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硕士学位论文

飞云江口外水域和苍南近岸水域浮游动物
生态特征比较

The comparison of the ecological characters of the
zooplankton between the coastal waters off Cangnan and the
waters off Feiyun River estuary

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摘 要

为了研究我国亚热带北部边缘浮游动物区系和生态类群,从而为分析我国亚热带海域浮游动物群落特征形成的成因提供科学依据。本研究根据 2010 年~2011 年在飞云江口外水域(27°46'~27°75'N, 120°66'~121°01'E)冬、春、秋 3 个季节和 2011 年在苍南近岸水域(26°94'~27°27'N, 120°41'~120°76'E)冬、春、夏季 3 个季节的海洋综合调查资料,在分析了我国亚热带北部边界的飞云江口外水域和苍南近岸水域这两个不同水域浮游动物的种类组成、区系适应性、优势种、物种多样性、丰度等季节变化特征的基础上,比较了这两个水域浮游动物的生态适应和区系特征,探讨了这些浮游动物生态特征对水团变化的响应。主要研究结果如下:

1. 飞云江口附近水域浮游动物群落特征

飞云江口附近水域秋、冬、春三季共鉴定出浮游动物 46 种(不包括浮游动物幼体)。冬季鉴定出 15 种,春季鉴定出 26 种,秋季鉴定出 30 种。从适温性看,研究水域浮游动物种类数冬季暖温带种较多,春、秋两季则以亚热带种为主,浮游动物丰度冬、春两季暖温带种占优势,秋季亚热带种占绝对主导。从适盐性看,三季浮游动物种类数和丰度均以近岸种为主。调查水域浮游动物丰度在秋、冬之间和冬、春之间有较大变化,秋、冬、春三季浮游动物平均丰度分别为 221.69 ind./m³、19.52 ind./m³和 137.50 ind./m³。秋、冬、春季种类数近岸较少,外海较多。三季中,秋季浮游动物 Shannon-Weaver 多样性指数(H')最高,高值区位于调查水域的东南部;其次为春季,最高值出现在飞云江口外海域;冬季为三季中最低,最高值出现在调查水域北侧岛群之间。中华哲水蚤(*Calanus sinicus*)是冬、春季影响总丰度变化最主要的种类,秋季总丰度变化主要受针刺拟哲水蚤(*Paracalanus aculeatus*)和百陶箭虫(*Sagitta bedoti*)影响。

2. 苍南近岸水域浮游动物群落特征

冬、春、夏 3 个季节共鉴定出浮游动物 77 种(不包括浮游动物幼体),分别为夏季(54 种) > 春季(40 种) > 冬季(16 种)。从浮游动物的温度适应性上看,研究水域冬季是暖温带种种类数居多,春、夏季亚热带种居多。随着冬季向夏季的过渡,暖温带种比例逐渐降低,亚热带种类升高。从盐度适应性上看,随着冬季向夏季的过渡,近海种类比例逐渐降低,外海种类相应升高,冬、春季近海种较多,夏季外海种占优势。研究水域三季一共出现优势种 13 种,分别为冬季 3 种,

春季 5 种, 夏季 7 种。冬季和春季的优势种主要由暖温带近海种组成, 例如中华哲水蚤、五角水母(*Muggiaea atlantica*)和中华箭虫(*Sagitta sinica*)等。夏季的优势种则全部为亚热带种, 例如肥胖箭虫(*Sagitta enflata*)、中华假磷虾(*Pseudeuphausiasinica*)和左突唇角水蚤(*Labidocera sinilobata*)等。苍南近岸水域夏季浮游动物的多样性指数均值最高, 春季次之, 冬季均值最低。

3. 飞云江口外和苍南近岸水域浮游动物群落特征的比较

通过将飞云江口外水域和苍南近岸水域冬、春两个季节的浮游动物生态特征相互对照和比较, 显示出水团变化是影响两地浮游动物各项生态特征的重要因素。

根据浮游动物区系适应性的比较来看, 春季苍南近岸水域比飞云江口外水域出现更多的外海种和亚热带种, 甚至出现大洋种和热带种, 这显示出苍南近岸水域受台湾暖流影响更强。冬季两水域相差不大, 显示出两地均在沿岸流控制之下。根据多样性比较来看, 两调查水域浮游动物多样性指数和丰富度都是按照冬、春的季节演替的顺序呈现上升趋势, 在相同的季节, 飞云江口外水域浮游动物多样性指数和丰富度的平均值都比苍南近岸水域要低。根据优势种比较来看, 两地冬、春季的优势种都是以暖温带近海种为主, 但是苍南近岸水域优势种的暖水属性和外海属性却都要高于相应季节的飞云江近岸水域, 这都与水团异同息息相关。总之飞云江及其以北水域冬、春季更多地受到了东海沿岸流的影响, 而苍南海域冬季也受到沿岸流的影响, 但是春季台湾暖流的影响已经开始突显。两地春季主要水团的区别是造成该季节浮游动物生态特征异同的主要原因。

关键词: 浮游动物; 生态特征; 水团; 苍南近岸水域; 飞云江口外水域

Abstract

Based on three oceanographic surveys conducted off the Feiyun River estuary (27°46'~27°75'N, 120°66'~121°01'E) in November 2010, January & May 2011, and three oceanographic surveys conducted in the coastal waters off Cangnan (26°94'~27°27'N, 120°41'~120°76'E) during February, May and September 2011. The species composition, Shannon-Weaver diversity, eco-groups, abundance, horizontal distribution, and seasonal variation of zooplankton were investigated. The ecological characteristics of zooplankton and response to environmental changes were also discussed.

