第24卷第1期　　热带海洋学报　　Vol. 24, No. 1
2005年1月　　JOURNAL OF TROPICAL OCEANOGRAPHY　　Jan., 2005
文章编号:1009-5470(2005)01-0041-09

台湾南湾秋末冬初浮游管水母类种类多样性和数量分布

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摘要:2001年11月2—3日和12月8—10日在台湾南湾12个测站分别用2种锥形浮游生物网(网长180cm,网口直径45cm,筛绢网目孔径333μm和200μm)采集表层和底层(水深约50m)92份浮游动物样品。共鉴定出管水母31种,其中有7种是台湾周围海域新记录。舟状玫瑰水母 *Rosacea cymbiformis* 为我国海域首次记录。爪室水母 *Chelophyes appendiculata*、巴斯水母 *Bassia bassensis*、拟双生水母 *Diphyes bojani*、异双生水母 *Diphyes dispar*、小拟多面水母 *Abylopsis eschscholtzi* 和扭歪爪室水母 *Chelophyes contorta* 为优势种,它们分别占11月和12月管水母类总量的76%和63%以上。南湾管水母类的种类数和个体丰度均以12月(25种,1.99个·m^{-3})明显多于11月(19种,0.438个·m^{-3}),这与12月外海高盐水团增强有关。大部分测站表层的种类和个体数多于底层。讨论了2种网型浮游生物网的采集效果,并比较了南湾与邻近海域同期管水母类种类数、丰度的季节变化和区系性质。
关键词:海洋浮游动物;管水母类;种类多样性;数量分布;台湾;南湾
中图分类号:Q959.1315　　**文献标识码**:A

海洋浮游管水母类在海洋食物网中的利弊[1—3]以及在生物海洋学和水声学[4—6]研究中的作用已被人们广泛重视,尤其近年来越来越多的报道评论"水母旺发"与全球变暖、海域富营养化、捕捞过度等海洋环境变化有关,使人们对水母的数量变化更加关注。这里所指的水母包括水螅水母类、管水母类、钵水母类和栉水母动物等,管水母类是重要成员之一。

有关台湾周围海域浮游管水母类的记载先见于Sears的报道,他记录了1929年在台湾北部、东部和南部的一些测站采到的5种管水母[7],即齿角舟水母 *Ceatocymba dentata*、四角舟水母 *Ceratocymba leuckarti*、双翼多面水母 *Abyla bicarinata*、顶大多面水母 *Abyla schmidti* 和三角多面水母 *Abyla trigona*。相隔了半个世纪,我国学者才记录了一些种类,先是陈清潮等[8]在《台湾周围水域和南海北部浮游动物种类与分布》一书中记录了3种管水母,即拟铃浅室水母 *Lensia campanella*、拟细浅室水母 *Lensia subtiloides* 和方拟多面水母 *Abylopsis tetragona*,随后张金标等[9]报道了台湾西部海域冬春季管水母26种,至此,台湾周围海域的管水母共有31种记录。

收稿日期:2003-09-30;**修订日期**:2003-12-12
基金项目:台湾NSC计划(902621-B019001-A10);福建省自然科学基金项目(D97009)
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本文分析了台湾海洋大学海洋生物研究所2001年11月和12月在台湾垦丁南湾研究珊瑚礁生态时采集的浮游动物样品，报道了南湾管水母类的种类组成和数量分布，并讨论了其与水文要素的关系，为今后进一步了解台湾周围海域管水母类的多样性和生态特征积累基础资料。

1 材料与方法

1.1 样品采集

本文所用材料系2001年11月2—3日和12月8—10日2个航次在台湾垦丁南湾12个测站（21°52′12″—21°57′7″N，120°43′13″—120°51′0″E，图1）采集的浮游动物样品。采集时用2种圆锥形浮游生物网（网长180cm，网口直径45cm，网目有2种规格：333μm和200μm）在各测站表层和底层（大部分测站采集50m层样品，12号站因水浅，仅采表层样品）水平拖网约10min。2个航次共获92份样品，其中333μm网目样品和200μm网目样品各46份。用流量计测其滤水量，样品用5%中性福尔马林海水固定带回实验室分析鉴定。考虑到管水母大多数种类个体较大，属大型浮游动物，定量丰度只计网目333μm网所采样品，而种类组成则综合2种网具所获。

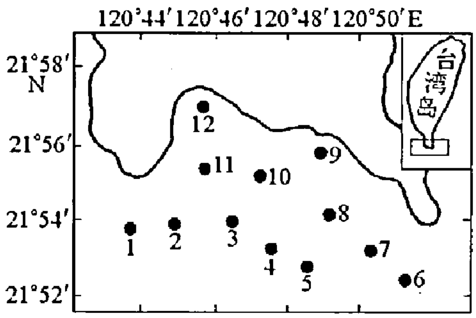

图1 采集站位

Fig. 1 Locations of sampling stations of Siphonophores in Nanwan Bay, Taiwan Island

本文使用的水温、盐度数据用CTD仪(美国YSI6600型产品)测定。

1.2 资料分析

管水母类的种类多样性以下列Shannon-Wiener多样性指数(H')、Pielou均匀度(J)和优势度(Y)公式计算[10-12]：

$$H' = -\sum_{i=1}^{s} P_i \log_2 P_i,\ J = \frac{H'}{\log_2 s},\ Y = \frac{n_i}{N} f_i$$

式中P_i为第i种的个体丰度与同一样品管水母类总个体丰度的比值；s为某站样品管水母的种类数；n_i为某航次第i种的平均丰度；N为同航次管水母总平均丰度；f_i为第i种在同航次所有测站的出现率。

2 结 果

2.1 种类组成

经分析鉴定，南湾11月和12月共出现管水母31种，包括胞泳目Physonectae 2科5种，钟泳目Calycophorae 6科26种，其中有7种在台湾周围海域为首次记录(表1注*号者)，舟状玫瑰水母*Rosacea cymbiformis*是我国海域的新记录。至此，若包括台湾周围海域以前记录的种类(有的这次未出现)，那么台湾周围海域的管水母共有38种记录。

从表 1 可以看出，11 月出现的管水母仅 19 种，而 12 月增至 29 种；从分布的层次看，均以表层略多于底层。

表 1　台湾南湾 11—12 月管水母类名录和出现水层

Tab. 1　Species list of Siphonophores and sampling water layer in Nov. and Dec. at Nanwan Bay, Taiwan Island

