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东海中华哲水蚤的年产量估算

王 荣[1]，陈亚瞿[2]，王 克[1]，左 涛[1]

(1. 中国科学院海洋研究所，海洋生态与环境科学重点实验室，青岛 266071；2. 中国水产科学院东海水产研究所，上海 200090)

摘要：1997 年至 2000 年在东海陆架区进行了 4 个航次的大面调查，用获得的大型浮游生物网样品分析资料应用产量/生物量比值(P/B)法对中华哲水蚤的年产量做了初步估算。中华哲水蚤的 P/B 比值为 6.7353，在东海的平均年产量为 263.94 C mg/(m^2/a)。全测区年产量为 110.745×10^3 t 碳，即 11 万 t，相当于活体重 144.3 万 t。

关键词：东海；中华哲水蚤；年产量。

Estimation of the annual production of *Calanus sinicus* Brodsky (Copepoda: Calanoida) in the East China Sea

WANG Rong[1], CHEN Ya-Qu[2], WANG Ke[1], ZUO Tao[1] (1. *Key Laboratory of Marine Ecology & Environmental Science, Institute of Oceanology, Chinese Academy of Sciences, Qingdao* 266071, *China*; 2. *East China Sea Fisheries Research Institute, Chinese Academy of Fisheries Sciences, Shanghai* 200090, *China*). **Acta Ecologica Sinica, 2003, 23(6): 1212～1215.**

Abstract: *Calanus sinicus is* a widely distributed planktonic copepod in the wide ranging temperature and salinity marginal seas of the western North Pacific from Japan to Vietnam. It dominates the mesozooplankton in the East China Sea and constitutes important food for the commercially most important fish stocks (e.g. sardine, anchovy etc.) especially for their larvae. This copepod can be found throughout the year in the East China Sea but shows strong seasonal variation, with the year's maximum in early summer. Although it has been the subject of intensive research dating back to the 1950's, there are still questions about its ecology. One of the fundamental questions is what is its annual production or how much energy can be provided by this copepod to its predator each year.

This work is the first attempt to estimate the annual production of *C. sinicus* in the East China Sea by using the biomass/production ratio method. Zooplankton samples for the measurement of *C. sinicus* biomass were collected during 4 cruises conducted in different season, i.e. Oct. to Dec. 1997, April to May 1998, June to Aug. 1999 and Jan. to Mar. 2000 respectively. The research area (Figure 1) covered most of the distribution area of *C. sinicus* in the East China Sea. Vertical tow with an 80 cm diameter plankton net was made at each of the 142 stations from sea bottom to sea surface or from 200 m depth to sea surface when the water depth was greater than 200 m. The dry weight (DW, μg) and carbon contents (C, μg) of *C. sinicus* were estimated from body length (L, μm) by using the relationship established by

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作者简介：王 荣(1934～)，男，济南人，研究员，从事海洋生态学研究。

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Uye (1982) as $\log DW = 2.66 \times \log L - 6.68$ and $\log C = 2.64 \times \log L - 7.00$. The energy density ($Ms$) of *C. sinicus* we measured was 22.86 kJ/g. dry wt. The P/B ratio (P/B) for *C. sinicus* was calculated by the equation $\log P/B = -0.16 - 0.34 \log Ms$ given by Banse and Mosher (1980) and has a value of. 6.7353.

The average annual production of *C. sinicus* (in carbon) calculated was 263.94 mg/(m^2 · a). Figure 1 shows the horizontal distribution of the annual production. The annual production in the whole research area is 110.745×10^3 t. carbon, which equals to about 1.443 million ton living animal.

Key words: East China Sea; *Calanus sinicus*; annual production

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中华哲水蚤(*Calanus sinicus* Brodsky)是西北太平洋边缘海的特有种，分布在从日本近海到北部湾的西北太平洋近海[1]。它在中国近海的分布中心是在黄海和东海；台湾海峡以南只在冬春出现，数量也远不及黄、东海[2]。中华哲水蚤在东海全年出现，数量高峰在 4～7 月份。这时正是许多经济鱼类的生殖季节。中华哲水蚤的卵、无节幼体、桡足幼体和成体为这些鱼类的仔、稚、幼和成鱼提供了不同粒径的食饵。作为东海浮游动物的优势种之一，研究其种群生产力对了解东海这个高生产力区的生态系统结构功能特点和资源补充机制有重大意义。一个最基本的问题是，中华哲水蚤的种群生产力有多大？它向高层捕食者提供了多少能量？

桡足类的产量估计有许多方法，大体有 3 类：现场测定法、种群动态法和产量/生物量比值(P/B)法。现场测定法是近 10a 来发展起来的方法，在现场环境中进行活体培养，测定生长率和产卵率[3,4]。这一方法测定的是种群的瞬时增长率，便于研究种群增长与环境因子的关系；缺点是操作困难，难以获得大量数据。种群动态法是最早应用的方法[5～7]，前提是要清楚地了解该种的生活史、各发育阶段的停留时间、各阶段间个体生物量的增长量、以及在不同时间各发育阶段(instars)的数量。如果有足够的(间隔密，范围要覆盖种群的分布区)各发育期的数量分布资料和必要的生物学参数，种群动态法在估计一定时间间隔(大于一个世代长度)内的种群产量时，是比较可靠的。P/B 法是利用生物量(biomass，或称现存量 standing stock)和已建立的 P/B 关系去推算产量。它是一种宏观的方法，只能估算年产量或至少一个世代的产量[8～10]。它不需要有生物学参数，只要有较全面的生物量资料就可应用。本文采用 P/B 法对东海陆架区的中华哲水蚤年产量进行了估算。

