第 14 卷第 1 期
2007 年 1 月

中国水产科学
Journal of Fishery Sciences of China

Vol. 14 No. 1
January 2007

东海区沙海蜇的动态分布

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摘要: 根据 2003～2005 年 6 月和 9 月东海区中、北部海域沙海蜇(*Stomolophus meleagris*)的监测结果,分析沙海蜇的生物量、分布、栖息环境及其与海水温度、盐度间的关系,调查范围为 29°00′～34°00′N,127°00′E 以西至机轮底拖网禁渔区线。结果表明,2003 年 6 月～2005 年 6 月,沙海蜇出现样点内的平均生物量分别为 1 555 kg/h、1 139 kg/h、839 kg/h。2003 年 9 月～2005 年 9 月沙海蜇出现样点内的平均生物量分别为 7 144 kg/h、2 292 kg/h、608 kg/h。2003～2005 年 6 月和 9 月,东海区沙海蜇均呈现生物量逐年降低、分布海域面积逐年减少、分布区逐年往北偏移的趋势。6 月,东海区沙海蜇分布区内的表层温度为 17～25 ℃,底层温度为 10～19 ℃,表层盐度为 23～33,底层盐度为 31～34.5;6 月最适生存的表层温度为 17～21 ℃,底层温度为 15～18 ℃,表层盐度为 28～32,底层盐度 31～32.5。沙海蜇为偏冷水性,高盐种类。在春、夏季黄海冷水团势力强的年份,沙海蜇的发生和危害程度严重;而在春、夏季长江冲淡水势力强的年份,沙海蜇的发生较少,分布偏北。[中国水产科学,2007,14(1):83－89]

关键词: 沙海蜇;分布;温度;盐度;东海区
中图分类号: S931 **文献标识码:** A **文章编号:** 1005－8737－(2007)01－0083－07

沙海蜇(*Stomolophus meleagris*),属刺胞动物亚门(Cnidaria),钵水母纲(Scyphomedusae),根口水母目(Rhizostomeae),口冠水母科(Stomolophidae),口冠水母属(*Stomolophus*)[1]。沙海蜇广泛分布于西北太平洋沿岸海域[2－3],其中在中国主要分布于东海北部和黄海南部[1,4]。自 20 世纪 90 年代中后期起,东海北部及黄海海域连年发生大型水母的大量暴发现象,其中 2003 年其发生程度最严重。水母大量暴发区内不仅渔业生产活动受到严重影响,而且渔业资源也相应锐减,造成了严重的生态灾难[5－7]。近年来,该海域大量发生的主要水母种类为沙海蜇和霞水母(*Cyanea* sp.),其中生物量最高、影响范围最广的种类为沙海蜇[8]。本研究室于 2003～2005 年将沙海蜇作为重点对象进行监测。程家骅等[8]曾对东海区大量发生的大型水母种类及其分布进行过描述,并分析了其分布数量及特征与环境间的关系,但就单一种类的研究尚未见报道。为此,本研究结合近 3 年的监测资料,对东海区沙海蜇的生物量、分布、栖息环境等进行总结,以期为沙海蜇的进一步研究提供理论和事实依据。

1 材料方法

2003～2005 年 6 月和 9 月在东海区中、北部海域进行大型水母动态的大面监测,监测范围为 29°00′～34°00′N,127°00′E 以西至机轮底拖网禁渔区线。监测船为 220 kW 的拖网渔船,取样网具为 4 m×100 目的底拖网,取样拖速为 3 kn/h。每个取样点的监测内容包括沙海蜇的单位时间渔获量(湿重)、伞径,海水温度、盐度等,其中,海水温度、盐度用 Seabird-37 型 CTD 测定。各样点内沙海蜇的单位时间渔获量用生物量表示(kg/h),其中将沙海蜇生物量高于 1 000 kg/h 的海域视为生物量较高密集区,将沙海蜇生物量高于 10 000 kg/h 的海域视为生物量最高密集区。

2 结果与分析

2.1 沙海蜇生物量分布

2.1.1 6 月

(1) 2003 年 6 月,出现样点内最高生物量为 15 000 kg/h,最低生物量为 2.75 kg/h,平均生物量为 1 555 kg/h。此时,沙海蜇广泛分布于29°30′～

收稿日期:2005－12－20; 修订日期:2006－04－03.
基金项目:国家科技部公益性研究项目.
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34°00′N 海域,其中生物量较高密集区在 30°30′～33°00′N,122°30′～126°00′E 间,生物量最高密集区在 32°00′N,124°00′E 附近海域(图 1)。

(2) 2004 年 6 月,出现样点内最高生物量为 10 667 kg/h,最低生物量为 1 kg/h,平均生物量为 1 139 kg/h。此时,沙海蜇广泛分布于 30°00′～34°00′N 海域,其中生物量较高密集区在 31°00′～33°00′N,123°00′～125°30′E 间,生物量最高密集区在 32°00′N,124°30′E 附近海域(图 1)。

(3) 2005 年 6 月,出现样点内最高生物量为 5 333 kg/h,最低生物量为 3 kg/h,平均生物量为 839 kg/h。此时,沙海蜇广泛分布于 31°00′～34°00′N 海域,其中生物量较高密集区在 31°30′～33°00′N,122°30′～125°00′E 间,生物量最高密集区在 32°30′N,124°30′E 附近海域(图 1)。

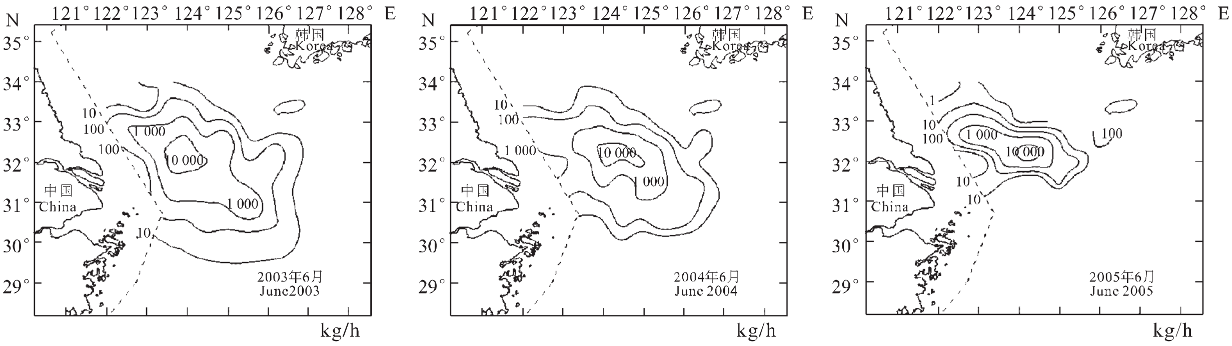

图 1 2003 年 6 月、2004 年 6 月和 2005 年 6 月东海区沙海蜇生物量分布

Fig. 1 Biomass distribution of *S. meleagris* in Junes of 2003, 2004 and 2005 in the East China Sea Region

2.1.2 9 月

(1) 2003 年 9 月,出现样点内最高生物量为 30 000 kg/h,最低生物量为 2.5 kg/h,平均生物量为7 144 kg/h。此时,沙海蜇广泛分布于 30°30′～34°00′N 海域,其中生物量较高密集区在 31°00′～34°00′N,122°00′～126°00′E 间,生物量最高密集区在 32°00′N 以北海域(图 2)。