种	名	11 月		12 月	
		表层	底层	表层	底层
气囊水母	*Physophora hydrostatica*		+	+	
盛装水母	*Agalma okeni*			+	+
华丽盛装水母	*Agalma elegans*			+	
性轭小型水母	*Nanomia bijuga*	+	+	+	+
翼钟水母	*Forskalia edwardsi* *		+		
马蹄水母	*Hippopodius hipopus* *				+
光滑拟蹄水母	*Vogtia glabra*			+	+
支管双钟水母	*Amphicaryon ernesti* *			+	
盾状双钟水母	*Amphicaryon peltifera* *			+	
褶玫瑰水母	*Rosacea plicata*			+	+
舟状玫瑰水母	*Rosacea cymbiformis* **				+
长囊无棱水母	*Sulculeolaria chuni*	+	+	+	+
四齿无棱水母	*Sulculeolaria quadrivalvis*	+		+	+
热带无棱水母	*Sulculeolaria tropica* *				+
拟铃浅室水母	*Lensia campanella*	+	+		
小体浅室水母	*Lensia hotspur*			+	+
细浅室水母	*Lensia subtilis*	+	+	+	
拟细浅室水母	*Lensia subtiloides*	+		+	+
拟双生水母	*Diphyes bojani*	+	+	+	+
双生水母	*Diphyes chamissonis*	+		+	+
异双生水母	*Diphyes dispar*	+	+	+	+
爪室水母	*Chelophyes appendiculata*	+	+	+	+
扭歪爪室水母	*Chelophyes contorta*	+	+	+	+
尖角水母	*Eudoxoides mitra*	+	+	+	+
螺旋尖角水母	*Eudoxoides spiralis*	+		+	+
细球水母	*Sphaeronectes gracilis*		+	+	+
顶大多面水母	*Abyla schmidti*			+	+
小拟多面水母	*Abylopsis eschscholtzi*	+	+	+	+
方拟多面水母	*Abylopsis tetragona*	+	+	+	+
巴斯水母	*Bassia bassensis*	+	+	+	+
晶莹九角水母	*Enneagonum hyalinum* *				+

* 示台湾周围海域首次记录的种类，** 示我国海域首次记录的种类。

2.2　管水母类个体总量及优势种的数量分布

2.2.1　个体总量的分布

11 月管水母类的平均丰度较低，只有 0.438 个$\cdot m^{-3}$，表层（平均为 0.435 个$\cdot m^{-3}$）和底层（平均为 0.441 个$\cdot m^{-3}$）相差不多。从图 2a 可以看出，不管是表层或底层，均以西部的丰度较高。12 月管水母类的平均总丰度大为增高，达 1.99 个$\cdot m^{-3}$，比 11 月增高约4.5 倍，其中表层增幅更大（近 6 倍），平均丰度达 2.536 个$\cdot m^{-3}$，底层增幅没有那么大（3 倍

多)，平均为 1.395 个·m^{-3}，其绝对值不低(图 2b)，但仅有表层的一半。

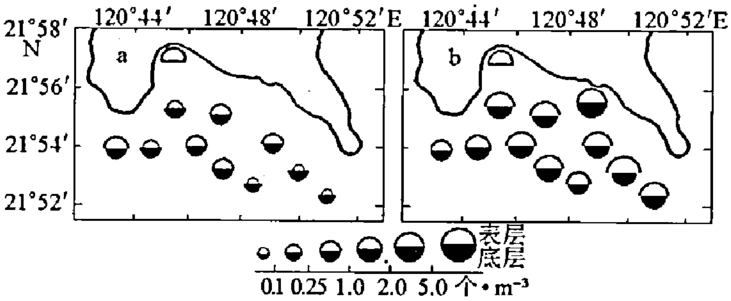

图 2 11 月(a)和 12 月(b)管水母类总个体丰度的平均分布

Fig. 2 Horizontal distribution of Siphonophores abundance in Nov. (a) and Dec. (b)

2.2.2 爪室水母 *Chelophyes appendiculata* 的分布

该种在 11 月和 12 月的优势度分别为 0.26 和 0.16，是本次调查中个体丰度最高的管水母种类(图 3Aa、Ab)。11 月爪室水母平均为 0.154 个·m^{-3}，占 11 月管水母类总量的 35.5%，其表层丰度(0.131 个·m^{-3})略低于底层(0.179 个·m^{-3})，而且西部的丰度高于东部(图 3Aa)；12 月丰度大增，平均为 0.342 个·m^{-3}，占该月管水母类总量的 17.2%，其中表层(0.531 个·m^{-3})明显高于底层(0.136 个·m^{-3})，表层以近岸的丰度高于外海，而底层分布较为均匀(图 3Ab)。

爪室水母为大洋高温高盐广布种[5]，广泛分布于三大洋[13]，我国东海、台湾海峡和南海北部、中部和南部均有分布[5]，而且是南海中部[14]和南部[15]管水母类的优势种。据 Alvarino[16]报道，该种和扭歪爪室水母 *Chelophyes contorta* 在中美洲海域的分布是不重迭的；而 Rengarajan[17]发现这 2 种管水母在印度西岸是很普通的种类，但爪室水母经常出现在开阔海域，而扭歪爪室水母分布靠近海岸。Stepanyants[18]发现爪室水母在太平洋中部最大量分布于盐度不低于 35.5 的水域，而扭歪爪室水母最大量分布在盐度 34.0—34.5 的水域。我们这次调查的范围不大，尚没有发现它们在南湾有异地分布现象，而只是爪室水母的丰度比扭歪爪室水母大，有待今后在更大范围内调查比较。

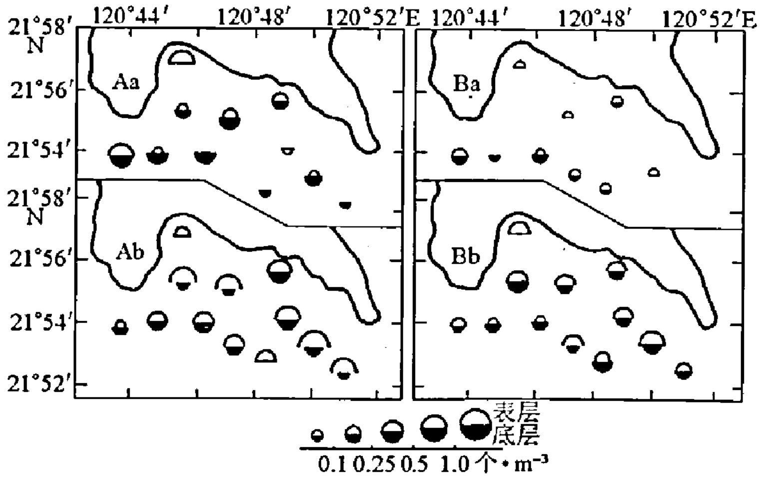

图 3 11 月(a)和 12 月(b)爪室水母(A)和巴斯水母(B)的平面分布

Fig. 3 Horizontal distributions of *Chelophyes appendiculata* (A) and *Bassia bassensis* (B) abundance in Nov. (a) and Dec. (b)

