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目次

前沿理论与学科综述

- 岩溶山区水分时空异质性及植物适应机理研究进展..... 陈洪松, 聂云鹏, 王克林 (317)
- 红树林植被对大型底栖动物群落的影响 陈光程, 余 丹, 叶 勇, 等 (327)
- 淡水湖泊生态系统中砷的赋存与转化行为研究进展..... 张 楠, 韦朝阳, 杨林生 (337)
- 纳米二次离子质谱技术(NanoSIMS)在微生物生态学研究中的应用 胡行伟, 张丽梅, 贺纪正 (348)
- 城市系统碳循环: 特征、机理与理论框架 赵荣钦, 黄贤金 (358)
- 城市温室气体排放清单编制研究进展..... 李 晴, 唐立娜, 石龙宇 (367)

个体与基础生态

- 科尔沁沙地家榆林的种子散布及幼苗更新..... 杨允菲, 白云鹏, 李建东 (374)
- 环境因子对木棉种子萌发的影响 郑艳玲, 马焕成, Scheller Robert, 等 (382)
- 五花米草与短叶荳蔻落物分解过程中碳氮磷化学计量学特征 欧阳林梅, 王 纯, 王维奇, 等 (389)
- 性别、季节和体型大小对吐鲁番沙虎巢域的影响 李文蓉, 宋玉成, 时 磊 (395)
- 遮蔽行为对海刺猬摄食、生长和性腺性状的影响..... 罗世滨, 常亚青, 赵 冲, 等 (402)
- 水稻和玉米苗上饲养的稻纵卷叶螟对温度的反应 廖怀建, 黄建荣, 方源松, 等 (409)

种群、群落和生态系统

- 亚热带不同林分土壤表层有机碳组成及其稳定性 商素云, 姜培坤, 宋照亮, 等 (416)
- 禁牧条件下不同类型草地群落结构特征 张鹏莉 陈 俊 崔树娟, 等 (425)
- 高寒退化草地狼毒与赖草种群空间格局及竞争关系 任 珩, 赵成章 (435)
- 小兴安岭 4 种典型阔叶红松林土壤有机碳分解特性 宋 媛, 赵溪竹, 毛子军, 等 (443)
- 新疆富蕴地震断裂带植被恢复对土壤古菌群落的影响 林 青, 曾 军, 张 涛, 等 (454)
- 长期施肥对紫色土农田土壤动物群落的影响 朱新玉, 董志新, 况福虹, 等 (464)
- 潮虫消耗木本植物凋落物的可选择性试验 刘 燕, 廖允成 (475)
- 象山港网箱养殖对近海沉积物细菌群落的影响 裘琼芬, 张德民, 叶仙森, 等 (483)
- 2005 年夏季东太平洋中国多金属结核区小型底栖生物研究 王小谷, 周亚东, 张东声, 等 (492)
- 川西亚高山典型森林生态系统截留水文效应 孙向阳, 王根绪, 吴 勇, 等 (501)

景观、区域和全球生态

- 中国水稻生产对历史气候变化的敏感性和脆弱性 熊 伟, 杨 婕, 吴文斌, 等 (509)
- 1961—2005 年东北地区气温和降水变化趋势 贺 伟, 布仁仓, 熊在平, 等 (519)
- 地表太阳辐射减弱和臭氧浓度增加对冬小麦生长和产量的影响 郑有飞, 胡会芳, 吴荣军, 等 (532)

资源与产业生态

- 基于环境卫星数据的黄河湿地植被生物量反演研究 高明亮, 赵文吉, 官兆宁, 等 (542)
- 黄土高原南麓县域耕地土壤速效养分时空变异 陈 涛, 常庆瑞, 刘 京, 等 (554)

不同水稻栽培模式下小麦秸秆腐解特征及对土壤生物学特性和养分状况的影响..... 武 际,郭熙盛,鲁剑巍,等 (565)

施氮时期对高产夏玉米光合特性的影响 吕 鹏,张吉旺,刘 伟,等 (576)

城乡与社会生态

城市景观组分影响水质退化的阈值研究 刘珍环,李正国,杨 鹏,等 (586)

长株潭地区生态可持续性 戴亚南,贺新光 (595)

外源 NO 对镉胁迫下水稻幼苗抗氧化系统和微量元素积累的影响 朱涵毅,陈益军,劳佳丽,等 (603)

达里诺尔湖沉积物中无机碳的形态组成 孙园园,何 江,吕昌伟,等 (610)

绿洲土 Cd、Pb、Zn、Ni 复合污染下重金属的形态特征和生物有效性 武文飞,南忠仁,王胜利,等 (619)

柠檬酸和 EDTA 对铜污染土壤环境中吊兰生长的影响 汪楠楠,胡 珊,吴 丹,等 (631)

研究简报

海州湾生态系统服务价值评估 张秀英,钟太洋,黄贤金,等 (640)

内蒙古羊草群落、功能群、物种变化及其与气候的关系 谭丽萍,周广胜 (650)

氮磷供给比例对长白落叶松苗木磷素吸收和利用效率的影响 魏红旭,徐程扬,马履一,等 (659)

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封面图说: 科尔沁沙地榆树——榆树疏林草原属温带典型草原地带,适应半干旱半湿润气候的隐域性沙地顶级植物群落,具有极强的适应性、稳定性,生物产量较高。在我国仅见于科尔沁沙地和浑善达克沙地。是防风固沙、保护沙区生态环境和周边土地资源的一种重要的植物群落类型,是耐旱沙生植物的重要物种基因库和荒漠野生动物的重要避难所和栖息地。这些年来,由于人类毁林开荒、过度放牧、甚至片面地建立人工林群落等的干扰,不同程度地破坏了榆树疏林的生态环境,影响了其特有的生态作用。

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王小谷, 周亚东, 张东声, 洪丽莎, 王春生. 2005 年夏季东太平洋中国多金属结核区小型底栖生物研究. 生态学报, 2013, 33(2): 0492-0500.