1. Characteristics of zooplankton communities off the Feiyun River estuary

A total of 46 species (zooplankton larvae were not included) belonging to 11 groups were identified, including 42 species belonging to 9 groups in autumn, 20 species belonging to 5 groups in winter and 34 species in 8 groups in spring. The results showed that the abundance of zooplankton has changed significantly. The abundance of zooplankton was highest in autumn (221.69 ind./m³), least in the winter (19.52 ind./m³), and intermediate in spring (137.50 ind./m³). Spatially, the zooplankton was most numerous in the offshore. The Shannon-Weaver diversity of zooplankton was highest in autumn followed by spring and winter. The high value area of diversity was situated in the southeast of investigation waters (autumn), in the outer area of Feiyun River estuary (spring) and among archipelago in the north (winter) respectively. In winter and spring, *Calanus sinicus* was the predominant which determined the distribution pattern of zooplankton abundance. In autumn, *Paracalanus aculeatus* and *Sagitta bedoti* exerted the greatest influence on the distribution of zooplankton abundance. Furthermore, the abundance and community composition of zooplankton was influenced by seasonal variation of several water masses to some extent.

2. Community of zooplankton characteristics in the coastal water of Cangnan area

A total of 77 species were identified (zooplankton larvae were not included), including 16 in winter, 40 in spring and 54 in summer. From winter to summer, the number of subtropical water species increased gradually and the warm temperate water species decreased gradually. The number of species of warm temperate water

species was dominant in winter, and the number of species of subtropical water species took the lead in spring and summer. The number of species of offshore species increased gradually and the nearshore species decreased gradually. The number of species of offshore species was dominant in summer, and the number of species of nearshore species took the lead in spring and summer. The dominant species also had obvious seasonal changes. There were three dominant species in winter, five dominant species in spring, and seven dominant species in summer. In winter and spring, dominant species were mainly warm temperate water species, such as *Calanus sinicus*, *Muggiaea atlantica* and *Sagitta nage*. In summer, dominant species were mainly subtropical species, like *Sagitta enflata*, *Pseudeuphausia sinica* and *Labidocera sinilobata*. The species diversity of zooplankton was the lowest in winter and the highest in summer.

3. Comparing the ecological characters of zooplankton in winter and spring in the waters off the Feiyun River estuary and the coastal water of Cangnan area

This research analyzed and compared the differences on the ecological characters of the zooplankton in different seasons in the coastal waters off Cangnan and the waters off Feiyun River estuary. As a whole, both the two research areas were under the control of the China Coastal Water with low water temperature and low salinity in winter. In spring, with the increase of Strait Warm Current Water, the outer region of the coastal water of Cangnan area started to be influenced. The results indicated that this two area had some common grounds and obvious differences, and that was related to the difference of the water masses of these two areas and their seasonal variation. Compared with the Feiyun River estuary, the zooplankton in the coastal waters off Cangnan had more subtropical water species and offshore species in spring. That revealed Cangnan area was more influenced by the Strait Warm Current Water than the Feiyun River estuary. In winter, these two areas had little difference because they were all charged by the China Coastal Water. The species diversity and richness of zooplankton community in the coastal waters off Cangnan were higher than that in the waters off Feiyun River estuary in same season. The dominant species in both areas were mainly warm temperate water species and nearshore species in winter and spring. The dynamics of different water masses and their interaction led to the seasonal variations of temperature and salinity of the investigated waters, and further influenced the ecological characters of the zooplankton.

Key words: zooplankton; ecological characters; water masses; the waters off Feiyun River estuary; the coastal waters off Cangnan area

厦门大学博硕士学位论文摘要库

第一章 绪论

浮游动物(Zooplankton)是指一类营异养性生活的浮游生物,主要由各类无脊椎动物以及底栖动物和游泳动物的幼体组成。它们生活在自由水域中,却因为缺乏发达的运动器官而无法自由游泳,不得不在水流的作用下随波逐流。浮游动物具有数量庞大,种类繁多和分布广泛的特点。浮游动物的类群组成相当广泛,从最低等的原生动物到较高等的被囊动物均有涉及,还主要包括腔肠动物、栉水母、轮虫、甲壳动物、腹足动物、毛颚动物、以及各类浮游幼虫。目前全世界范围内尚未精确统计出海洋浮游动物的具体种类数,但如果在现有已确定的大约有7000种的基础上,再加上所有浮游幼体可以大致推测出全球范围内海洋浮游动物可高达36,000余种(Lenz, 2000)。我国是世界上领海纬度跨度最大的国家之一,多变的海洋环境使得我国拥有丰富海洋浮游动物资源,尽管经过数次大规模海洋调查,仍未完全确认我国的海洋浮游动物种类,目前已有的资料表明仅我国台湾海峡水域就已经鉴定出各门类浮游动物高达1300余种(李少菁等, 2001)。