2.2.3　巴斯水母 *Bassia bassensis* 的分布

这种水母在 11 月和 12 月的优势度分别为 0.06 和 0.11,是调查期间第 2 位优势种。11 月巴斯水母的丰度较低,平均为 0.044 个$\cdot m^{-3}$,表、底层平均丰度相差不多,表层分布较为均匀,底层以外海数量较多(图 3Ba);12 月数量大增,平均丰度达 0.217 个$\cdot m^{-3}$,占 12 月管水母类总量的 10.9%,其中表层丰度(0.254 个$\cdot m^{-3}$)较底层(0.177 个$\cdot m^{-3}$)高,表层丰度近岸明显高于外海,底层则近岸略高于外海(图 3Bb)。

巴斯水母也是广泛分布于三大洋的高温高盐广布种[5,14],在西太平洋热带水域是管水母类的优势种[19,20],在我国自东海至南海南部均有分布[5],其中在南海中部是管水母类的优势种之一[14]。

2.2.4　其它优势种的分布

11 月和 12 月除上述 2 种优势种外,拟双生水母 *Diphyes bojani*、异双生水母 *Diphyes dispar*、小拟多面水母 *Abylopsis eschscholtzi* 和扭歪爪室水母的优势度也较高(表 2),其中拟双生水母和异双生水母在 12 月的数量较多,不管是在表层或底层,这 2 种占管水母类总量都在 10%以上,且表层高于底层。拟双生水母表、底层分布均较为均匀,而异双生水母的丰度则近岸高于外海(图 4)。

表 2　11 月和 12 月管水母类优势种的丰度和优势度

Tab. 2　Abundance and dominance of dominant species of Siphonophores in Nov. and Dec.

种名	11 月				12 月			
	丰度/个·m^{-3}			优势度	丰度/个·m^{-3}			优势度
	表层	底层	平均		表层	底层	平均	
爪室水母 *Chelophyes appendiculata*	0.131	0.179	0.154	0.26	0.531	0.136	0.342	0.16
巴斯水母 *Bassia bassensis*	0.044	0.043	0.044	0.06	0.254	0.177	0.217	0.11
拟双生水母 *Diphyes bojani*	0.032	0.036	0.034	0.04	0.273	0.193	0.234	0.11
异双生水母 *Diphyes dispar*	0.013	0.035	0.024	0.02	0.271	0.190	0.232	0.12
小拟多面水母 *Abylopsis eschscholtzi*	0.031	0.032	0.031	0.04	0.141	0.113	0.128	0.06
扭歪爪室水母 *Chelophyes contorta*	0.037	0.049	0.043	0.06	0.112	0.084	0.099	0.04

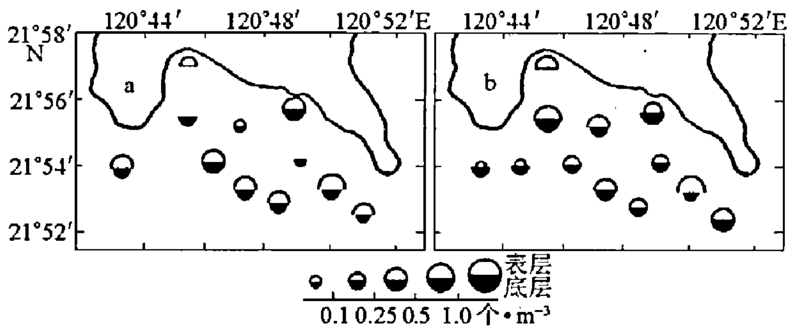

图 4　12 月拟双生水母(a)和异双生水母(b)的平面分布

Fig. 4　Horizontal distributions of *Diphyes bojani* (a) and *Diphyes dispar* (b) in Dec.

2.3　多样性指数的分布

11 月管水母类种类多样性指数略低(图 5a),表层平均 1.86,底层平均 1.96,相差不大。表层以中部较高,最高达 3.0(10 号站),湾的东南和西北两端指数较低,最低小于 1.0,主要是出现的种类少;底层也以中部略高于东西两端。

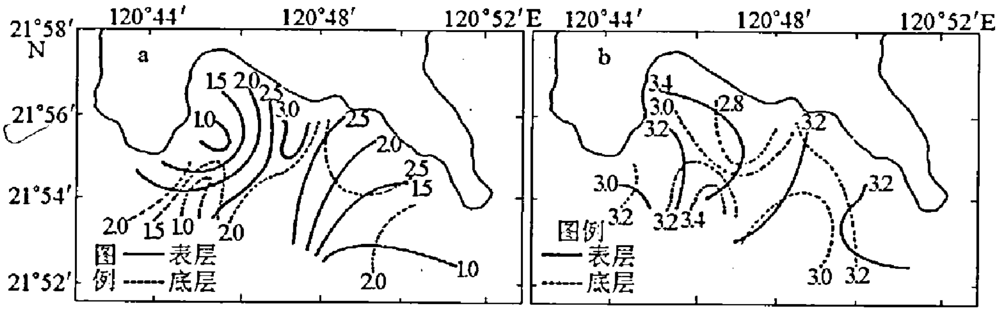

图 5 11 月(a)和 12 月(b)管水母类多样性指数的平面分布

Fig. 5 Horizontal distribution of Shannon-Wiener index of Siphonophores in Nov. (a) and Dec. (b)

12 月多样性指数比 11 月增高，这表明 12 月各测站出现种类增多，且各种的数量较为均衡，其表、底层平均分别达 3.24 和 3.14。从图 5b 看，表层多样性指数平面分布较均匀，仅以海湾中部略高，东西部略低；而底层却以外海的指数较高，湾的北部略低。

这 2 个月管水母类的均匀度(J)都很高，11 月平均达 0.87(0.69—1.0)，表层(0.90)比底层(0.84)更高，表层仅西部稍低(小于 0.8)，底层以湾的东西两端略低；12 月均匀度更高，平均达 0.88(0.83—0.94)，底层(0.89)与表层(0.81)相差不多。

3 讨论

3.1 与邻近海区管水母类的比较

从表 3 可以看出，自秋季转入冬季，各邻近海区管水母类的种类数和丰度大都不同程度减少，惟独南湾明显增多，呈现出很独特的季节变化；另外，从秋冬季的优势种看，东海、台湾海峡和南海北部多以近岸性种类双生水母、拟细浅室水母和五角水母(*Muggiaea atlantica*)占优势，惟独南湾和南海中部以大洋高温高盐广布种占优势；从区系性质看，南湾与南海中部海域更加靠近，同属印度-西太平洋区-马印亚区[5]。

表 3 南湾与邻近海区管水母类的比较

Tab. 3 Statistical comparison of Siphonophores in waters of Nanwan Bay with that in neighbouring waters