Wang Xiaogu^{1,2,*}, Zhou Yadong^{1,2}, Zhang Dongsheng^{1,2}, Hong Lisha^{1,2}, Wang C S. A study of meiofauna in the COMRA's contracted area during the summer of 2005. Acta Ecologica Sinica, 2013, 33(2): 0492-0500.

2005 年夏季东太平洋中国多金属结核区 小型底栖生物研究

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摘要:“大洋一号”调查船于 2005 年 7 月在太平洋结核区中国合同区东、西小区调查中共进行了 12 个站位的小型底栖生物的取样。研究表明:调查区域小型底栖生物共有 13 个类群。东、西两小区小型底栖生物平均密度分别为 (104.4 ± 20.48) 个/ 10 cm^2 , (40.26 ± 25.84) 个/ 10 cm^2 , 线虫平均生物量分别为 (5.25 ± 0.99) ($\mu\text{g} \cdot \text{干重}$)/ 10 cm^2 , (1.68 ± 0.77) ($\mu\text{g} \cdot \text{干重}$)/ 10 cm^2 , 东小区小型底栖生物平均密度、线虫生物量明显高于西小区。线虫是绝对优势类群, 分别占东、西小区小型底栖生物总密度的 93.13% 和 91.36%, 其它优势类群有桡足类, 多毛类, 介形类等。小型底栖生物密度随着沉积物深度的增加而减少, 其数量的 75% 以上分布在 0—2 cm 层, 东小区深层的小型底栖生物所占比例比西小区要大。与环境因子相关分析表明:调查区域的小型底栖生物密度、线虫密度、线虫生物量、桡足类密度、多毛类密度与经、纬度呈显著负相关, 与脱镁叶绿素呈显著正相关, 与沉积物微型生物生物量相关性不显著。小型底栖生物密度、线虫密度、线虫生物量、多毛类密度与叶绿素 a 呈显著正相关, 桡足类与叶绿素 a 相关性不显著。脱镁叶绿素与沉积物微型生物生物量呈显著正相关。

关键词:小型底栖生物;群落结构;密度;生物量;中国多金属结核区

A study of meiofauna in the COMRA's contracted area during the summer of 2005

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Abstract: Polymetallic nodules were discovered on the Pacific Ocean in 1891. They exist at the sediment surface, sometimes in upper layers of sediments, and cover more than 50% of the sea floor at Clarion-Clipperton fracture Zone (CCFZ) in the north Pacific. The huge economic value from nodule mining has brought to many research programs dedicated to resource evaluation and design of collecting tools in the 1970s. China has carried out surveys on polymetallic nodules and sediment in the CCFZ for many years. Since the late 1980s, China has already got 75000 km^2 exclusive pioneer areas in COMRA's contracted area. One of the potential impacts of nodule mining is the destruction of the fauna attached to the partial covering of surrounding epifauna by sediment blanketing. Meiofauna, the important components of benthic ecosystem, are considered to be energetically important in benthic food web. as they play a critical role in the recycling of nutrients. In order to manage and mitigate these impacts, we need to better understand the composition and the distribution of meiofauna and its relationship to the environment.

A quantitative study was carried out on “Dayang Yihao” in July 2005. The meiofauna samples were collected from 12

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stations in eastern and western sub-area at COMRA's contracted areas, Samples were collected using a multiple corer with four tubes of 9.5cm in diameter, and only undisturbed cores with clear overlying water were used. Thirteen benthic groups were found from the surveyed area,. The average density of meiofaunal were (104.4 ± 20.48) ind/10cm² and (40.26 ± 25.84) ind/10cm² in eastern and western sub-area, respectively. The average biomass of nematode were (5.25 ± 0.99) ($\mu\text{g} \cdot \text{Dry}$) /10cm² and (1.68 ± 0.77) ($\mu\text{g} \cdot \text{Dry}$) /10cm² in each sub-area. The analysis of spatial distribution has shown that the density of meiofauna and the biomass of nematode in eastern sub-area were substantially higher than that in western sub-area. Nematodes, copepods, polychaeta, and ostracoda were found to be the dominant taxa, and nematodes were the predominant one, constituting 93.13% and 91.36% of total density of meiofauna in eastern and western sub-area, respectively. The analysis of vertical distribution has shown that the density of meiofauna decreased with the depth in the sediment. The top 0—2cm layer of sediment accounted for over 75% of meiofauna. The proportion of meiofauna distributed in the deeper sediment was higher in eastern sub-area than that in western sub-area.

In such an oligotrophic environment, low food supply may limit meiofaunal abundance, biomass, and to a lesser extent species richness. In eastern sub-area, the average concentrations of chlorophyll *a* and phaeopigment in the top 6cm sediment were 0.004 $\mu\text{g}/\text{cm}^2$ and 0.169 $\mu\text{g}/\text{cm}^2$ respectively. In western sub-area, the average concentrations of chlorophyll *a* and phaeopigment in the top 6cm sediment were 0.002 $\mu\text{g}/\text{cm}^2$ and 0.082 $\mu\text{g}/\text{cm}^2$, respectively. There were significant positive relationships between chlorophyll *a* and phaeopigment in the surface sediment. The correlation between the meiofauna distribution and the environmental factors was investigated. The results indicated that (1) the density of the dominant groups (i. e. nematode, copepods, polychaetes) and the biomass of nematodes were significantly negatively correlated with the latitude and longitude; (2) but were significantly positively correlated with the amount of phaeopigment; (3) the biomass in the sediment had no significant impact on the density of meiofauna and their major groups, but was significantly positively correlated with the amount of phaeopigment; (4) the density of meiofauna, nematodes and polychaetes and the biomass of nematodes were significantly positive correlated with the amount of chlorophyll *a*; (5) the density of copepods has no significant correlation with the amount of chlorophyll *a*.