1.1 浮游动物生态学研究的重要意义

海洋浮游动物因其数量庞大、代谢活动强、分布广等特点(杨宇峰等, 2000),在整个海洋食物网中起到了承上启下的枢纽作用,是海洋生态系统物质循环和能量流动的关键环节(朱延忠, 2008),有着极为重要的生态学意义。

浮游动物本身是诸多经济水产动物,尤其是众多经济鱼类的重要饵料,很多植食性鱼类和消费层级较高的鱼类在幼鱼阶段也是以浮游动物作为主要的开口饵料。因此,浮游动物在海洋渔业生产中起着至关重要的作用,其数量变化甚至可以直接影响渔业资源的数量(郑重等, 1984)。它们的丰度及地理分布情况,也与各种经济鱼类的集群和生长有着密切的联系(徐兆礼等, 1989)。

浮游动物作为海洋生态系统中次级生产力的代表者,通过其在海洋食物网中上行和下行的控制作用来调控海洋环境的物质循环和能量流动。一方面,浮游动物通过摄食海洋浮游植物,将浮游植物通过光合作用积累的初级生产力产物转化为次级生产力,国内外研究学者研究表明,海洋中的其他生物对浮游植物通过光合作用固定的物质与能量的利用,依赖于浮游动物的传递作用(Wickstead, 1976; 徐兆礼等, 2006e)。同时,通过其对海洋浮游植物的下行摄食压力,可以控制海

洋浮游植物积累的初级生产力,甚至可以调控赤潮的发生与发展(曾祥波等, 2008; Frost, 1987; Urban et al., 2001)。另一方面,海洋浮游动物作为众多海洋鱼类以及幼鱼的饵料,其生物量的波动会直接或间接地对海洋鱼类和海鸟等更高营养级产生深刻的影响(Ware & Thompson, 2005)。此外, Cushing(1990)的研究表明作为饵料的浮游动物数量的丰富与否对仔稚鱼的存活率的高低具有至关重要的影响。Durant 等人(2013)在对北海海域食物网捕食者控制即下行控制的研究中发现,浮游动物的数量波动与高营养级的捕食者的数量之间有明显的匹配作用。由于温室效应导致南大洋海水温度的升高进而使得浮游动物小型化,这一现象使得以大型浮游动物为食物的侏海雀(*Alle alle*)数量逐渐减少,正在逐步被其他海鸟所取代(Stempniewicz et al., 2007)。

作为海洋生态系统中生物泵的主要驱动者之一,海洋浮游动物在主要的生源要素例如碳、氮和磷的海洋生物地球化学循环中扮演重要角色(Colloquium, 2001)。一方面海洋浮游动物通过摄食浮游植物固定的碳、氮、磷等生源要素传递至更高的营养级,另一方面通过浮游动物本身的各项生理代谢活动,例如分泌、蜕皮、排便以及死亡后尸体经由自然沉降或垂直移动等方式参与到将碳氮磷等生源要素向海洋下层输送的过程当中(Sampej et al., 2012; 郭东晖等, 2012)。凭借较高的摄食率和旺盛的代谢作用,海洋微型浮游动物在真光层中生源要素的再循环过程中扮演了关键角色,这是由于微型浮游动物的代谢排泄物和分泌物粒径较小,沉降速率缓慢,还在真光层内就被微生物分解为无机物了。

海洋浮游动物因其生命周期短和随波漂流等特性导致其对周围的海洋生态环境变化十分敏感,因此海洋浮游动物生态学与全球气候变化和局部海域水文等环境因素变化有着密切的联系。随着海洋生态系统动力学对全球气候等因素变化的响应过程越来越受关注,国内外科学家越来越多地将生态环境效应与浮游动物群落生态学的研究结合起来,做了大量的探究。例如徐兆礼等研究表明气候变暖引发了东海近海海域内平滑真刺水蚤数量的降低(Xu et al., 2013)。Bamstedt(1980)的研究证明水体的环境因子(如温度和盐度)能够对浮游动物分布产生重要的影响。Richardson 等(2008)研究发现气候变化带来的水文环境因素变化可以通过热带海域浮游动物的群落结构、种群分布情况和生态习性的变化上体现出来。此外,全球气候变暖对海洋浮游动物多样性及其分布情况有着深刻影响(李君华等, 2008)。

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