	东海[21]		台湾海峡西部[22]		台湾海峡东部[9]	南海北部*		南海中部[14]		南湾	
	秋	冬	秋	冬	冬	11 月	12 月	秋	冬	11 月	12 月
种类数	26	37	28	19	19	26	28	54	52	19	29
丰度/个·m^{-3}	1.81	1.56	9.00	0.11	0.95	4.03	1.55	1.51	1.24	0.438	1.99
优势种	双生水母 五角水母 拟细浅室水母		双生水母 拟细浅室水母 五角水母		双生水母 拟细浅室水母	双生水母 拟细浅室水母 性轭小型水母		扭歪爪室水母 爪室水母 尖角水母 方拟多面水母 巴斯水母 螺旋尖角水母		爪室水母 巴斯水母 拟双生水母 异双生水母 小拟多面水母 扭歪爪室水母	

注：除南湾外，其它海区采集网具筛绢网目孔径均为 505μm。 * 据张金标、许振祖手稿。

3.2 不同网型管水母类种数的比较

本调查采用 2 种筛绢网目的浮游生物网同时采集样品。从表 4 可以看出，11 月和 12 月网目 333μm 网所获的种类均比网目 200μm 网所获的种类多，表明网目 333μm 网比网

目200μm网采集管水母类更有效。可能由于绝大多数管水母个体较大，属大型浮游动物，粗网目采集的效果更好。国内过去采集各类浮游水母多用网目孔径505μm的大型浮游生物网，其采集效果是否更好有待今后进一步比较研究。

从表4还可以看出，不管是哪种网所采的样品，均以表层种类多于底层，这与台湾海峡西部管水母类的垂直分布以25m以浅水层的种类多于25—50m层的情况相类似[23]，也再次证实管水母类是以营上层水生活为主的浮游动物类群[3]。

表4　不同网目采获管水母种数的比较

Tab.4　Comparison of species number of Siphonophores collected with nets of different mesh size

月　份	11月				12月			
网目孔径/μm	200		300		200		300	
水　层	表层	底层	表层	底层	表层	底层	表层	底层
种类数	13	12	15	13	17	15	25	23
表、底层综合种类数	15		19		18		29	

3.3　管水母类分布与水文要素的关系

根据生活习性，南湾11月和12月出现的31种管水母可分为3个生态类群：(1)近岸暖水广布类群，仅出现拟细浅室水母和双生水母2种，个体数量不大，以近岸稍多；(2)大洋暖水广布类群，约有84%的种类属于这个类群，南湾调查海区所有优势种均属于这个类群，个体数量也占优势；(3)大洋赤道狭布类群，仅出现顶大多面水母 *Abyla schmidti*、褶玫瑰水母 *Rosacea plicata* 和拟铃浅室水母 *Lensia campanella* 3种。由上可以看出，南湾11月和12月管水母类不管是种数还是丰度，均以大洋暖水性种类为主，表明调查期间南湾主要受外洋水的影响，尤其是12月比11月增加了12种，其中10种是大洋暖水广布种，2种是典型的大洋赤道种，更显示南湾12月几乎完全受外洋水控制。据报道，南湾秋季主要被混合水团(由南海中盐水、沿岸低盐水和黑潮水混合组成)所占据，而冬季无沿岸水，主要由黑潮水和南海水组成的混合水团占据[21]，管水母类从秋末进入冬初的变化反映外洋水影响加强的趋势。南海东北部的许多水文调查研究表明，冬季西北太平洋有一支西向或西南向海流通过巴士海峡进入南海，被称为黑潮南海分支[25,26]，而且冬季的流量最大[27]。台湾南部的水文调查也表明，冬季受黑潮影响最大[28]。我们认为，12月管水母类种类和数量增多与黑潮的影响有关，黑潮水带来了更多的适高盐的大洋暖水种和大洋赤道种。CTD实测的数据表明，南湾11月份水温较高，表、底层平均分别达27.56和27.21℃，12月则明显下降，表、底层分别为24.64和23.98℃；而盐度则相反，11月盐度较低，表、底层分别平均为33.25和33.59，12月表、底层分别增高到34.25和34.34，这个变化也体现了外洋水的影响明显加强。

南湾12月有29种管水母(表3)，比台湾海峡东、西部海域和南海北部同期的管水母种类数多，表明12月南湾比上述海区受外洋高温高盐水的影响更大。但值得注意的是，台湾周围海域先前曾经记录的另一些典型的大洋赤道种[7]如四角舟水母、齿角舟水母、双翼多面水母和三角多面水母这次未在南湾出现，这可能是先前上述种类的记录分别是在台湾北部、东部和南部黑潮直接流经的海域出现，而南湾是个近岸的小海湾；另一种可能是12月仅是冬初，还不是黑潮影响南湾最强烈的月份，这都有待今后进一步研究证实。

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SPECIES DIVERSITY AND ABUNDANCE DISTRIBUTION OF PELAGIC SIPHONOPHORES FROM NANWAN BAY OF TAIWAN ISLAND IN LATE AUTUMN AND EARLY WINTER

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Abstract: Zooplankton surveys were carried out in November 2—3 and December 8—10, 2001 at 12 sampling stations in the Nanwan Bay of Taiwan Island. Up to 92 zooplanktonic samples were collected from the subsurface and bottom layers with two conical plankton nets (180cm in length, 45cm in opening diameter, 333 μm and 200 μm in mesh size). Totally 31 species of siphonophores were identified. Among them, 7 species were new records in the waters around the Taiwan Island, of which *Rocacea cymbiformis* was a new record in China. These samples were dominated by *Chelophyes appendiculata*, *Bassia bassensis*, *Diphyes bojani*, *Diphyes dispar*, *Abylopsis eschscholtzi* and *Chelophyes contorta*, which accounted for over 76% and 63% of the total abundance in November and December. The species number and siphonophores abundance were more and higher in December (25 species, 1.99 ind $\cdot$ m^{-3}) than in November (19 species, 0.438 ind $\cdot$ m^{-3}), and in the subsurface water layer than in the bottom layer at most sampling stations. In early winter, the offshore hyperhyline water mass was the main factor influencing the distribution. The sampling efficiency of two plankton nets were discussed and the seasonal variations of species number and abundance of siphonophores in the Nanwan Bay and in the neighbouring waters were compared.