Key Words: meiofauna; community structure; abundance; biomass; COMRA's poly-metallic nodule

东北太平洋海底蕴藏大量多金属结核,其主要存在于热带东北太平洋克拉里昂—克里帕顿断裂带 (Clarion-Clipperton Fracture Zones, CCFZ) 的表层沉积物中间,结核覆盖面积超过 50%^[1-2]。20 世纪 70 年代开始,多国为了获取结核区巨大的矿产资源,开始在该区进行大面积的勘探^[3-4],我国从 20 世纪 80 年代末期开始,对位于 CCFZ 的多金属结核以及沉积物进行了多年调查,现已在 CCFZ 区获得 7.5 万 km² 的专属开辟区—中国多金属结核区合同区(The COMRA's Contract Area)。

小型底栖生物作为底栖生态系统的重要组成部分,是构成底栖食物网的基本环节,对整个底栖群落(种类,密度,新陈代谢)作出巨大贡献^[5-7]。多年来,人们对近岸、陆架以及深海边缘的小型底栖生物已经进行了广泛的研究^[8-15]。从 20 世纪 70 年代开始,基于采矿势必给深海生物及环境带来破坏的共同认识^[16-20],国际上为了控制和减轻采矿所带来的影响,保护矿区生物多样性,开始在 CCFZ 进行深海环境及生物基线的调查,并取得了一定成果^[21-28]。目前我国仅高爱根,杨俊毅等^[29-30]对我国多金属结核合同区的小型底栖生物进行过研究。本研究的主要目的是加深对结核区小型底栖生物的认识,评估小型底栖生物的群落组成,密度,生物量以及分布特征,以便将来采矿后对海洋环境的持续管理。

1 材料和方法

1.1 调查区域和站位

研究样品由“大洋一号”调查船于 2005 年夏季采自东太平洋中国多金属结核开辟区东、西两小区(以下简称东、西小区)内(图 1),东、西两小区各设 6 个采样站位,具体站位经纬度及深度见表 1。

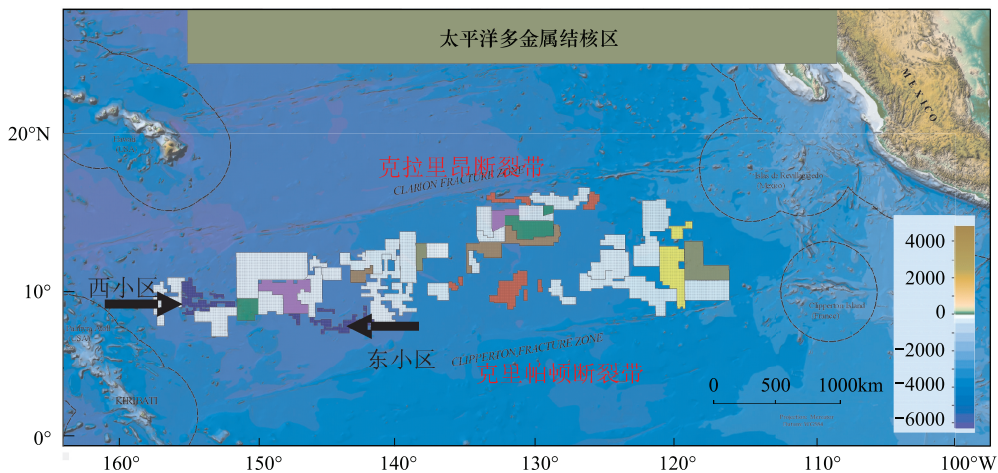


图 1 研究海域图

Fig.1 Map of the study area

表 1 中国多金属结核区小型底栖生物采样站位及深度

Table 1 Locations and depth of sampling stations

区块 Area	站位 Stations	经度 WLongitude/(°)	纬度 NLatitude/(°)	深度 Depth/m
东小区 Eastern area	ES0501	145.3968	8.3916	5329
	ES0502	145.3968	8.3251	5307
	ES0503	145.3967	8.3583	5322
	ES0504	145.3530	8.3916	5236
	ES0505	145.3514	8.3740	5257
	ES0506	145.3530	8.3581	5263
西小区 Western area	WS0501	154.0444	10.0690	5147
	WS0502	154.0562	10.0556	5159
	WS0503	154.0700	10.0456	5149
	WS0504	154.0037	10.0501	5074
	WS0505	154.0169	10.0688	5120
	WS0506	154.0275	10.0266	5139

1.2 采样及样品处理

小型底栖生物样品使用 MCS-1 型沉积物多管取样器采集,每根取样管长 61 cm,内径 9.5 cm,每站取 2 根取样管样品进行小型底栖生物分样。每根样现场处理如下:(1)将上覆水虹吸入 32 μm 孔径的网筛,滤取其中的小型底栖动物,(2)用分样器把每根样按 0—1 cm、1—2 cm、2—4 cm 和 4—6 cm 分层装瓶,上覆水滤样与 0—1 cm 层合装一瓶,用 7% 的中性福尔马林溶液固定。回实验室后样品经 250 μm、125 μm、63 μm、38 μm 孔径的网筛过滤后,采用改进后的 ludox 离心法进行离心分选^[31],虎红染色后在显微镜下鉴定并计数。