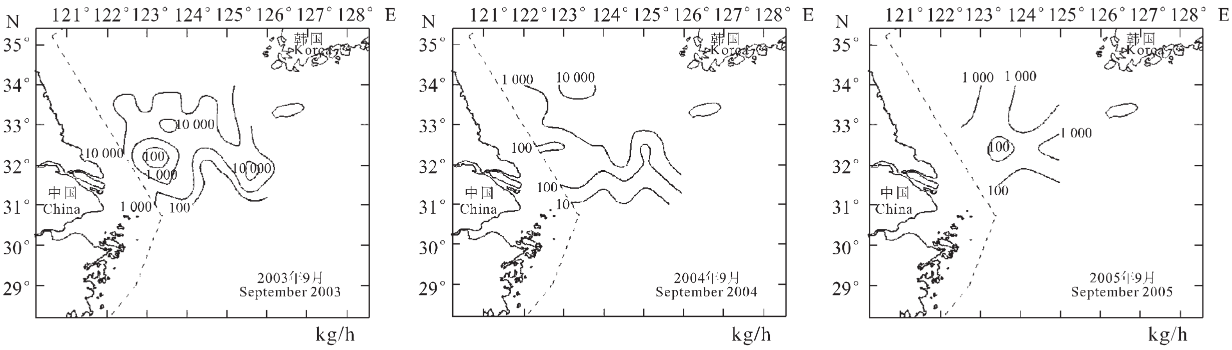

图 2 2003 年 9 月、2004 年 9 月和 2005 年 9 月东海区沙海蜇生物量分布

Fig. 2 Biomass distribution of *S. meleagris* in Septembers of 2003, 2004 and 2005 in the East China Sea Region

(2) 2004 年 9 月,出现样点内最高生物量为 15 000 kg/h,最低生物量为 3.6 kg/h,平均生物量为2 292 kg/h。此时,沙海蜇广泛分布于 31°00′～34°00′N 海域,其中生物量较高密集区在 32°00′～34°00′N,122°00′～126°00′E 间,生物量最高密集区在 33°30′～34°00′N,123°00′～124°00′E 海域(图 2)。

(3) 2005 年 9 月,出现样点内最高生物量为 3 000 kg/h,最低生物量为 50 kg/h,平均生物量为 608 kg/h。此时,沙海蜇广泛分布于31°30′～34°00′N 海域,其中生物量较高密集区在 32°00′～34°00′N,

122°00′～125°00′E 间,未出现明显的生物量最高密集海域(图 2)。

2.2　海水温度和盐度分布

海水的温度和盐度变化可影响水母数量[9],这种影响主要是通过影响水母水螅体的无性繁殖速度以及水母幼体期的成活率而实现的[10]。另外,由于 6 月东海区沙海蜇的分布范围较 9 月更广,且 6 月沙海蜇个体较小。为了更好的反映沙海蜇分布与海水温度和盐度之间的关系,在此以 6 月为例进行分析。(图 3～6)

2.2.1　温度

(1)2003 年 6 月沙海蜇分布区内的表层温度为 17～23 ℃,底层温度为 10～19 ℃;生物量较高密集区内的表层温度为 17～21 ℃,底层温度为 13～18 ℃;生物量最高密集区内的表层温度为 17～20 ℃,底层温度为 15～17 ℃。

(2)2004 年 6 月沙海蜇分布区内的表层温度为 19～25 ℃,底层温度为 11～19 ℃;生物量较高密集区内的表层温度为 19～23 ℃,底层温度为 13～18 ℃;生物量最高密集区内的表层温度为 19～21 ℃,底层温度为 15～18 ℃。

(3)2005 年 6 月沙海蜇分布区内的表层温度为 17～24 ℃,底层温度为 11～19 ℃;生物量较高密集区内的表层温度为 17～23 ℃,底层温度为 15～18 ℃;生物量最高密集区内的表层温度为 18～21 ℃,底层温度为 15～17 ℃。

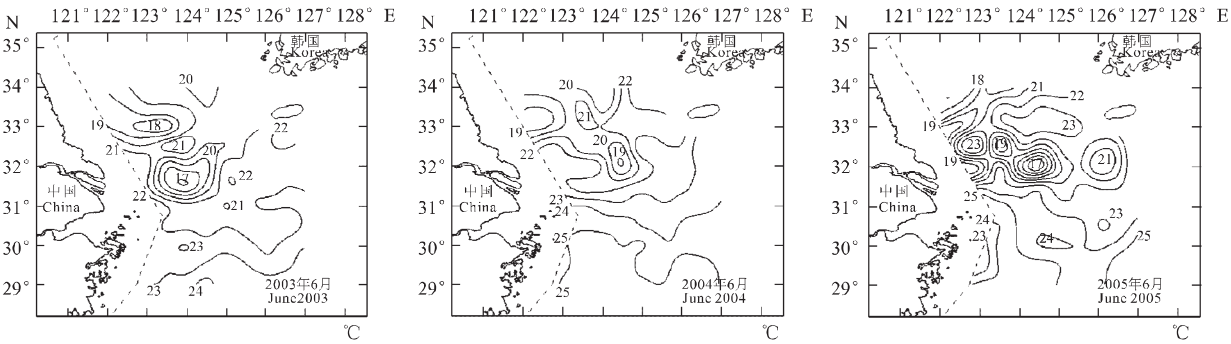

图 3　2003 年 6 月、2004 年 6 月和 2005 年 6 月东海区表层温度分布图

Fig. 3　Surface water temperature of the East China Sea Region in Junes of 2003,2004 and 2005

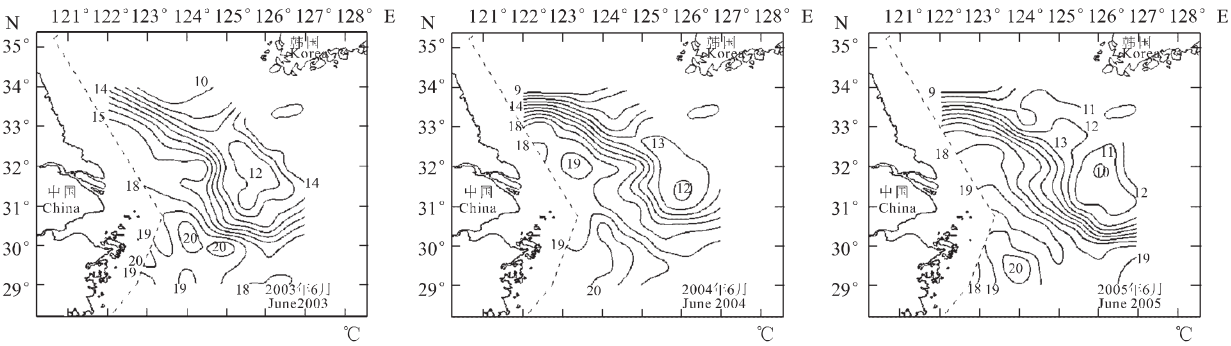

图 4　2003 年 6 月、2004 年 6 月和 2005 年 6 月东海区底层温度分布图

Fig. 4　Bottom water temperature of the East China Sea Region in Junes of 2003,2004 and 2005

综上,6 月沙海蜇适应的表层温度为 17～25 ℃,底层温度为 10～19 ℃。最高密集区的表层温度为 17～21 ℃,底层温度为 15～18 ℃。2004 年和 2005 年 6 月沙海蜇分布区内的水温相似,而 2003 年 6 月沙海蜇分布区内的表层温度均比 2004 年和 2005 年同期表层温度偏低 1～2 ℃。