Key words: marine zooplankton; siphonophore; species diversity; abundance distribution; Taiwan Island; Nanwan Bay

Species Diversity and Abundance Distribution of Pelagic Siphonophores in Nan Wan Bay of Taiwan, China, in Late Autumn and Early Winter

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Abstract Zooplankton surveys were carried out on November 2-3 and December 8-10, 2001 at 12 stations in the Nan Wan Bay of Taiwan, China. Altogether 92 quantitative zooplankton samples were collected from subsurface water and bottom water layers with two conical plankton nets (180 cm in length, 45 cm in opening diameter, 333 μm and 200 μm in mesh size). A total of 31 species of Siphonophores were identified, among them 7 species are new records in the waters around Taiwan Island, of which *Rocacea cymbiformis* is a new record in China. Dominated by *Chelophyes appendiculata, Bassia bassensis, Diphyes bojani, Diphyes dispar, Abylopsis eschscholtzi* and *Chelophyes contorta*, these species accounted for over 76 % and 63 % of the total abundance in November and December. The species number and Siphonophores abundance in December (25 species, 1.99 inds/m^3) were more than those in November (19 species, 0.438 inds/ m^3), and they were more in the surface water layer than in the bottom layer at most sampling stations. In early winter, the offshore high salinity water mass was a main factor influencing the distribution. The sampling efficiency for two plankton nets is discussed and the seasonal variation of species number and abundance in the Nan Wan Bay is compared with that in the neighboring waters.

Keywords marine zooplankton, Siphonophores, species diversity, abundance distribution, Taiwan, Nan Wan bay

The role of marine Siphonophores in the bio-oceanography and hydro-acoustics has long been recognized extensively, as well as their advantages and disadvantages in the food web[1-6]. In recent years many research publications have ascribed the "jellyfish bloom" to marine environmental changes, for example, the global warming, water eutrophication and overfishing. The variation of jellyfish abundance has received much attention. In this report the so-called "jellyfish" refer to the animals such as hydromedusa, Siphonophores, Scyphomedusae and Ctenophora, among which, the most important jellyfish is Siphonophores.

The Siphonophores recorded in the waters around Taiwan were *Ceatocymba dentata, Ceratocymba*

Received on June 7. 2005

leuckarti, *Abyla bicarinata*, Abyla *schmidti* and *Abyla trigona*. These 5 species were described by M. Sears in his "Dana Expedition" according to the specimens collected from the stations of northern, eastern and southern Taiwan as early as 1929 [7]. Almost half a century had passed when the species was first found by Chinese scientists. Another 3 species, *Lensia campanella*, *Lensia subtiloides* and *Abylopsis tetragona*, were first recorded by Chen Qingchao in his publication "Zooplankton and its distribution in the waters around Taiwan and in the northern South China Sea"[8]. Later on, 26 species of Siphonophores in the western waters of Taiwan were reported by Zhang Jinbiao[9]. These records make up a total of 31 species reported in the waters around Taiwan Island.

In this report the zooplankton samples were analyzed and reported with samples collected by the Institute of Marine Biology, the Marine University of Taiwan, during the study on the ecology of Kending coral reef of Taiwan in November and December, 2001. As results, the species and numerical distribution of Siphonophores and their relation to hydrographic environments were reported and the data can be fundamentally important both for biodiversity and for ecological study of Siphonophores in the waters around Taiwan Island.

1 Materials and Methods

1.1 Sampling

The zooplankton samples were collected from 12 stations (21° 52′ 12″ —21° 57′ 7″ N, 120° 43′ 13″ — 120° 51′ 0″ E, Fig. 1) in the Nan Wan Bay, Taiwan, during 2 cruises on November 2-3 and December 8-10, 2001. Two kinds of conical planktonic nets, which are 180 cm in length, 45 cm in opening diameter, and 333 μm and 200 μm in mesh size respectively, were used to tow samples in surface and bottom water layers for 10 min horizontally, respectively. Except for the station 12 where no samples were collected in the bottom water layer because it is shallow, most of the tows were done at the depth of 50 m. During the 2 cruises a total of 92 samples were obtained with 46 each by nets of

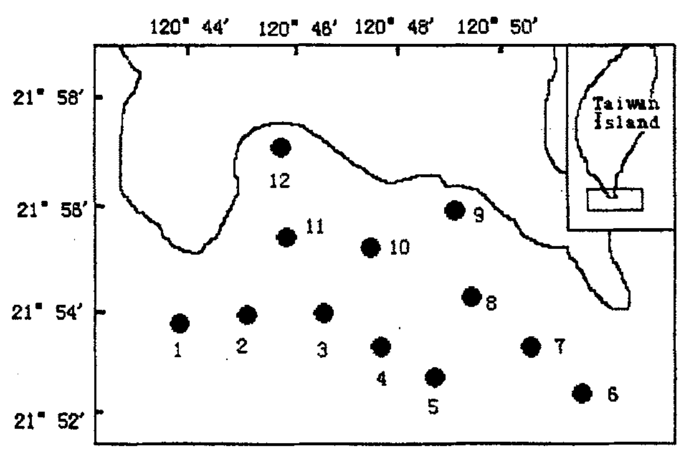

Fig. 1 Locations of stations for Siphonophores sampling in the Nan Wan Bay, Taiwan

different mesh sizes. Flow meters were used to measure the volume filtered and samples were fixed with 5 % Formalin solution before they were brought back to lab. Since macrozooplankton Siphonophores are larger, the abundance of jellyfish was only counted with samples from the net with a mesh size of 330 μm, while for species identification, the specimens from two different nets were used.

Water temperature and salinity data present in this report were collected by CTD, Model USA-YSI6600.

1.2 Data analysis

Index for Siphonophores Diversity is calculated with Shannon-Wiener formula (H'), Evenness (J) and Dominance (Y) [10-12]

$$H' = -\sum_{i=s}^{s} P_i \log_2 P_i, \qquad J = \frac{H'}{\log_2 s}, \qquad Y = \frac{n_i}{N} f_i$$

where P_i is the ratio of numbers of the ith Siphonophores species to the total in a sample; S, the total species number in a sample; n_i, the average density of the ith species in a cruise; N, the total abundance of Siphonophores in the same cruise; f_i, the occurring frequency of the ith species in all stations of the same cruise.

2 Results

2.1 Species composition

By the data, 31 species of Siphonophores are identified, among which, 5 species of 2 families are Physonectae, and 26 species of 6 families are Calycohorae. Of 31 species, 7 species (Table 1, marked with asterisk) are the first records in the waters around Taiwan Island, among which, the species *Rosacea cymbiformis* is first recorded in China. Up to data, there are totally 38 Siphonophores in the waters around Taiwan Island when all Siphonophores, including the species that were not obtained in these two cruises, are accounted.

Table 1 shows that only 19 species occurred in November and it increased to 29 in December and that more species occurred in the surface water than in the lower water layer.

2.2 Distribution of total abundance and numbers of dominant species

2.2.1 Distribution of total abundance

The abundance of Siphonophores was low (0.438 inds/m^3) in November and there was no difference between the surface water layer (0.435 inds/m^3 on an average) and bottom water layer (0.441 ind/m^3 on an average). From Fig. 2a, it is showed that the abundance is higher in the west waters both at surface and bottom water layer. The total abundance increased rapidly to 1.99 inds/m^3, which is 4.5 times higher in December than in November. The magnitude raised is high, almost 6 times (2.536 inds/m^3 on an average) in the surface water layer, while it is lower, only over 3 times (1.395 inds/m^3 on an average) in the bottom water layer where abundance was only half that of surface water though with a high absolute value.