小型底栖生物生物量的测定步骤:

(1)在显微镜下利用 Leica QWin 软件测量生物体最大体宽和体长(线虫包括细尾),并由公式计算体积:

$$V=L\times W^2\times C$$

式中,L 为体长(mm),W 为直径(mm),系数 C。

(2)体积 V 到湿重生物量(g)的换算系数为 1.13,湿重生物量到干重乘以系数 0.25^[32]。另取一根芯样按 0—1 cm、1—2 cm、2—4 cm 和 4—6 cm 分层,分取现场参数测定子样,叶绿素和脱镁叶绿素现场采用唐纳荧光法进行测定^[33]。沉积物中微型生物的生物量用 ATP 法(三磷酸腺苷)测定计算^[34-35]。

1.3 数据处理

小型底栖生物密度和生物量分布图采用 Surfer8.0 软件绘制。小型底栖生物密度和生物量与环境因子相

关性分析使用 primer 6.0 软件。

2 结果

2.1 沉积物叶绿素 a 和脱镁叶绿素的水平分布

中国开辟区东小区和西小区沉积物(0—6cm)叶绿素 a 含量极低,变化范围为 0.001—0.007 $\mu\text{g}/\text{cm}^2$,平均值为 0.003 $\mu\text{g}/\text{cm}^2$,其中东小区沉积物叶绿素 a 平均值为 0.004 $\mu\text{g}/\text{cm}^2$,西小区为 0.002 $\mu\text{g}/\text{cm}^2$;东、西小区沉积物(0—6cm)脱镁叶绿素变化范围为 0.074—0.199 $\mu\text{g}/\text{cm}^2$,平均值为 0.125 $\mu\text{g}/\text{cm}^2$,其中东小区沉积物脱镁叶绿素平均值为 0.169 $\mu\text{g}/\text{cm}^2$,西小区为 0.082 $\mu\text{g}/\text{cm}^2$ 。

中国开辟区东区和西区之间的沉积物叶绿素含量显然有所差异,东小区沉积物叶绿素 a 含量、脱镁叶绿素含量均高于西小区(图 2),表明上层水体有机碎屑沉降于两个区域的通量是不同的。

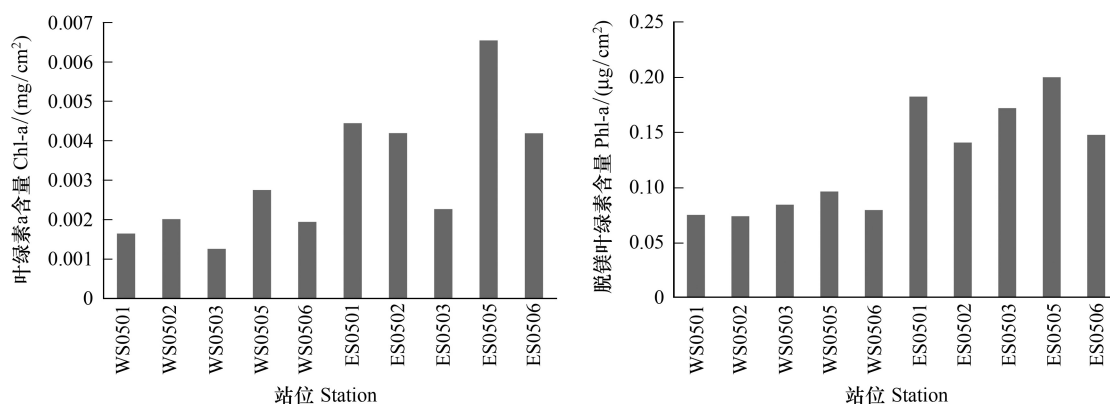


图 2 各站位沉积物(0—6cm)叶绿素和脱镁叶绿素

Fig. 2 Top 6cm sediment Chl-a and Phl-a of the survey stations

2.2 沉积物微生物生物量水平分布

中国开辟区东小区和西小区沉积物(0—6 cm)微型生物生物量变化范围为 0.043—0.477 $\mu\text{g}/\text{cm}^2$,平均值为 0.163 $\mu\text{g}/\text{cm}^2$,其中东小区沉积物叶绿素 a 平均值为 0.252 $\mu\text{g}/\text{cm}^2$,西小区为 0.074 $\mu\text{g}/\text{cm}^2$ 。中国开辟区东小区沉积物微生物生物量明显高于西小区(图 3)。

2.3 小型底栖生物类群组成

调查海域共有 13 个类群的小型底栖生物,其中东小区 11 类,西小区 12 类。包括线虫(Nematoda)、腹毛类(Gastrotricha)、动吻类(Kinorhyncha)、多毛类(Polychaeta)、寡毛类(Oligochaeta)、介形类(Ostracoda)、桡足类(绝大部分为猛水蚤 Harpacticoida)、等足类(Isopoda)、缓步类(Tardigrada)、蜱螨类(Acari)、双壳类(Bivalvia)、铠甲类(Loricifera)、其他未鉴定种类(Other)。

其中海洋线虫为绝对优势类群,其他较为重要的类群有底栖桡足类,多毛类,介形类等。东、西两小区小型底栖生物主要类群的密度见表 2。

2.4 小型底栖生物密度和生物量水平分布

调查海域东、西两小区小型底栖生物平均密度分别为 (104.4 ± 20.48) 个/ 10 cm^2 , (40.26 ± 25.84) 个/ 10 cm^2 ,密度占前五位的类群依次为线虫、桡足类、多毛类、介形类和缓步类。东小区最高密度值出现在 ES0506 站,为 137.55 个/ 10 cm^2 ,最低密度出现在 ES0504 站,为 84.65 个/ 10 cm^2 ;西小区最高密度值出现在