2.2.2　盐度

(1)2003 年 6 月沙海蜇分布区内的表层盐度为 23～32,底层盐度为 31～34;生物量较高密集区内的表层盐度为 26～32,底层盐度为 31～33;生物量

最高密集区内的表层盐度为30～32,底层盐度为31.5～32.5。

(2)2004年6月沙海蜇分布区内的表层盐度为24～33,底层盐度为31.5～34.5;生物量较高密集区内的表层盐度为26～32,底层盐度为31.5～33;生物量最高密集区内的表层盐度为29～31,底层盐度为31.5～32.5。

(3)2005年6月沙海蜇分布区内的表层盐度为25～31,底层盐度为31～33.5;生物量较高密集区内的表层盐度为26～31,底层盐度为31～32.5;生物量最高密集区内的表层盐度为28～30,底层盐度为31～32。

综上,6月沙海蜇适应的表层盐度为23～33,底层盐度为31～34.5。最高密集区的表层盐度为28～32,底层盐度为31～32.5。2005年6月沙海蜇较高密集区和最高密集区的表层盐度和底层盐度均比2003年和2004年同期偏低0.5左右。

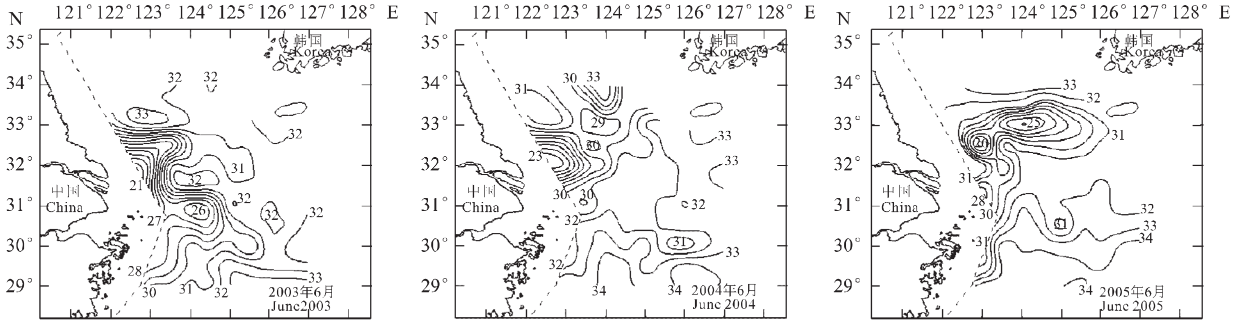

图5 2003年6月、2004年6月和2005年6月东海区表层盐度分布图

Fig. 5 Surface water salinity of the East China Sea Region in Junes of 2003,2004 and 2005

2.2.3 断面温盐度分布 2003年6月～2005年6月沙海蜇的分布均呈现沿西北至东南方向,即主要聚集在34°00′N,122°00′E～29°30′N,126°30′E断面上,并向周围逐渐减少(图1)。因此,年间该断面上沙海蜇分布变化及其温盐度变化情况也能有效地反映出海水温度与盐度变化对沙海蜇分布的影响。

该断面上,2003年6月沙海蜇较高密集区主要在33°00′N,123°00′E～30°30′N,125°30′E范围间(图1),该范围间的温度为15～21 ℃(图7),盐度为28～33(图8)。2004年6月沙海蜇较高密集区主要在32°30′N,123°30′E～31°00′N,125°00′E范围间(图1),该范围间的温度为17～23 ℃(图7),盐度为29～33(图8)。2005年6月沙海蜇较高密集区主要在33°00′N,123°00′E～32°00′N,124°00′E范围间(图1),该范围间的温度为16～24 ℃(图7),盐度为26～31(图8)。

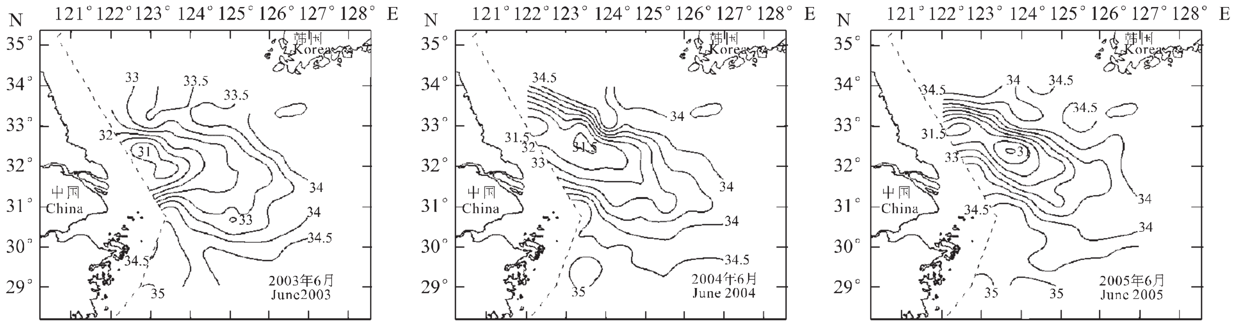

图6 2003年6月、2004年6月和2005年6月东海区底层盐度分布图

Fig. 6 Bottom water salinity of the East China Sea Region in Junes of 2003,2004 and 2005

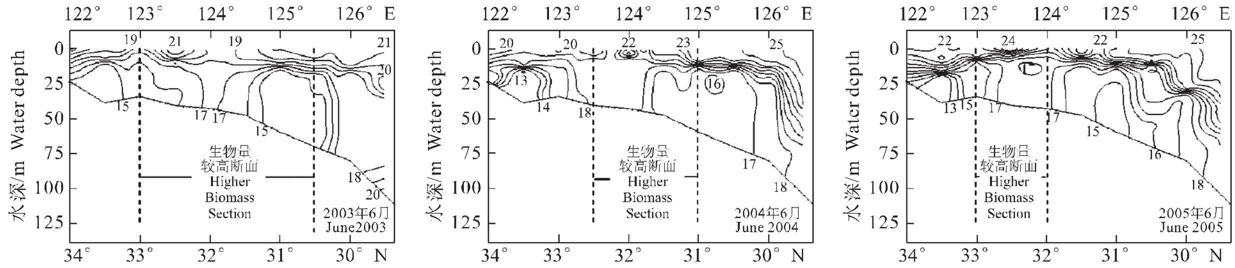

图 7　2003 年 6 月、2004 年 6 月和 2005 年 6 月 34°00′N,122°00′E～29°30′N,126°30′E 断面水温(℃)分布图

Fig. 7　Seawater temperature(℃) in the section of 34°00′N,122°00′E—29°30′N,126°30′E in Junes of 2003,2004 and 2005