Tab. 1 Species list of Siphonophores and its distribution in the Nan Wan Bay, Taiwan, in November and December

List of species	November		December	
	surface	bottom	surface	bottom
Physophora hydrostatica Forskal		+	+	
Agalma okeni Eschscholtz			+	+
Agalma elegans (Sars)			+	
Nanomia bijuga (Chiaje)	+	+	+	+
Forskalia edwardsi Kölliker*		+		
Hippopodius hipopus Forskål*				+
Vogtia glabra Bigelow			+	+
Amphicaryon ernesti Totton*			+	
Amphicaryon peltifera (Haeckel)*			+	
Rosacea plicata Quoy et Gaimard			+	+
Rosacea cymbiformis (Chiaje)**				+
Sulculeolaria chuni (Lens et van Riemsdijk)	+	+	+	+
Sulculeolaria quadrivalvis Blainxille	+		+	+
Sulculeolaria tropica Zhang*				+
Lensia campanella (Moser)	+	+		
Lensia hotspur Totton			+	+
Lensia subtilis (Chun)	+	+	+	
Lensia subtiloides (Lens et van Riemsdijk)	+		+	+
Diphyes bojuni (Eschscholtz)	+	+	+	+
Diphyes chamissonis Huxley	+		+	+
Diphyes dispar Chamisso et Eysenhardt	+	+	+	+
Chelophyes appendiculata (Eschscholtz)	+	+	+	+
Chelophyes contorta	+	+	+	+
Eudoxoides mitra	+	+	+	+
Eudoxoides spiralis (Bigelow)	+		+	+
Sphaeronectes gracilis (Claus)		+	+	+
Abyla schmidti Sears			+	+
Abylopsis eschscholtzi (Huxley)	+	+	+	+
Abylopsis tetragona(Otto)	+	+	+	+
Bassia bassensis (Quoy et Gamard)	+	+	+	+
Enneagonum hyalinum (Quoy et Gamard)*				+

* : first species recorded in the waters around Taiwan

** : first species recorded in China Seas

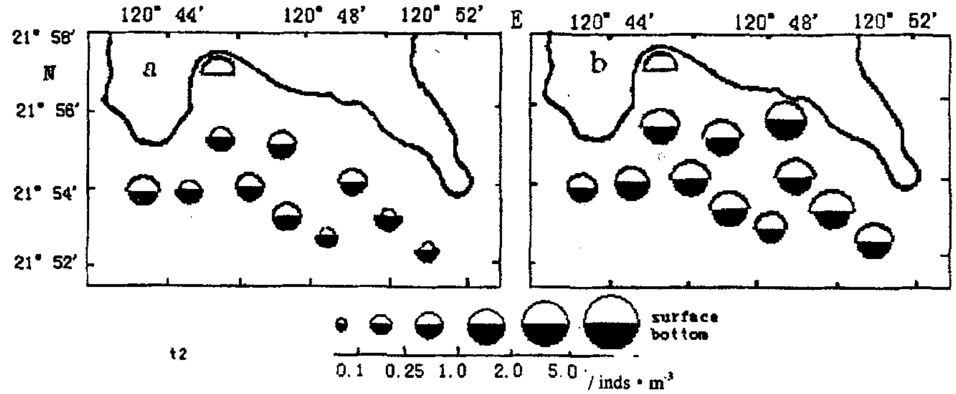

Fig. 2 Horizontal distribution of Siphonophores abundance in November (a) and December (b)

2.2.2 Distribution of Chelophyes appendiculata

Being the most abundant species from the surveys, the dominance of the species was 0.26 and 0.16 in November and December (Fig. 3a), respectively. The average abundance of the species was 0.154 inds/m^3 (35.5 % of the total) in December with a slightly lower abundance in the surface water layer (0.131 inds/m^3) than in the bottom water layer, while it increased markedly (0.342 inds/m^3 on an average, 17.2 % of the total) in November, showing a significant increment of abundance in the surface water layer (0.531 inds/m^3) compared with the lower water layer (0.136 inds/m^3). The abundance was

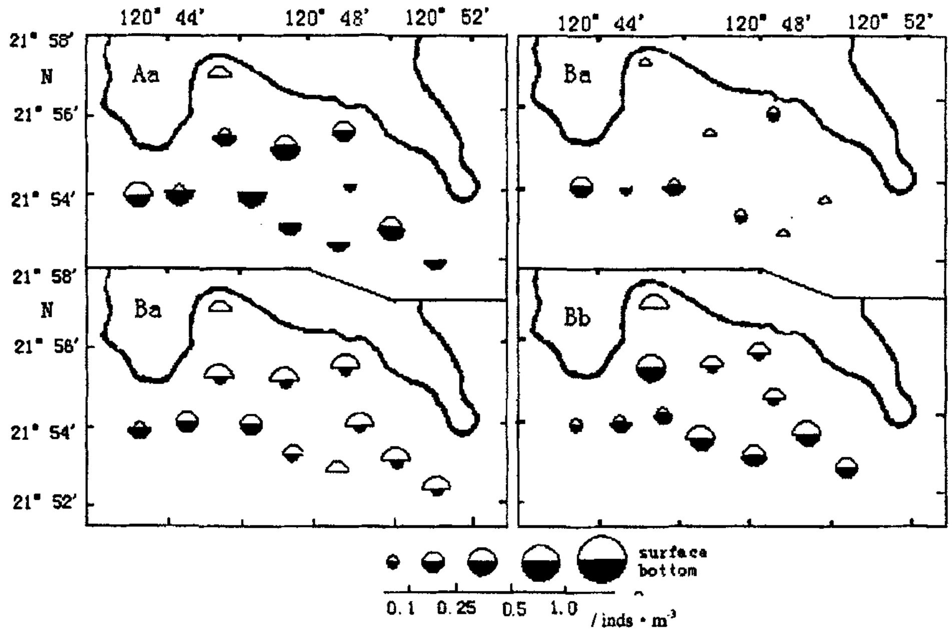

Fig. 3 Horizontal distribution of *Chelophyes appendiculata* (A) and *Bassia bassensis* (B) abundance in November (a) and December (b)

higher in in-shore waters than in offshore waters besides a much homogeneous distribution in bottom water layers (Fig. 3Ab).