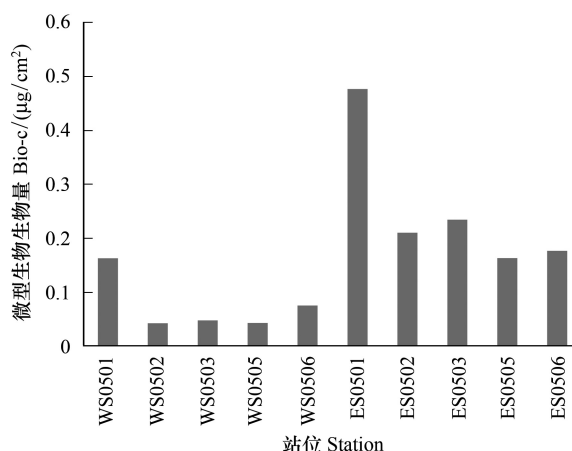


图 3 各站位沉积物(0—6 cm)微型生物生物量

Fig. 3 Top 6cm sediment microbial biomass of the survey stations

WS0502 站,为 90.15 个/10 cm²,最低密度出现在 WS0504,为 17.35 个/10 cm²。线虫是小型底栖生物中的绝对优势种,东、西两小区平均密度分别为(97.23±19.51) 个/10 cm² 和(36.78±25.08) 个/10 cm²;桡足类东、西两小区平均密度分别为(4.21±1.05) 个/10 cm² 和(2.08±0.82) 个/10 cm²,东小区最高值出现在 ES0503 站,为 5.50 个/10 cm²,最低值出现在 ES0502 站,为 2.82 个/10 cm²;西小区最高值出现在 WS0502,为 3.1 个/10 cm²,最低值出现在 WS0504,为 0.85 个/10 cm²。多毛类在东小区平均密度较高,有(1.03±0.39) 个/10 cm²,而在西小区平均密度仅有 0.14 个/10 cm²(图 4)。

表 2 东、西小区小型底栖生物各类群平均密度
Table 2 Abundanc of meiofaunal groups and nematode biomass

类群 Groups	东小区	西小区
	平均密度 Abundance(个/10cm ²)	平均密度 Abundance(个/10cm ²)
线虫 Nematoda	97.23±19.51 (93.13%)	36.78±25.08 (91.36%)
腹毛类 Gastrotricha	—	0.02±0.06 (0.06%)
桡足类 Copepoda	4.21±1.05 (4.03%)	2.08±0.82 (5.66%)
多毛类 Polychaeta	1.03±0.39 (0.9%)	0.14±0 (0.35%)
动物类 Kinorhyncha	0.02±0.069 (0.02%)	0.02±0.06 (0.06%)
双壳类 Bivalvia	0.05±0.07 (0.05%)	0.05±0.07 (0.05%)
寡毛类 Oligochaeta	0.02±0.06 (0.02%)	0.02±0.06 (0.06%)
介形类 Ostracoda	0.19±0.17 (0.07%)	0.21±0.23 (0.53%)
缓步类 Tardigrada	0.11±0.14 (0.11%)	0.14±0.23 (0.35%)
蜱螨类 Acari	0.07±0.12 (0.07%)	0.02±0.06 (0.06%)
等足类 Isopoda	—	0.09±0.16 (0.23%)
铠甲类 Loricifera	0.09±0.15 (0.09%)	—
其他类 Others	0.23±0.26 (0.22%)	0.05±0.07 (0.12%)
总计 Total	104.40±20.48	40.26±25.84

括号内的表示该类群生物丰度占总丰度的百分比;-表示未出现

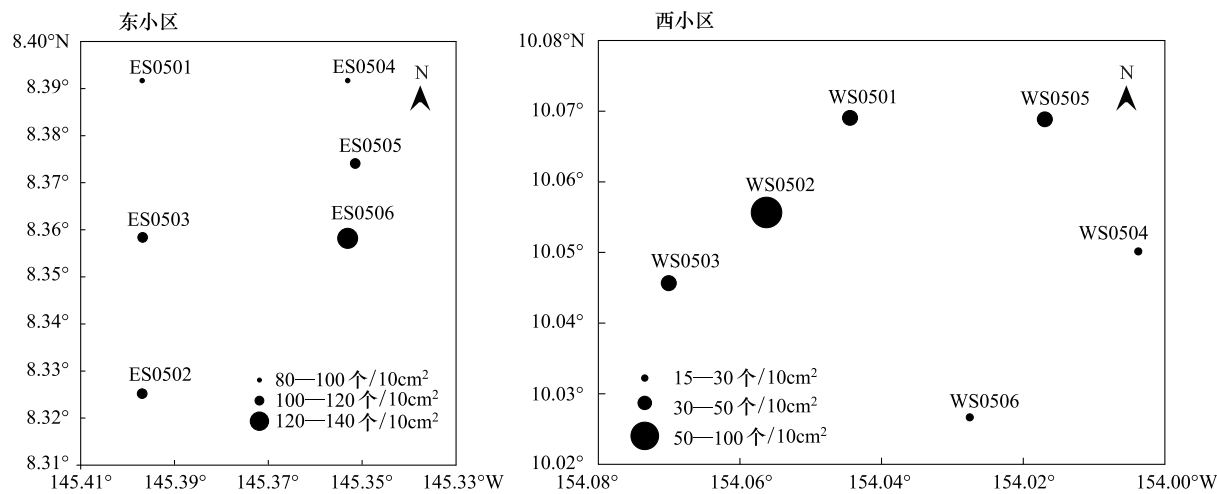


图 4 小型底栖生物密度水平分布
Fig. 4 horizontal distribution of the abundance of meiofauna

调查海域东、西两小区线虫平均生物量分别为(5.25±0.99) μg 干重/10 cm²和(1.68±0.77) μg 干重 /10cm²。东小区线虫最高生物量出现在 ES0506 站,为 6.57μg 干重/10cm²,最低生物量出现在 ES0504 站,仅为 3.86 μg 干重/10cm²;西小区线虫最高生物量出现在 WS0502,为 3.15 μg 干重/10cm²;最低出现在 WS0504,为 0.96 μg 干重/10cm²。深海线虫生物量较近岸低,与其个体小有一定关系。

