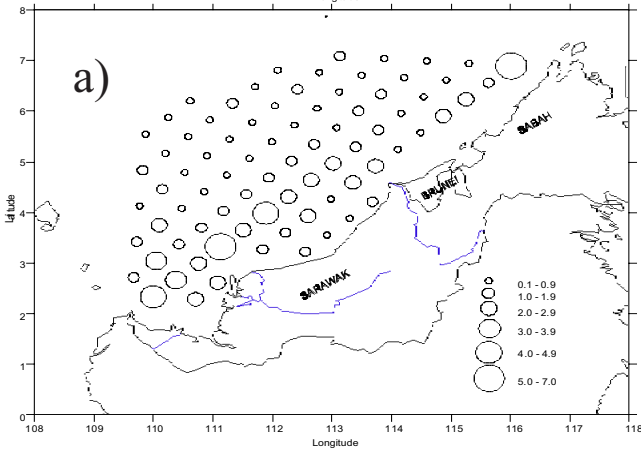


Fig. A17 Distribution and abundance of fish eggs from July-August 1996 (a) and April-May 1997(b)



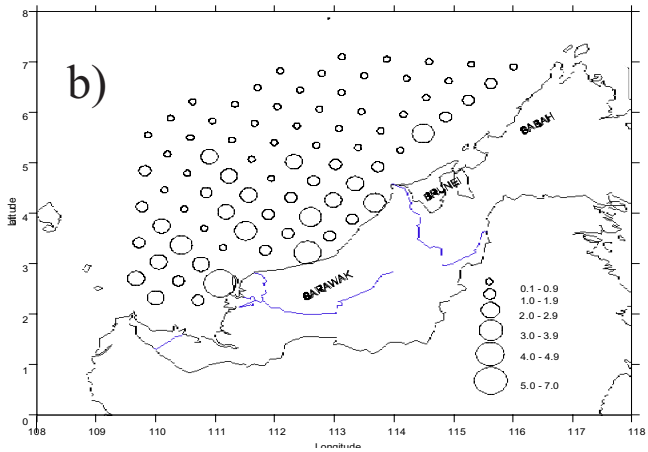


Fig. A18 Distribution and abundance of fish larvae from July-August 1996 (a) and April-May 1997(b)