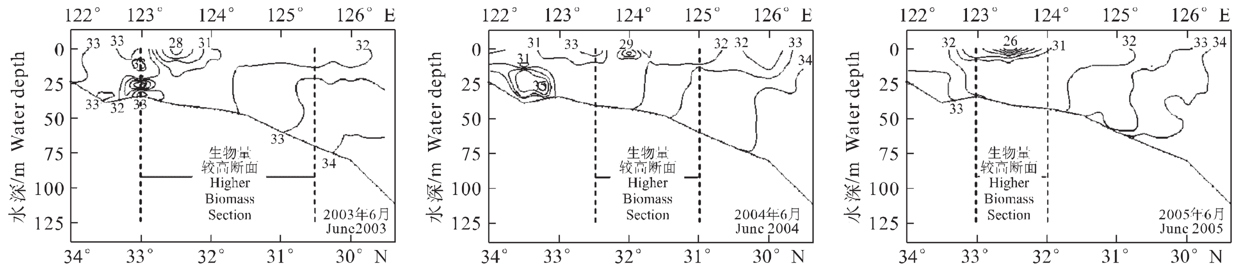

图 8　2003 年 6 月、2004 年 6 月和 2005 年 6 月 34°00′N,122°00′E～29°30′N,126°30′E 断面盐度分布图

Fig. 8　Seawater salinity in the section of 34°00′N,122°00′E—29°30′N,126°30′E in Junes of 2003,2004 and 2005

综上,6 月在 34°00′N,122°00′E～29°30′N,126°30′E断面内的沙海蜇较高密集区内,2003 年沙海蜇分布范围最大,2005 年最小;2003 年温度比 2004 年和 2005 年偏低 1～2 ℃;2005 年盐度较 2003 年和 2004 年偏低 2 左右。

3　讨论

3.1　东海区沙海蜇分布及其生态类型

2003 年 6 月～2005 年 6 月间,东海区沙海蜇不仅生物量逐年降低,而且分布海域面积也逐年减少,分布区也有逐年往北偏移的趋势。同样,2003 年 9 月～2005 年 9 月间东海区沙海蜇也呈现这种趋势。

2003～2005 年间,6 月沙海蜇生物量最高密集区主要分布于 32°00′N,124°00′E 附近海域。9 月沙海蜇生物量的最高密集区,在 2003 年范围最广,主要分布于 32°00′N 以北海域;在 2004 年集中在 33°30′～34°00′N,123°00′～124°00′E 海域;而 2005 年未出现明显的生物量最高密集区。

6 月份,东海区沙海蜇分布区内的表层温度为 17～25 ℃,底层温度为 10～19 ℃,表层盐度为 23～33,底层盐度为 31～34.5。如果将沙海蜇最高密集区内的环境条件视为其生存的最适环境,那么 6 月东海区沙海蜇最适生存的表层温度为 17～21 ℃,底层温度为 15～18 ℃,表层盐度为 28～32,底层盐度 31～32.5,可见沙海蜇为偏冷水性,高盐种类[1]。

3.2　沙海蜇分布与海水温度、盐度间的关系

由于水母生长速度很快,生命周期较短(通常仅为 8～10 个月),因此水母的发生、分布以及生物量等可能随年间水体环境变化而变化[10]。一般认为,随着全球温暖化的趋势,海水温度升高可能是近几十年来全球水母频繁并大量发生的原因之一[11-12],但这并不是绝对的。例如 1973～1983 年间丹麦西北部海域的海月水母(*Aurelia aurita*)和霞水母(*C. lamarckii*)以及 1971～1982 年间苏格兰东部海域的海月水母数量随水温升高而降低,随水温降低而升高[10,13]。另外,盐度变化也可能会影响到水母数量的变化。例如在中国的辽东湾,由于辽东湾北部河流淡水注入量的猛增,导致了 1986 年海蜇(*Rhopilema esculenta*)大幅度减产[14],同样在美国的切萨皮克湾,在淡水输入量较多的 1996 年,由于海水盐度较低,导致了远洋水母(*Chrysaora quinquecirrha*)数量与盐度较高的 1995 年同期相比锐减[15]。

6 月,东海区沙海蜇分布区内的水团主要包括:黄海冷水团、东海暖水团和长江冲淡水。其中,黄海冷水团为低温、中盐水体,东海暖水团为高温、高盐水体,长江冲淡水为低盐水体,夏季长江冲淡水的低

盐水舌一般伸向东北方向[16-17]。

2003年6月～2005年6月间,东海区水温和盐度存在年间差异。2003年6月水温偏低,沙海蜇分布区内的表层温度均比2004年和2005年同期偏低1～2 ℃,在34°00′N,122°00′E～29°30′N,126°30′E断面上的沙海蜇较高密集区内的水温均比2004年和2005年同期偏低1～2 ℃左右。2003年6月偏低的水温主要是由势力较强的黄海冷水团引起的,而同期沙海蜇生物量最高,影响范围最广。另外,由于沙海蜇为偏冷水性种类,因此可以初步认为在春、夏季水温偏低,即黄海冷水团势力较强的年份,沙海蜇的生物量偏高且分布范围偏广[8]。

2005年6月沙海蜇较高密集区和最高密集区内的表层盐度和底层盐度均比2003年和2004年同期偏低0.5左右,在34°00′N,122°00′E～29°30′N,126°30′E断面上的沙海蜇较高密集区内的盐度较2003年和2004年同期偏低2左右。另外,33°00′N,124°00′E附近海域的表层盐度,2003年6月为31,2004年6月为29,2005年6月仅为25(图5),而这种盐度变化主要是由长江冲淡水势力强弱引起的,可见2005年春、夏季长江冲淡水势力可能最强。2005年6月长江冲淡水在到达33°00′N,124°00′E附近海域的过程中,其途经海域的盐度将会更低(<25),此时正值春、夏季,是沙海蜇水螅体进行无性繁殖以及水螅体生成水母幼体的重要时期,该时期沙海蜇对环境条件变化极为敏感[11]。由于沙海蜇成体的最适生存的表层盐度为28～32,为高盐性种类,2005年春、夏季较低的海水盐度可能会严重影响其发生量,而有关盐度对沙海蜇水螅体以及水母幼体的影响还需要进一步的生态实验方面的验证。另外,由于2005年6月长江冲淡水的影响范围更广,更加偏北,必将引起同期沙海蜇分布的偏北状况。

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Dynamic distribution of *Stomolophus meleagris* in the East China Sea Region

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Abstract: Since the mid-1990s, jellyfish blooms have been occurring every year in the northern part of the East China Sea and the Yellow Sea, which have caused ecological disaster in those areas. The main species in the blooms include *Somolophus meleagris* and *Cyanea* sp. , and *S. meleagri* is the dominant species. We monitored the dynamic distribution of *S. meleagris* in the central and northern parts of the East China Sea Region in Junes and Septembers of 2003, 2004 and 2005. Based on the monitoring results, the biomass, distribution and inhabited environment of *S. meleagris*, as well as their relationships with water temperature and salinity were analyzed. In Junes of 2003 to 2005, the mean biomasses of *S. meleagris* in the monitoring stations were 1 555 kg/h, 1 139 kg/h and 839 kg/h, respectively. In Septembers of 2003 to 2005, the mean biomasses were 7 144 kg/h, 2 292 kg/h and 608 kg/h, respectively. The results suggest that, from 2003 to 2005, the biomass and distributed range of *S. meleagris* in June and September decreased and tended northward. The temperatures and salinities of sea surface water and bottom water within the distributed areas of *S. meleagris* in Junes from 2003 to 2005 were 17—25 ℃, 10—19 ℃ , and 23—33 and 31—34. 5, respectively. Assuming the area with the highest biomass was the optimum environment for *S. meleagris*, the optimum water temperature and salinity of sea surface and bottom for *S. meleagris* in June in the East China Sea Region were 17—21 ℃, 15—18 ℃, and 28—32 and 31—32. 5, respectively. Thus *S. meleagris* is a relatively low-temperature and high-salinity species. The water masses which affect the distribution of *S. meleagris* include Yellow Sea Cold Water Mass(YC), East China Sea Warm Water Mass(EW) and Yangtze Diluted Water(YD) in June. YC is a water mass of low temperature and moderate salinity, while EW is a water mass of high temperature and high salinity, and YD is a water mass of low salinity. YD usually extends northeastwards in summer. The sea surface water temperature in the distribued range of *S. meleagris* was lower in June of 2003 than those in Junes of 2004 and 2005, which was caused by the strong YC in 2003. Since *S. meleagris* is a relatively low temperature species, the stronger YC in 2003 induced the largest blooms and widest distribution of *S. meleagris* during 2003—2005. Thus in spring and summer, if YC is strong, *S. meleagris* would bloom in the East China Sea Region. The salinity in the distribution area of *S. meleagris* was lower in June of 2005 than those in Junes of 2003 and 2004, which was caused by the strongest YD in June 2005. Since *S. meleagris* is a high-salinity species, the strong YD resulted in the smallest blooms and occurrence range of *S. meleagris* in 2005. Thus, in spring and summer, if YD is strong, *S. meleagris* blooms would be small and distributed narrowly. The blooms would also occur further northwards in the East China Sea Region. [Journal of Fishery Sciences of China, 2007, 14(1): 83—89]