2.5 小型底栖生物密度垂直分布

中国开辟区小型底栖生物密度的垂直分布趋势为:至表层向底层递减的趋势,小型底栖生物分布集中在沉积物表面 0—2 cm 层中,占总数的 75% 以上(图 5)。

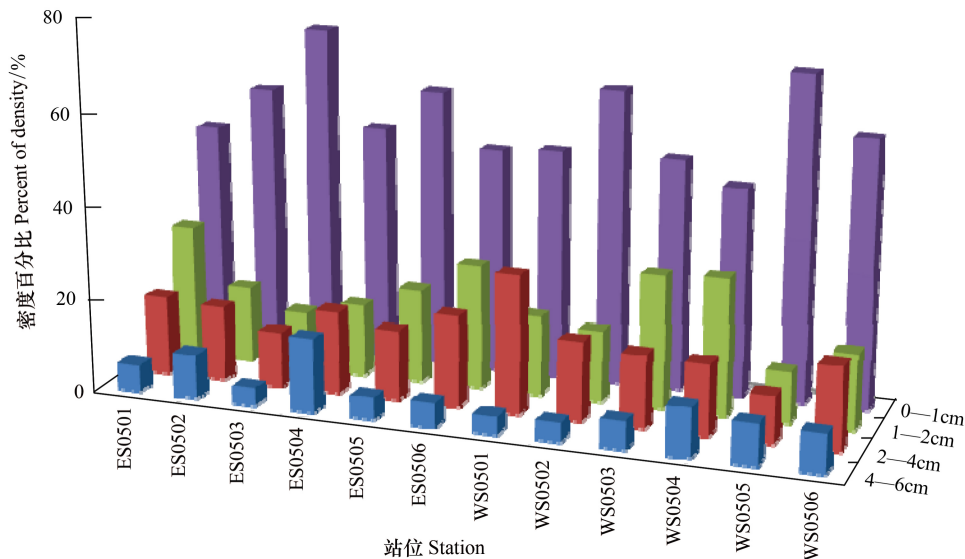


图 5 小型底栖生物垂直分布

Fig.5 Vertical distribution of meiobenthic abundance

2.6 小型底栖生物密度与环境变量的相关性

对 2005 年调查中同步测定的小型底栖生物密度,线虫密度,线虫生物量,桡足类密度,多毛类密度分别对各站位的经、纬度($n=12$),沉积物叶绿体含量($n=10$),沉积物微生物生物量($n=10$)进行相关分析,分析结果见表 3。

表 3 小型底栖生物密度、生物量与环境因子的相关分析结果

Table 3 Correlation analysis between meiobenthic abundance, biomass and environmental variables

	经度 Latitude	纬度 Longitude	小型底栖 生物总密度 Meiobenthic abundance	线虫密度 Nematoda abundance	线虫生物量 Nematoda biomass	多毛类 密度 Polychaeta abundance	桡足类 密度 Copepoda abundance	沉积物 叶绿素 a Chl-a	沉积物脱 镁叶绿素 Phl-a
经度 Latitude	—								
纬度 Longitude	0.99 **								
小型底栖生物总密度 Abundance of meiobenthic	-0.83 **	-0.84 **							
线虫密度 Abundance of Nematoda	-0.83 **	-0.83 **	0.99 **						
线虫生物量 Biomass of Nematoda	-0.91 **	-0.91 **	0.97 **	0.96 **					
多毛类密度 Abundance of Polychaeta	-0.87 **	-0.86 **	0.74 **	0.74 **	0.78 **				
桡足类密度 Abundance of Copepoda	-0.74 **	-0.74 **	0.81 **	0.79 **	0.83 **	0.74 **			
沉积物叶绿素 a Chl-a	-0.76 **	-0.76 **	0.65 *	0.65 *	0.68 *	0.63 *	0.30		
沉积物脱镁叶绿素 Phl-a	-0.93 **	-0.93 **	0.70 *	0.70 *	0.82 **	0.86 **	0.66 *	0.82 **	
微生物生物量 bio-C	-0.71 *	-0.70 *	0.38	0.37	0.50	0.44	0.53	0.47	0.70 *

** $P < 0.01$, * $P < 0.05$

结果显示:调查区域的小型底栖生物密度,线虫密度,线虫生物量,桡足类密度,多毛类密度与经、纬度呈

显著负相关,与脱镁叶绿素呈显著正相关,与沉积物微型生物生物量相关性不显著。小型底栖生物密度,线虫密度,线虫生物量,多毛类密度与叶绿素 a 呈显著正相关,桡足类与叶绿素 a 相关性不显著。脱镁叶绿素与沉积物微型生物生物量呈显著正相关。