1　材料与方法

1.1　样品

测区范围为 26°N 至 33°N 之间、从近岸到陆架边缘的东海陆架区(图 1)，经、纬度每隔 30′ 设一测站。调查时间为 1997 年 10～12 月(代表秋季)1998 年 3～5 月(代表春季)，1999 年 6～8 月(代表夏季)和 2000 年 1～3 月(代表冬季)。每个航次在各测站用大型浮游生物网从底(水深大于 200m 时从 200m 开始)至表进行垂直拖网。样品中的中华哲水蚤数量以每平方米水柱内的个体数(ind/m^2)表示。

1.2　生物量

个体数量换算为干重和有机碳用 Uye 的经验公式[12]：$\log DW = 2.66 \times \log L - 6.68$ 和 $\log C = 2.64 \times \log L - 7.00$。$DW$ 为干重(μg)，C 为含碳量(μg)，L 为前体部长(μm)。中华哲水蚤的能量密度采用实测值，即 22.86 kJ/g. dry wt。

1.3　P/B 值

P/B 值的计算采用 Banse and Mosher 的公式[7]：$\log P/B = -0.16 - 0.34 \log Ms$。用初次性成熟个体的含能量($Ms$)作为个体生物量的尺度。从能量生态学的角度含能量较之体长和体重更准确地反映了生物体的现存量。

2　结果

计算的中华哲水蚤的 P/B 比值为 6.7353，在东海的平均年产量为 263.94 C mg/(m^2 · a)，全测区年产量为 1.10745×10^5t，即 11 万 t 碳。年产量的分布(图 1)是不均匀的，主要取决与生物量的分布。

3 讨论

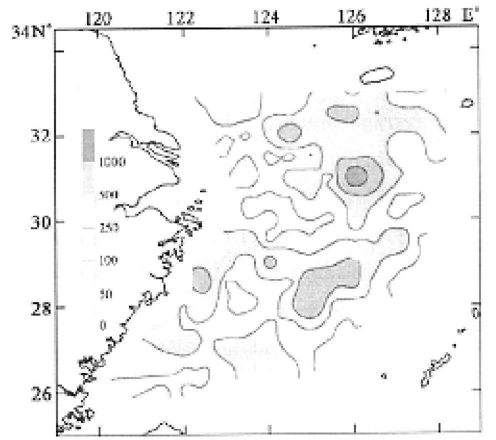

图 1 东海中华哲水蚤的年产量分布

Fig. 1 Distribution of the annual production of *Calanus sinicus* in the East China Sea

P/B 法估算桡足类的年产量的优点是,不需要太多的生物学参数。这特别适合我国目前的情况。虽然中华哲水蚤的生活史是清楚的,有关发育过程与温度和饵料的关系也有文献可参考,但要获得大面的不同时间种群组成的资料相当困难。在一个点进行密集的、长时间序列的观察是可能的,对整个东海则不现实。因此用种群动态法去估计中华哲水蚤的年产量很困难。用现场测定法的困难在于它测定的是种群的瞬时增长率,要通过长时间大量观测求积才能计算年产量。P/B 法是建立在海洋生物生长发育普遍规律的基础上的,它的立论完全符合当代粒径谱(particle-size spectrum)和生物量谱(biomass spectrum)的理论[13]。用 P/B 法估算结果的准确度主要取决于 P/B 的准确度。本研究所用的 P/B 的公式是 Banse and Mosher 以 33 种已知产量与生物量关系的无脊椎动物(包括 6 种桡足类)的资料为基础建立的经验公式,与实测资料离差很小($p=0.01$, $r=0.9072$)。计算结果的极端误差是-50%和$+100\%$,但发生这种情况的概率小于 1%。测算的中华哲水蚤的 P/B 为 6.7353。这一比值与 Tremblay and Roff 在大西洋对飞马哲水蚤(*Calanus finmarchicus*)测算的结果(6.6)非常接近。飞马哲水蚤和中华哲水蚤是近缘种,分布纬度和个体大小相似。结果应当说是可信的。

东海中华哲水蚤的平均年产量为 263.94 C mg/(m^2·a),全测区面积为 $4.1958\times\times10^5$ km^2,全测区年产量为 1.1075×10^5 t 碳,即 11 万 t 碳。换算为活体湿重大约为 144.3 万 t。测区年平均初级生产力大约在 500 C mg/(m^2·d)上下[14],或大约为 182 C g/(m^2·a)。如果 1/10 转化为次级生产力,相当于 18.2 C g/(m^2·a)。通过中华哲水蚤转化的仅占 1.45%。这个比重比预期的小。这可能是因为,中华哲水蚤是滤食性的桡足类,它不光滤食单细胞藻类同时也滤食微型浮游动物以及大量的非生命的悬浮有机颗粒。东海非生命颗粒有机物(non-living particulate organic matter)在总悬浮有机颗粒中所占比重非常大,春季为 90.05%。秋季为 95.99%[15],这说明活的单细胞藻类在中华哲水蚤的食谱中比重可能不是很大。另一种解释是,愈来愈多的证据说明小型桡足类在从初级生产到次级生产转化中起着更重要的作用[16]。

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