Key words: *Stomolophus meleagris*; distribution; seawater temperature; seawater salinity; the East China Sea Region

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第14卷第1期
2007年1月

中国水产科学
Journal of Fishery Sciences of China

Vol. 14 No. 1
January 2007

Effects of sand on survival and growth of sand shrimp, *Crangon uritai* (Decapoda: Crangonidae) reared in laboratory

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Abstract: The sand shrimp, *Crangon uritai*, collected by a beam trawl in coastal area of Busan (Korea), was reared individually in laboratory under controlled conditions: 14 ℃, salinity, 32.5, L∶D 12∶12, feeding meat of frozen prawns. To investigate the effect of sand on survival and growth of the shrimp, 40 shrimps were reared with sand substratum while the others were reared without sand substratum. The size of shrimp was determined from exuviae, and the intermolt period was recorded. As a result, the survival rates were 38% and 25% for female and male reared with sand, respectively, and 28% and 10% for female and male reared without sand. The mean intermolt periods were 15.0 d and 15.3 d for females and males reared with sand, respectively, which were shorter than those of females and males reared without sand (16.9 d and 16.9 d, respectively). The mean molt increments were 5.2% and 4.8% for females and males reared with sand, and 3.7% and 3.2% for females and males reared without sand, respectively, which showed that molt increment was greater in both female and male with sand offered than those without sand. Consequently, this led to a higher growth rate with sand rearing. [Journal of Fishery Sciences of China, 2007, 14(1): 90−98]

Key words: *Crangon uritai*; sand; survival; growth; intermolt period; molt increment

CLC number: S96　　**Document code**: A　　**Article ID**: 1005−8737−(2007)01−0090−09

Sand shrimp, *Crangon uritai* Hayashi and Kim, 1999, is one of the most abundant macrobenthic species in Dadaepo coastal area in Korea. The species in habits upon soft sandy or sand-muddy bottoms from intertidal zone to *ca*. 40 m, and is distributed geographically along the eastern Asian coast—the Yellow Sea, the northern East China sea, the central and southern parts of the Sea of Japan and the Seto Inland Sea[1]. Just like other *Crangon* shrimp, *C. uritai* not only feeds benthic polycheata, bivalve, algae and detritus, but also is preyed by fish in these areas (unpublished data). In spite of the ecological importance of this species in trophical energy flow, previous study has only covered its larval development[2].

The growth of Crustacea is a discontinuous process because of the inextensible exoskeleton. Increase only occurrs, therefore, when they shed the old exoskeleton and renew a new exoskeleton[3−7]. As a consequence of the discontinuity, crustacean growth can be broken down into the following two components (growth factors). One is intermolt period (the duration between two successive molts and thus the length of an instar), and the other is molt increment (the increase in size occurring at a molt)[3]. In order to understand the crustacean growth properly, the two components need to be analyzed separately. Both of the intermolt period and the molt increment can display different response to environmental changes such as substratum (including sand) absence or presence.

Received date: 2006−07−17; **Revised date**: 2006−08−25.

Foundation item: Research supported by Open Laboratory of Marine Estuarine Fisheries (开−3−04−1).

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It was reported that the size of particles (for instance grain size in sand) the animal buried with affected burying ability for some decapod (example in *Crangon crangon*)[8]. It was also found that sand could be used as a stimulus for settlement (such as ghost shrimps *Callichirus major* and *C. islagrande*[9−11]), and several studies have shown that the absence of sand cue may delay the shrimp to settle and then reslts in metamorphosing[12−19], which ultimately, leads to postponing of the growth (intermolt period was increased). In addition, the growth of shrimps reared with sand was better than that of shrimp reared without sand[20−22]. The above studies led to a hypothesis that sand could affect one of the growth components (intermolt period and molt increment) of *C. uritai*. However, there is no empirical evidence so far.

In order to verify this hypothesis, a laboratory experiment was conducted for both sexes of *C. uritai* reared with and without sand. And the present study is focusing on the effects of sand on survival and growth (including intermolt period and molt increment) of sand shrimp *C. uritai*.

1 Materials and methods

1.1 Materials

C. uritai were collected by a beam trawl at about 4 m depth in Dadaepo (35°02′N, 128°57′E), Busan, Korea. The shrimps were transported to the laboratory in coolers containing sea water from the collection site with mild aeration, and gradually acclimated to the laboratory conditions at 14 ℃, salinity 32.5 and L∶D 12∶12 for 3 d before the experiment began.

1.2 Experiment design

The experiment was conducted with 80 plastic tanks of 2 L each. Forty tanks were provided with sand obtained from the natural habitat (collection site) of this species, whereas the rest 40 tanks were without sand. A total of 80 shrimps (40 females and 40 males) were used in this experiment. Twenty females and 20 males were kept individually in tanks with sand while the others were kept in tanks without sand. Carapace length and sex of each shrimp were determined before the experiment. During the rearing, fresh food (meat of frozen prawns) was provided every day and the residual food was siphoned off 24 h after feeding. NSF and NSM refer to treatments of females and males reared without sand; SAF and SAM refer to females and males reared with sand, respectively.

The experiment lasted for 100 d. All of the individually rearing tanks were covered with mesh lids to prevent the shrimps from escaping. The shrimps were checked daily for the presence of exuvia, dead individuals and the amount of food remaining in each tank. The molting time was also recorded and considered as intermolt period. Seawater was exchanged every three days.

In order to reduce the stress of handling, the carapace length (CL), from the tip of the rostrum to the posterior margin in the middle, was determined by measuring the exuvia to the nearest 0.1 mm with ocular micrometers equipped in wild microscope. Growth was determined by linear increments of carapace length of the exuvia. The molt increment (growth factor, I_{i+1}) of *Crangon uritai* was defined here as the ratio of the carapace lengths in successive stage (i, $i+1$):

$$I_{i+1} = (CL_{i+1} - CL_i)/CL_i$$

1.3 Statistical analysis

Kolmogorov-Smirnov two-sample test was used to analyze any significant difference in the size distribution of shrimps at the beginning of the experiment. Survival data were analyzed with separate 2-way (sand and time) ANOVA for female and male shrimps. Data were expressed as the proportion of the initial number of shrimp that survived to each census. The effects of sand on the intermolt period and molt increment were examined by regressing the logarithm of each variable against carapace length (CL)[3,23−24]. Analysis of covariance (ANCOVA) was used to compare regression slopes and elevations to determine whether differences occurred between the two sand treatments or between females and males. A common slope was also computed and the elevations were compared when the individual slopes were not significantly different. In all statistical analyses, significant difference was determined at $P<0.05$. This statistical analysis was conducted by MINITAB program(version 12).