3 讨论

3.1 深海小型底栖生物密度的影响因子

深海海盆通常食物贫瘠,食物来源主要依靠表层水体中有机碎屑的沉降,有机碎屑沉降通量对深海沉积物中底栖生物密度,生物量高低起着决定性影响。调查结果显示,中国开辟区小型底栖生物密度及线虫生物量与沉积物中叶绿素 a 和脱镁叶绿素含量均呈显著正相关(表 2),这与以往相关研究结果相同^[26,36-38]。此外,沉积物特性也对小型底栖生物密度、垂直分布有一定影响,中国开辟区内的沉积物以硅质粘土、硅质软泥和含硅质粘土为主。其中东小区表层沉积物以硅质粘土为主,硅质软泥和含硅质粘土次之,它们分别约占东区面积为 70%、26%、4%,沉积物松软^[40];西小区表层沉积物硅质软泥含量偏低,占西区的 16%,硅质粘土占 79%,含硅质粘土占 4%,表明东区的沉积物组分更细,更松软,西区沉积物则较东区粗而硬,两区在沉积环境上存在着差异^[39]。由于底质颗粒越细越有利于有机物的富集^[40-41],底质越松软则越有利于小型底栖生物上下活动,向深层分布,从大面分布来看东区小型底栖生物的密度要高于西区,从垂直分布来看,东区小型底栖生物在深层的分布的比例要比西区的比例大一些。

3.2 与历史资料的比较

由于受到采样技术的限制,历史上对深海的小型底栖生物研究相对近海而言较少,特别是在太平洋 CCZ,加之不同的研究运用采样和室内分选的方法有所差异,因此要进行精确比较是相对困难的。从群落结构上来说,各项研究差异性不大,线虫,底栖桡足类,多毛类是小型底栖生物的优势类群,尤其是线虫,为深海小型底栖生物的绝对优势类群^[23,42]。

表 4 记录了国际上关于太平洋 CCFZ 以及周边深海小型底栖生物的数据,由于沉积物样品的厚度以及研

表 4 本研究与历史资料比较

Table 4 Comparison between present study and history data

区域 Area	深度 Deep/m	样品厚度 Sampling depth/cm	小型底栖生物密度 Density of meiofauna / (个/10cm ²)	参考文献 Reference
东北太平洋海盆, 克拉里昂-克里帕顿结核区, 北纬 30 度 NE Pacific Basin, CCNP, 30°N	5800	0—5	90±20	[27]
克拉里昂-克里帕顿断裂带, 中, 东太平洋 CCFZ, eastern, central Pacific	4905—5140	0—2.5	82±23	[23]
中太平洋夏威夷连续站 HOT Station, central Pacific	4871—4884	0—1	40±9 (仅线虫)	[26]
全球海通量研究赤道太平洋断面北纬 0—5 度 JGOFS EqPac transect 0—5°N, Equatorial Pacific	4301—4447	0—1	72±36 (仅线虫)	[26]
全球海通量研究赤道太平洋北纬 9 度 JGOFS EqPac transect 9°N, Equatorial Pacific	4986—4994	0—1	45±38 (仅线虫)	[26]
赤道太平洋, 克拉里昂-克里帕顿结核区, 北纬 9 度 Equatorial Pacific, CCNP, 9°N	5300	0—5	95	[28]
东北太平洋海盆, 克拉里昂-克里帕顿结核区, 北纬 14 度 NE Pacific Basin, CCNP, 14°N, NB site (有结核站位)	4877—5046	0—5	69±19 (仅线虫)	[25]
东北太平洋海盆, 克拉里昂-克里帕顿结核区, 北纬 14 度 NE Pacific Basin, CCNP, 14°N, NN site (无结核站位)	4877—5046	0—5	137±28 (仅线虫)	[25]
中国多金属结核区东小区 Eastern area of the COMRA's Contract Area	5100—5400	0—6	104.4±20.48	本次调查 (2005)
中国多金属结核区西小区 Western area of the COMRA's Contract Area	5100—5400	0—6	40.26±25.84	本次调查 (2005)

究的重点有所不同(Bown^[26]等调查沉积物最表层线虫密度,Renaud-Mornant 等对沉积物 2.5 cm 厚度的线虫进行研究,Snider 等^[27],A. Miljutina 等^[25],Kaneko 等^[28]对沉积物 5 cm 厚度的小型底栖生物进行研究),因此只能进行粗略的对比。A. Miljutina 等数据显示,CCFZ 沉积物表层 5 cm 线虫平均密度为 80 个/10 cm²,与本次研究的中国合同区东小区线虫密度((97.23±19.51) 个/10 cm²)相仿,但远高于中国合同区西小区的线虫密度((36.78±25.08) 个/10 cm²)。总体而言,CCFZ 线虫密度要远低于 Mokievskij 等^[43]2007 年所得到的全球深海线虫密度值((196±15) 个/10 cm²)。这与 CCFZ 位于透光层初级生产力很低的中北太平洋寡营养区有直接关系^[25]。

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ACTA ECOLOGICA SINICA Vol.33 ,No.2 January ,2013(Semimonthly)

CONTENTS

Frontiers and Comprehensive Review

- Spatio-temporal heterogeneity of water and plant adaptation mechanisms in karst regions; a review CHEN Hongsong, NIE Yunpeng, WANG Kelin (317)
- Impacts of mangrove vegetation on macro-benthic faunal communities CHEN Guangcheng, YU Dan, YE Yong, et al (327)
- Advance in research on the occurrence and transformation of arsenic in the freshwater lake ecosystem ZHANG Nan, WEI Chaoyang, YANG Linsheng (337)
- Application of nano-scale secondary ion mass spectrometry to microbial ecology study HU Hangwei, ZHANG Limei, HE Jizheng (348)
- Carbon cycle of urban system; characteristics, mechanism and theoretical framework ZHAO Rongqin, HUANG Xianjin (358)
- Research and compilation of urban greenhouse gas emission inventory LI Qing, TANG Lina, SHI Longyu (367)