Chelophyes appendiculata is a high-temperature and high-salinity cosmopolitan species[5], spreading widely in the three major oceans[13], the East China Sea, the Taiwan Straits and the north, the south and the center of South China Sea, dominating particularly in the center[14] and the south of South China Sea[15]. Reported by Alvarino, the distribution of Chelophyes *appendiculata* is not overlapped with *Chelophyes contorta* in the waters of Central America [16], while according to Rengarajan, these two species are common along the west coast of India except that *Chelophyes appediculata* is mainly found in the open sea and, the other, in the nearshore waters[17]. Stepanyants found that *Chelophyes appendiculata* is most dominant in the waters with salinity higher than 35.5 but *Chelophyes contorta* dominates in salinity from 34.0 to 34.5[18]. In this study we find little difference between their distributions, except that the abundance of *Chelophyes appendiculata* is higher than *Chelophyes contorta* in the Nan Wan Bay since the surveyed area was confined. As a result, it needs to be examined in much wider areas.

2.2.3 Distribution of Bassia bassensis

The abundance of the species was lower (0.044 inds/m^3 on an average) in November, showing no difference in abundance distribution between the surface water layer and the lower water layers, but more homogeneous in surface waters and higher abundance in offshore waters (Fig 3. Ba). The abundance increased markedly, reaching 0.217 inds/m^3 on an average (10.9 % of the total abundance in December) and it was significantly higher in the surface water (0.254 inds/m^3) than in the bottom (0.177 inds/m^3).

Bassia bassensis is also a high-temperature and high-salinity cosmopolitan species in the three major oceans [4, 14], and it dominates particularly in the tropical waters of west Pacific [19, 20]. Besides, it was found in the waters from the East China Sea to the south of South China Sea[5], where it mostly dominates in the central South China Sea [14].

2.2.4 Distribution of other species

Except for the above-mentioned species that dominated in November and December, *diphyes bojani*, *diphyes dispar*, *Abylopsis eschscholtzi* and *Chelophyes contorta* are also highly dominant species (Table 2), among them, the abundances of *diphyes bojani* and *Diphyes dispar* were higher whether in the surface or bottom water layers (10 % of the total abundance), where the abundance was higher in the surface water layer than in the bottom. In contrast, *diphyes bojani* distributed more homogeneously between surface and bottom water layers while *Diphyes dispar* showed a higher abundance in the nearshore waters than in the open sea (Fig. 4).

2.3 Distribution of diversity index

Diversity of Siphonophores was slightly lower in November (Fig. 5a) and there was no difference between the average diversity in surface (1.86) and bottom (1.96) water layers. However, the diversity was higher in the central area, reaching 3.0 at the station 10, compared with the lower value in the

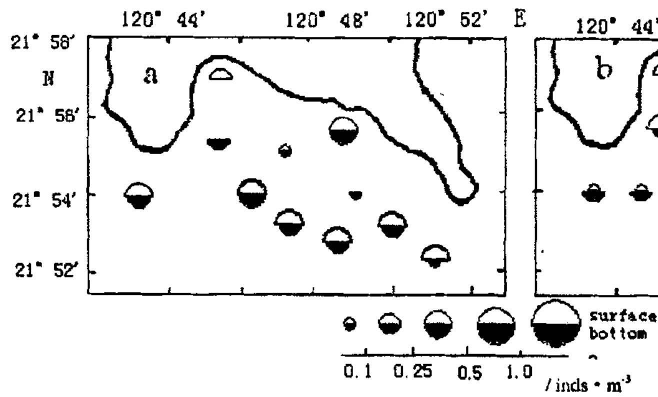

Fig. 4 Horizontal distribution of *Diphyes bojani* (a) and *Diphyes dispar* (b) in December

Tab.2 Abundance and dominance of dominant Siphonophores in November and December

species	November				December			
	Abundance / inds • m^{-3}			Dominance	Abundance / inds • m^{-3}			Dominance
	surface	bottom	average		Surface	bottom	average	
Chelophyes appendiculata	0.131	0.179	0.154	0.26	0.531	0.136	0.342	0.16
Bassia bassensis	0.044	0.043	0.044	0.06	0.254	0.177	0.217	0.11
Diphyes bogani	0.032	0.036	0.034	0.04	0.273	0.193	0.234	0.11
Diphyes dispar	0.013	0.035	0.024	0.02	0.271	0.190	0.232	0.12
Abylopsis eschscholtzi	0.031	0.032	0.031	0.04	0.141	0.113	0.128	0.06
Chelophyes contorta	0.037	0.049	0.043	0.06	0.112	0.084	0.099	0.04

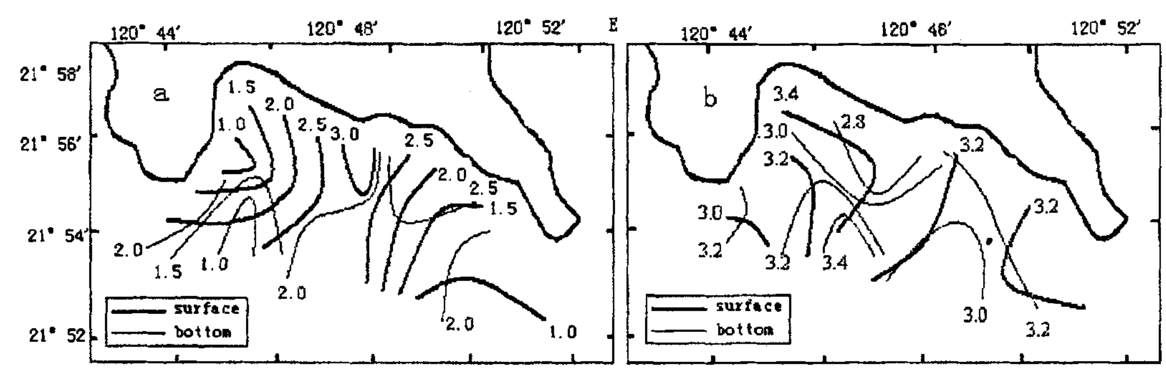

Fig. 5 Horizontal distribution of Siphonophores by Shannon-Winer index in November (a) and December (b)

southeast and northwest of the bay where it is less than 1 because less species were found. In the bottom water layer, a slightly higher index was located in the central than at the east and west ends of the bay.

Diversity was higher in December than in November due to the increased species. It is showed that the species numbers are quite similar among the species with 3.24 and 3.14 in the surface and bottom water layers, respectively. Diversities in the surface water were much the same horizontally except for some higher value in the central bay and lower in the east and west parts of the bay in contrast to the bottom water layers where diversity was higher in the open sea and a slightly lower in the north.

Evenness was high during these two months. It averaged 0.87 (0.69-1.0) and showed higher in the surface (0.90) than the bottom water layer (0.84) in November except for a lower evenness in the surface water layer in the west and in the bottom water layer at the west and east ends of the bay. The evenness was much higher 0.88 (0.83-0.94) by average and showed little difference between surface (0.89) and bottom (0.81) water layers in December.