2 Results and analysis

The initial carapace length was (8.9 ± 1.0) mm in NSF, (6.1±0.5) mm in NSM, (8.5±1.2) mm in SAF and (6.1±0.6) mm in SAM. No significant differences were found in initial size distribution in each treatment(Tab. 1).

Tab. 1 Kolmogorov-Smirnov two sample test for difference of size distribution of shrimps used in each treatment

表 1 小褐虾甲长分布的 Kolmogorov-Smirnov 检验

Treatment 分组	NSF	NSM	SAF
NSM	0.595(0.400)		
SAF	0.769(0.250)	0.472(0.514)	
SAM	0.778(0.333)	0.919(0.286)	0.549(0.417)

Note: 1) NSF—females without sand; NSM—males without sand; SAF—females with sand; SAM—males with sand.
2) Value in parenthesis indicate d_{max}.
注:1) NSF—无沙饲养的雌性个体;NSM—无沙饲养的雄性个体;SAF—有沙饲养的雌性个体;SAM—有沙饲养的雄性个体.
2) 括号里的数值表示 d_{max} 值.

2.1 Survival rate

Percentage survival is plotted against time in Fig. 1. At the end of the experiment(100th day), NSF and NSM showed 28% and 10% of survival rates, respectively, while SAF and SAM showed 38% and 25% of survival rates, respectively (Fig. 1). The survival rate of female shrimp decreased significantly in both treatments with time ($F=149.36, P<0.001$) but sand treatment had no significant effect on survival ($F=0.01, P>0.9$). The survival rate of male also decreased with time ($F=185.60, P<0.001$) but sand treatment had no significant effect($F=0.03, P>0.4$).

2.2 Intermolt period

Intermolt period was plotted against carapace length for NSF, NSM, SAF and SAM (Fig. 2A—D), and there were significant regressions of lg intermolt period on carapace length(Tab. 2).

The mean intermolt periods were 16.9 d, 16.9 d, 15.0 d and 15.3 d in NSF, NSM, SAF and SAM, respectively. An analysis by ANCOVA showed no significant difference in slopes among the four regimes of NSF, NSM, SAF and SAM($F=1.58$; $df=3,193$; $P=0.194$), so all of the four treatments were recalculated to a common slope (Fig. 2E). However, there was significant difference in elevations($F=7.35$; $df=3,196$; $P<0.001$). When the sexes were analysed separately, ANCOVA revealed significant difference for both females($F=1.031$; $df=1,85$; $P<0.05$) and males($F=8.74$; $df=1,116$; $P<0.05$). Intermolt periods are shorter in both females and males reared with sand than those reared without sand(Fig. 2E).

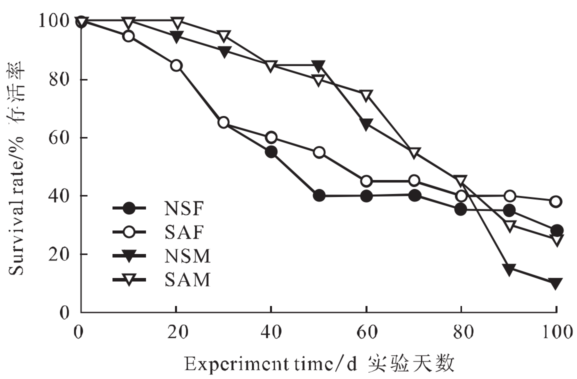

Fig. 1 Percentage survival plotted against time in each treatment(14 ℃, S 32.5)

Note: NSF—females without sand; NSM—males without sand; SAF—females with sand; SAM—males with sand.

图 1 对应于时间的存活率百分比(14 ℃, S 32.5)

注:NSF—无沙饲养的雌性个体;NSM—无沙饲养的雄性个体;SAF—有沙饲养的雌性个体;SAM—有沙饲养的雄性个体.

Tab. 2　Regression analysis on logarithm of intermolt period(days) on carapace length in each treatment

表 2　蜕皮间隔和甲长的回归分析

Treatment 处理	n	Regression parameters 回归系数 lg IP ＝ a＋b・CL		R^2	P
		a	b(±SD)		
NSF	49	0.920 0	0.033 3(±0.029)	0.83	＜0.05
NSM	50	0.661 0	0.090 8(±0.068)	0.90	＜0.05
SAF	36	0.536 2	0.081 3(±0.057)	0.76	＜0.05
SAM	66	0.784 3	0.067 0(±0.040)	0.88	＜0.05

Note：1)NSF－females without sand；NSM－males without sand；SAF－females with sand；SAM－males with sand.
2)IP－intermolt period；CL－carapace length.

注：1)NSF－无沙饲养的雌性个体；NSM－无沙饲养的雄性个体；SAF－有沙饲养的雌性个体；SAM－有沙饲养的雄性个体.
2)IP－蜕皮间隔；CL－甲长.