Autecology & Fundamentals

- Seed dispersal and seedling recruitment of *Ulmus pumila* woodland in the Keerqin Sandy Land, China YANG Yunfei, BAI Yunpeng, LI Jiandong (374)
- Influence of environmental factors on seed germination of *Bombax malabaricum* DC. ZHENG Yanling, MA Huancheng, Scheller Robert, et al (382)
- Carbon, nitrogen and phosphorus stoichiometric characteristics during the decomposition of *Spartina alterniflora* and *Cyperus malaccensis* var. *brevifolius* litters OUYANG Linmei, WANG Chun, WANG Weiqi, et al (389)
- Home range of *Teratoscincus roborowskii* (Gekkonidae): influence of sex, season, and body size LI Wenrong, SONG Yucheng, SHI Lei (395)
- Effects of the covering behavior on food consumption, growth and gonad traits of the sea urchin *Glyptocidaris crenularis* LUO Shibin, CHANG Yaqing, ZHAO Chong, et al (402)
- Biological response of the rice leaffolder *Cnaphalocrocis medinalis* (Güenée) reared on rice and maize seedling to temperature LIAO Huaijian, HUANG Jianrong, FANG Yuansong, et al (409)

Population, Community and Ecosystem

- Composition and stability of organic carbon in the top soil under different forest types in subtropical China SHANG Suyun, JIANG Peikun, SONG Zhaoliang, et al (416)
- The community characteristics of different types of grassland under grazing prohibition condition ZHANG Pengli, CHEN Jun, CUI Shujuan, et al (425)
- Spatial pattern and competition relationship of *Stellera chamaejasme* and *Aneurolepidium dasystachys* population in degraded alpine grassland REN Heng, ZHAO Chengzhang (435)
- SOC decomposition of four typical broad-leaved Korean pine communities in Xiaoxing' an Mountain SONG Yuan, ZHAO Xizhu, MAO Zijun, et al (443)
- The influence of vegetation restoration on soil archaeal communities in Fuyun earthquake fault zone of Xinjiang LIN Qing, ZENG Jun, ZHANG Tao, et al (454)
- Effects of fertilization regimes on soil faunal communities in cropland of purple soil, China ZHU Xinyu, DONG Zhixin, KUANG Fuhong, et al (464)
- Woody plant leaf litter consumption by the woodlouse *Porcellio scaber* with a choice test LIU Yan, LIAO Yuncheng (475)
- The bacterial community of coastal sediments influenced by cage culture in Xiangshan Bay, Zhejiang, China QIU Qiongfeng, ZHANG Demin, YE Xiansen, et al (483)
- A study of meiofauna in the COMRA's contracted area during the summer of 2005 WANG Xiaogu, ZHOU Yadong, ZHANG Dongsheng, et al (492)
- Hydrologic regime of interception for typical forest ecosystem at subalpine of Western Sichuan, China SUN Xiangyang, WANG Genxu, WU Yong, et al (501)

Landscape, Regional and Global Ecology

- Sensitivity and vulnerability of China's rice production to observed climate change XIONG Wei, YANG Jie, WU Wenbin, et al (509)

Characteristics of temperature and precipitation in Northeastern China from 1961 to 2005	HE Wei, BU Rencang, XIONG Zaiping, et al (519)
Combined effects of elevated O ₃ and reduced solar irradiance on growth and yield of field-grown winter wheat	ZHENG Youfei, HU Huifang, WU Rongjun, et al (532)
Resource and Industrial Ecology	
The study of vegetation biomass inversion based on the HJ satellite data in Yellow River wetland	GAO Mingliang, ZHAO Wenji, GONG Zhaoning, et al (542)
Temporal and spatial variability of soil available nutrients in arable Lands of Heyang County in South Loess Plateau	CHEN Tao, CHANG Qingrui, LIU Jing, et al (554)
Decomposition characteristics of wheat straw and effects on soil biological properties and nutrient status under different rice cultivation	WU Ji, GUO Xisheng, LU Jianwei, et al (565)
Effects of nitrogen application stages on photosynthetic characteristics of summer maize in high yield conditions	LÜ Peng, ZHANG Jiwang, LIU Wei, et al (576)
Urban, Rural and Social Ecology	
The degradation threshold of water quality associated with urban landscape component	LIU Zhenhuan, LI Zhengguo, YANG Peng, et al (586)
Ecological sustainability in Chang-Zhu-Tan region; a prediction study	DAI Yanan, HE Xinguang (595)
The effect of exogenous nitric oxide on activities of antioxidant enzymes and microelements accumulation of two rice genotypes seedlings under cadmium stress	ZHU Hanyi, CHEN Yijun, LAO Jiali, et al (603)
Forms composition of inorganic carbon in sediments from Dali Lake	SUN Yuanyuan, HE Jiang, LÜ Changwei, et al (610)
Fractionation character and bioavailability of Cd, Pb, Zn and Ni combined pollution in oasis soil	WU Wenfei, NAN Zhongren, WANG Shengli, et al (619)
Effects of CA and EDTA on growth of <i>Chlorophytum comosum</i> in copper-contaminated soil	WANG Nannan, HU Shan, WU Dan, et al (631)
Research Notes	
Values of marine ecosystem services in Haizhou Bay	ZHANG Xiuying, ZHONG Taiyang, HUANG Xianjin, et al (640)
Variations of <i>Leymus chinensis</i> community, functional groups, plant species and their relationships with climate factors	TAN Liping, ZHOU Guangsheng (650)
The effect of N:P supply ratio on P uptake and utilization efficiencies in <i>Larix olgensis</i> Henry. seedlings	WEI Hongxu, XU Chengyang, MA Lüyi, et al (659)

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