3 Discussion

3.1 Comparison with Siphonophores in the neighboring waters

From Table 3 we can find that the species number and abundance decrease more or less in the neighboring waters in contrast to the increase in the Nan Wan Bay since the turn of autumn to winter, demonstrating a unique pattern of seasonal alternations. Besides, viewed from the dominant species in autumn and winter, it is demonstrated that, when neritic species *Diphyes chamissonis*, *Lensia subtiloides* and *Muggiaea atlantica* dominated in the East China Sea, the Taiwan Straits and the north of South China Sea, only oceanic high-temperature and high-salinity species dominated in th Nan Wan Bay and central South China Sea. Thus, it is suggested that Nan Wan is geographically closer to the central South China Sea and both belong to the India-west Pacific-indo-Malayan Subregion [5].

Tab. 3 Statistical comparison of the Siphonophores in the waters of Nan Wan Bay with that in the neighboring waters

Seas	East China Sea[21]		West Taiwan Strait[22]		East Taiwan Strait[8]	North of South China Sea*		Central South China Sea[4]		Nan Wan Bay	
Month and Season	Autumn	Winter	Autumn	Winter	Winter	November	December	Autumn	Winter	November	December
Species number	26	37	28	19	19	26	28	54	52	19	29
Abundance /inds • m^{-3}	1.81	1.56	9.00	0.11	0.95	4.03	1.55	1.51	1.24	0.438	1.99
Dominant species	*Diphyes chamissonis, Muggiaea atlantica, Lensia campanella*		*Diphyes chamissonis, Lensia campanella, Muggiaea atlantica*		*Diphyes chamissonis, Lensia campanella*	*Diphyes chamissonis, Lensia campanella, Nanomia bijuga*		*Chelophyes cntorta, Chelophyes appendiculata, Eudoxiodes mitra, Abylopsis tetragona, Bassia bassenisi, Eudoxoides piralis*		*Chelophyes appendiculata, Bassia bassenisi, Diphyes bojani, Diphyes dispar, Abylopsis tetragona, Chelophyes cntorta*	

Note: Nets with a mesh size of 505 μm were used except for that used in the Nan Wan Bay.

* from the manuscripts of Zhang Jinbiao and Xu Zhengzu.

3.2 Comparison of Siphonophores towed by different nets

Two types of nets with different mesh sizes were simultaneously used in zooplankton surveys. It is showed by Table 4 that more species were collected with the net mesh size 333 μm than the mesh size 200 μm, demonstrating a more efficient collection of Siphonophores with the mesh size 333 μm. Probably, the net with a bigger mesh size is much proper for the collection of macrozooplankon of larger Siphonophores. In China it is used to collect various zooplankton with a mesh size of 505 μm and so a comparative study using different nets is necessary for a better result.

It is also found from Table 4 that the obtained species were much more from the surface water layers than from the bottom water layer. This is also the case in the west of Taiwan Strait where species in shallow water (< 25 m) are more than that from deeper water layers (25-50 m) by vertical distribution of Siphonophores. It can be again confirmed that Siphonophores are the pelagic zooplanktonic animals.

Tab. 4 Comparison of species number for Siphonophores collected with nets of different mesh sizes

Month	November				December			
Mesh size /.μm	200		300		200		300	
Water layer	surface	bottom	surface	bottom	surface	bottom	surface	bottom
Species number	13	12	15	13	17	15	25	23
Combined species number	15		19		18		29	

3.3 Distribution of Siphonophores and its relations to the hydrographic factors

According to the behaviors of Siphonophores in the Nan Wan Bay, 31 species can be divided into 3 ecological groups: (1) nearshore warm water cosmopolitan group, which is composed of only 2 species, *Lensia subtitles* and *Diphyes chamissonis*, characterized by lower abundance with higher number near shore; (2) Oceanic warm water cosmopolitan group, which accounts for 84 % of Siphonophores and all dominant species in the Nan Wan Bay are in this group; (3) Oceanic equatorial stenocoenose group, which is composed of only 3 species, *Abyla schmidti*, *Rosacea plicata* and *Lensia companella*. Thus, it is clear that the species appearing in the Nan Wan Bay in November and December are the dominant oceanic warm water species whether viewed from species number or abundance. It is demonstrated that the waters in the Nan Wan Bay is controlled by oceanic water mass and it is confirmed again particularly when 12 species, of which 10 are the oceanic warm water cosmopolitan species and 2 the typical oceanic equatorial species, added in December. It is reported that the water in the Nan Wan Bay is controlled by the mixed water masses of medium salinity from the South China Sea, low salinity water from along the coast and Kuroshio current in autumn while it is dominated by waters only from the South China Sea and Kuroshio due to lack of coastal currents in winter [24]. As a result, the variations of Siphonophores from autumn to winter reflect a trend of the increasing influence of the oceanic water. Many hydrographic studies in the northeast of South China Sea have demonstrated that there is a branch of current, a so-called Kuroshio branch [25,26], which has the highest volume in winter [27], flowing westward or southwestward to the South China Sea through the Bashi Channel. The surveys conducted in the south of Taiwan evidenced a strongest influence of Kuroshio current in winter [28] As a result, it is considered that the increase in Siphonophores' species number and abundance is related to the influence of Kuroshio, which brings in more salinephile oceanic warm water and oceanic equatorial species. Also, data obtained by CTD show that the water temperature is much higher in November reaching 27.56 ℃ and 27.21 ℃ and it decreases evidently to 24.64 ℃ and 23.98 ℃ in December in the surface and bottom water layers, respectively, while for salinity it is low in November averaged only 33.25 and 33.59 and increases to 34.25 and 34.34, respectively, in the surface and bottom water layers. The change in water temperature and salinity also reflects the increasing influence of the oceanic water masses.

Compared with species of Siphonophore in the waters of eastern and western Taiwan Strait and in the north of South China Sea, 29 Siphonophores in the Nan Wan Bay of December are many, which demonstrates that Nan Wan is influenced much by high-temperature high-salinity waters, However, it is noted that the previously recorded typical oceanic equatorial species, such as *Ceratocymba leuckarti*, *Ceatocymba dentata*, *Abyla bicarinata* and *Abyla trigona*, were not found in these surveys. It is probably that these species were collected in the regions where Kuroshio passes by while the Nan Wan Bay is only an inshore cove. Another reason may be that December is only the beginning of winter and it is not the month when Kuroshio influences the most. However, further studies are needed to confirm these hypotheses.

Acknowledgements

Financial support for this research was provided by the Foundation of NS C program of Taiwan and by the program of Fujian Nature and Science Foundation (D97009). The preparation of this manuscript was partly supported by the Start-up Research Foundation for Returned Overseas Personnel from the Ministry of Education, China.

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