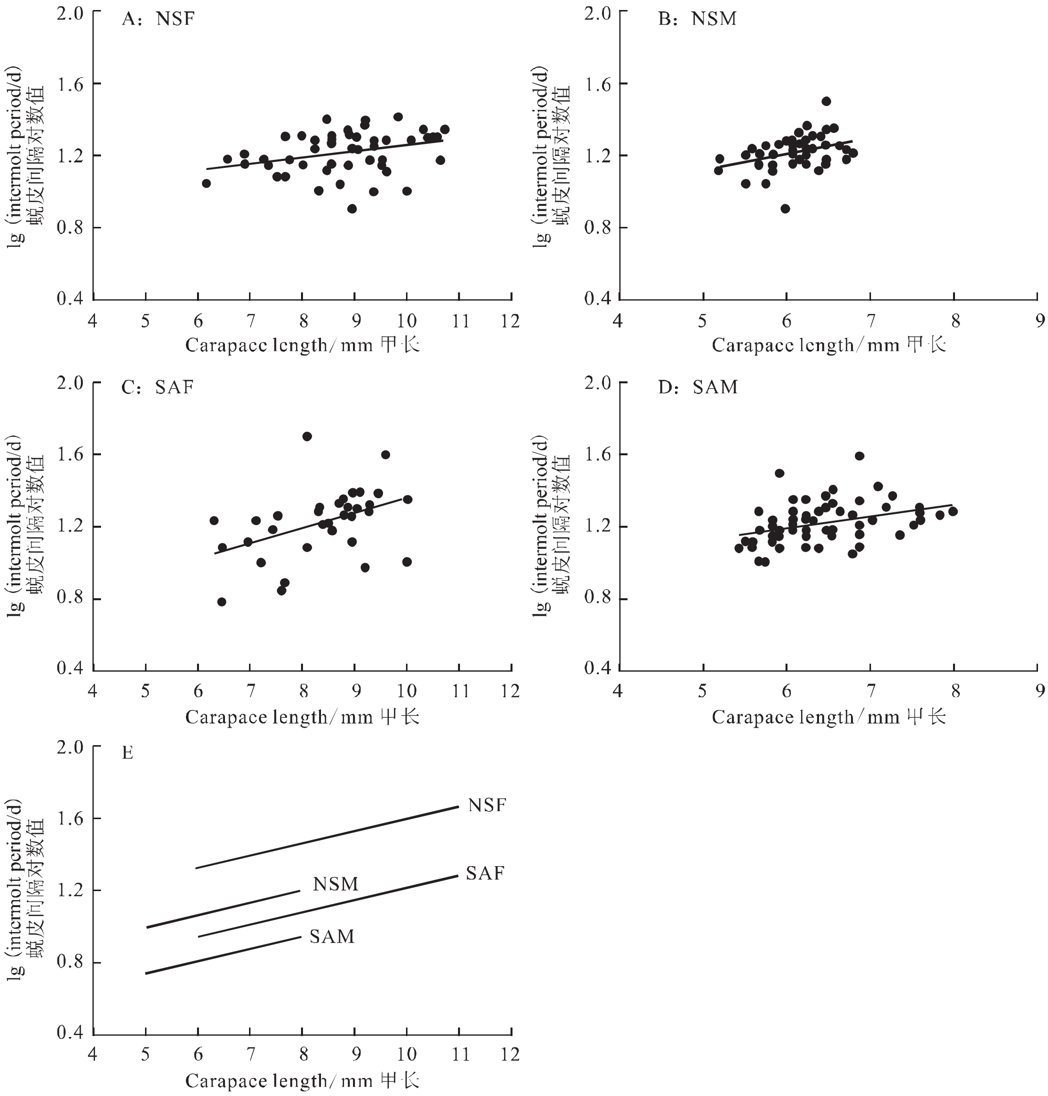

Fig. 2　Logarithm(lg) of intermolt period(days) plotted against carapace length in each treatment(14 ℃，S 32.5)

Note：NSF－females without sand；NSM－males without sand；SAF－females with sand；SAM－males with sand. Lines in E show the regressions recalculated to common slopes for males and females.

图 2　蜕皮间隔对数值和甲长的关系(14 ℃，S 32.5)

注：NSF－无沙饲养的雌性个体；NSM－无沙饲养的雄性个体；SAF－有沙饲养的雌性个体；SAM－有沙饲养的雄性个体. E 中斜线表示对雌雄个体重新计算的共同斜率.

2.3 Molt increment

Molt increment was plotted against carapace length for NSF, NSM, SAF and SAM(Fig. 3A—D), and there were significant regressions in logarithm of molt increment on carapace length (Tab. 3).

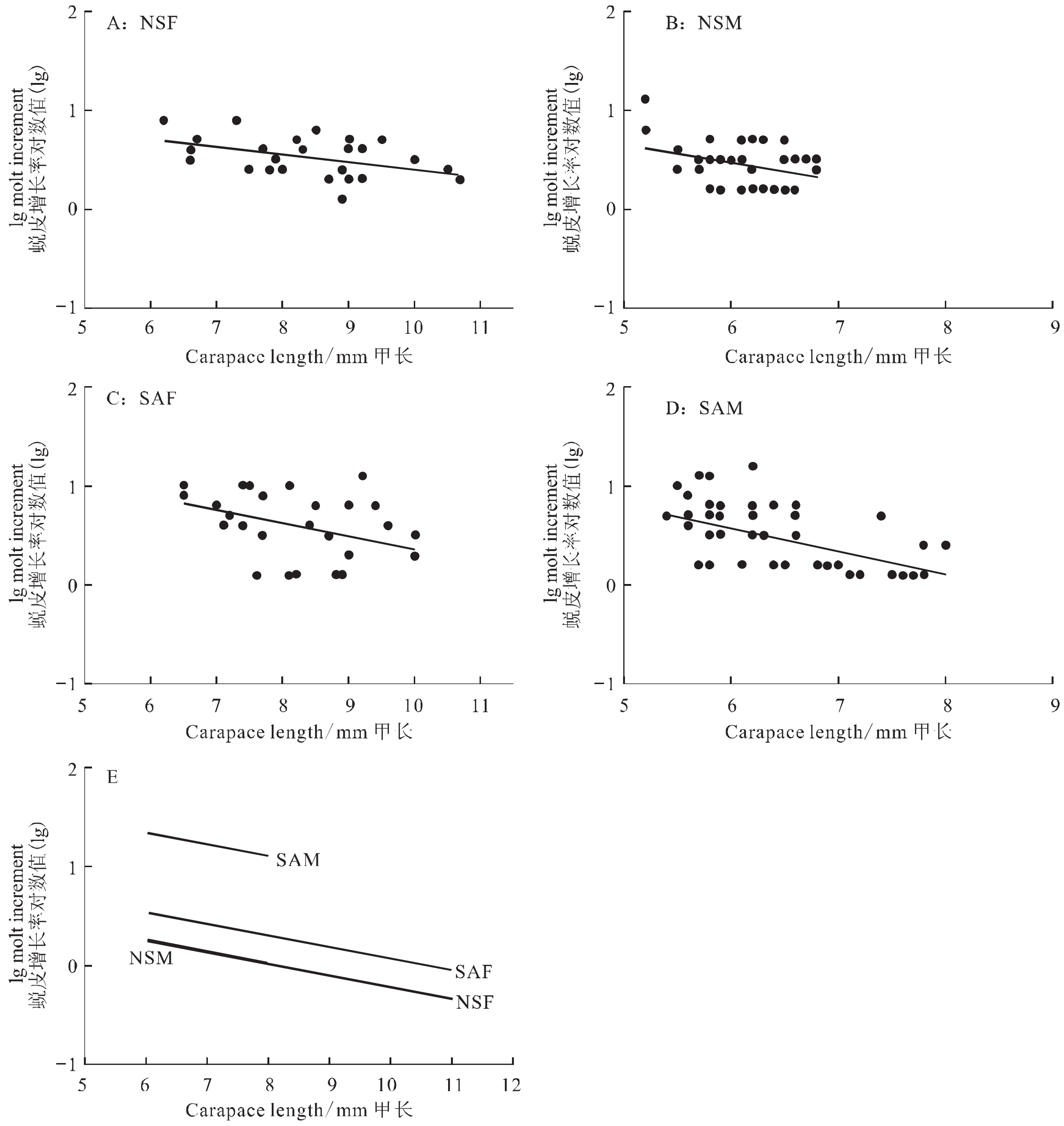

Fig. 3 Logarithm(lg) of molt increment plotted against carapace length in each treatment(14 ℃, S 32.5)

Note: NSF—females without sand; NSM—males without sand; SAF—females with sand; SAM—males with sand. Lines in E show the regressions reculated to common slopes for males and females.

图 3 蜕皮增长率对数值和甲长的关系(14 ℃,S 32.5)

注:NSF—无沙饲养的雌性个体;NSM—无沙饲养的雄性个体;SAF—有沙饲养的雌性个体;SAM—有沙饲养的雄性个体. E 图斜线表示对雌雄个体重新计算的共同斜率.

The mean molt increments in NSF, NSM, SAF and SAM were 3.7%, 3.2%, 5.2% and 4.8%, respectively. An analysis of the four treatments(NSF, NSM, SAF, SAM) by ANCOVA showed no significant difference in slopes ($F = 1.89$; $df = 3, 148$; $P = 0.133$). However, elevations, after determining a common slope, were significantly different for each of the four treatments ($F = 10.62$; $df = 3, 143$; $P < 0.001$). When the sexes were analyzed separately, there was significant difference in elevations between the two sand treatments for either females (ANCOVA: $F = 6.30$; $df = 1, 53$; $P < 0.05$) or males ($F = 5.33$; $df = 1, 96$; $P < 0.05$). This indicates that molt increment is greater in both females and males reared with sand than those reared without sand (Fig. 3E).

Tab. 3 Regression analysis on logarithm of molt increment on carapace length in each treatment

表 3 蜕皮增长率和甲长的回归分析

Treatment 处理	n	Regression parameters 回归系数 lg MI=a+b · CL		R^2	P
		a	b(±SD)		
NSF	25	0.068	−1.097(±0.544)	0.70	<0.05
NSM	46	0.186	−1.588(±0.993)	0.63	<0.05
SAF	28	0.127	−1.637(±1.034)	0.55	<0.05
SAM	50	0.239	−2.013(±0.725)	0.59	<0.001

Note: 1) NSF—females without sand; NSM—males without sand; SAF—females with sand; SAM—males with sand.
2) MI—molt increment; CL—carapace length

注:1)NSF—无沙饲养的雌性个体;NSM—无沙饲养的雄性个体;SAF—有沙饲养的雌性个体;SAM—有沙饲养的雄性个体.
2)MI—蜕皮增长率;CL—甲长

2.4 Growth

At the beginning of the experiment there were no significant differences among treatments in the mean carapace length of females ($F = 0.48$, $P = 0.493$) or males ($F = 0.04$, $P = 0.851$). Mean carapace length is plotted against time for each of the treatments to examine the growth during the experiment (Fig. 4). In both sexes, the growth of shrimp reared with sand was faster than that of shrimps reared without sand. The mean carapace length increased in the experiment was: 1.22 mm in NSF; 1.43 mm in SAF; 0.6 mm in NSM and 0.9 mm in SAM. Although it was not available to make effective comparison between the growth rates of the sexes due to the differences in initial size, the absolute increment during the experiment was higher for females within each sand treatment.

3 Discussion

Shrimps with burying ability exhibit different attitudes in their substrate requirements. *Penaeus vannamei* does not have specific substrate requirement[25]. On the other hand, *Metapenaeus macleayi* grew 11%−22% faster in aquaria with sediment than in aquarium without sediment[26]. Results of this study showed the beneficial effects of providing a sand substrate in reared *C. uritai*. Shrimps reared with sand showed better state in survival, intermolt period, molt increment and growth than those reared without sand.

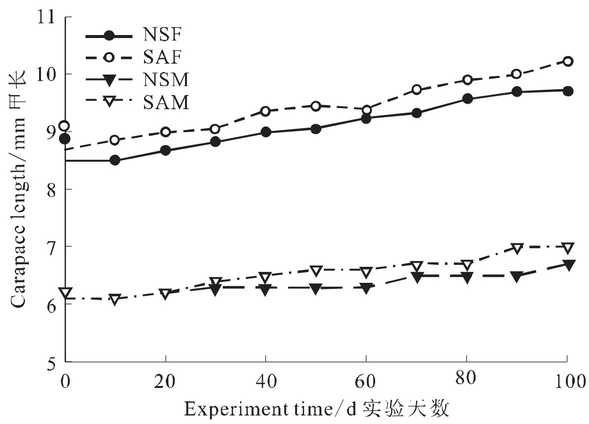

Fig. 4 Mean carapace length plotted against time in each treatment (14 ℃, S 32.5)

Note: NSF—females without sand; NSM—males without sand; SAF—females with sand; SAM—males with sand.

图 4 甲长与时间的关系(14 ℃,S 32.5)

注:NSF—无沙饲养的雌性个体;NSM—无沙饲养的雄性个体;SAF—有沙饲养的雌性个体;SAM—有沙饲养的雄性个体.

3.1 Survival

Survival was higher in both females and males reared with sand than those reared without sand. However, the differences were not significant. Similarly, the poorer survival reared without sand has been found in previous studies on *Penaeus semisulcatus* de Haan[20] and *Penaeus japonicus* Bate[21-22].

3.2 Intermolt period

Intermolt period increased steadily with increasing size of premolt stage in all of the treatments, which was found almost universally in Crustacean growth[3,23-24]. In both females and males the intermolt period was prolonged when the sand was not offered, with a relatively greater effect in females (Tab. 4). This increment was consistent with the results reported earlier. Several previous studies have shown that absence of sediment such as sand cue might delay to settle and then metamorphose, which consequently resulted in prolonged intermolt period[9-19]. This lengthened duration reflected that a longer time was needed for the accumulation of sufficient reserves in order to molt[27]. Actually in the present study, the efficiency of feeding was lower in shrimps reared without sand than those reared with sand.

3.3 Molt increment

Contrary to the intermolt period which was consistently prolonged with premolt size of shrimp, the molt increment decreased with increasing size of shrimp, as has been observed almost universally in previous studies[3,23-24]. In both females and males, molt increment increased when sand was offered (Tab. 4). Due to the scarce information in these studies, few data was available to compare with the present study. However, it has been observed that the shrimps reared without sand kept moving in the tanks, while those reared with sand were buried in the sand when not intaking. Hence, less energy has expended by the shrimps reared with sand than those without sand. As a result, the energy used in molting was greater in shrimps reared with sand, which ultimately led to a greater molt increment.

Tab. 4 Effects of sand on survival, intermolt period, molt increment and size increase

表 4 沙质底质对存活率、蜕皮间隔、蜕皮增长率和个体大小的影响

Treatment 处理	Survival/% 存活率	IP/d	MI/%	Size increment/mm 甲长增长量
NSF	28	18.9	3.4	1.22
SAF	38	16.9	4.4	1.43
Difference/%	35.7	−10.6	29.4	17.2
NSM	10	17.6	3.4	0.6
SAM	25	17	3.7	0.9
Difference/%	150	−3.4	8.9	50.0

Note: 1) NSF—females without sand; NSM—males without sand; SAF—females with sand; SAM—males with sand.
2) The difference between the two sand treatments is given as a percentage change from the values for the whole study.
3) IP—intermott period; MI—molt increment.
注:1)NSF—无沙饲养的雌性个体;NSM—无沙饲养的雄性个体;SAF—有沙饲养的雌性个体;SAM—有沙饲养的雄性个体.
2)不同沙质的影响分别以各组值差异的百分比来表示.
3)IP—蜕皮间隔;MI—蜕皮增长率.

3.4 Growth

In this investigation, the presence of sand affected both intermolt period and molt increment of females and males. And the presence of sand had substantially greater effect on molt increment than on intermolt period in both females and males (Tab. 4). Therefore, the growth of shrimps reared with sand was significantly better than that of shrimps reared without sand. Although insufficient information is known concerning the effect of the presence of sand on two components of growth (intermolt period and molt increment), the growth state in this study is similar to the results reported in other crustacean growth research[20-22,28]. Penaeid shrimp ingests micro-organisms and other living organisms continually, regardless of the presence of high food concentrations[1]. It is, therefore, assumed that these living organisms, such as benthic diatoms, copepods, and pol-

1) Kittaka J. Food and growth of Penaeid shrimp[C]. Proceedings of the first international conference on aquaculture nutrition. 1975: 249-285.

ychaetes growing on the sand, nutritionally play an important role in the growth of shrimp. Furthermore, sand had a significant buffering capacity to water quality and could reduce total nitrogen, nitrite, ammonia and sulfide concentrations in water, resulting in a better growth of shrimp[21]1).

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