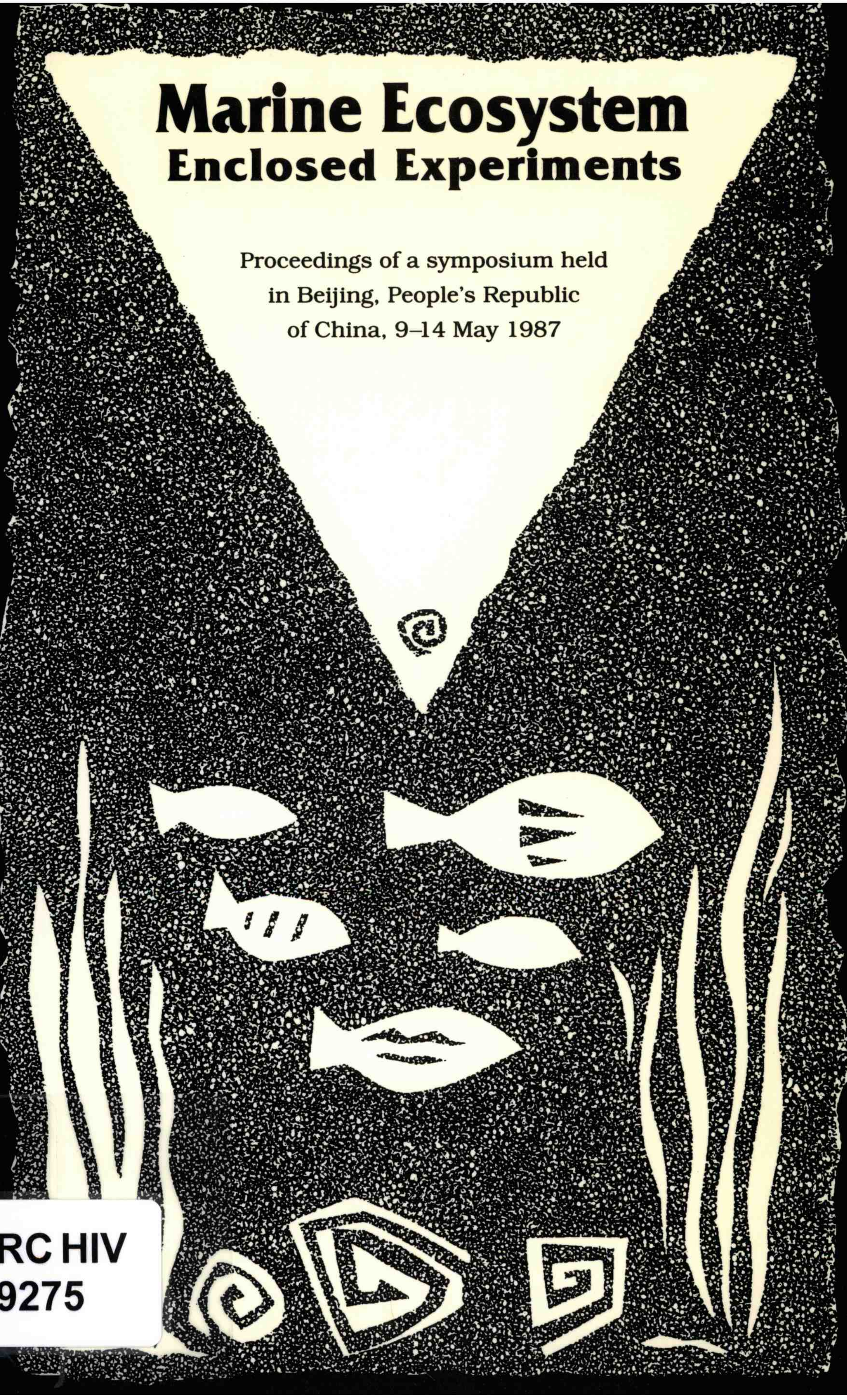
Marine Ecosystem Enclosed Experiments

Proceedings of a symposium held in Beijing, People's Republic of China, 9–14 May 1987



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Editor: C.S. Wong and P.J. Harrison

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Abstract

This symposium on marine ecosystem enclosed experiments (MEEE) consists of nine review papers that describe various types of ecosystem enclosures and a series of papers resulting from enclosure experiments in Xiamen, People's Republic of China, and Saanich Inlet, BC, Canada. The reviews on types of enclosures include benthic enclosures for rocky and sandy shores and the effects of pollutants (primarily hydrocarbons) on bacteria, macroalgae, and invertebrates. The pelagic enclosures were used to study the control of phytoplankton blooms, the uptake and release of dissolved organic substances, and the effects of pesticides on freshwater ecosystems.

Six enclosure experiments were conducted in China and Canada from 1986–87. Some of these experiments examined the effects of contaminated sediments, primarily heavy metals, on bacteria, phytoplankton, and zooplankton and the pathways and fates of these heavy metals in the seawater. Other experiments studied the chemistry and biological effects of chemically dispersed oil.

Résumé

Ce compte rendu du symposium sur les expériences faites en écosystèmes marins comprend neuf communications qui décrivent les écosystèmes retenus et les expériences faites à Xiamen en République populaire de Chine et à Saanich Inlet, C.-B., au Canada. Les communications portent, notamment, sur les écosystèmes benthiques des littoraux rocheux et sablonneux et sur les effets des polluants (surtout les hydrocarbures) sur les bactéries, les grandes algues et les invertébrés. Les expériences sur le contrôle des brutales pullulations ("blooms") du phytoplancton furent menées dans les écosystèmes pélagiques, ainsi que l'absorption et le dégagement des substances organiques dissoutes et les effets des pesticides sur les écosystèmes d'eau douce.

Six expériences ont été faites en Chine et au Canada entre 1983 et 1987. Certaines ont porté sur les effets des sédiments contaminés, principalement par des métaux lourds, sur les bactéries, le phytoplancton et le zooplancton et sur le cheminement et le sort de ces métaux lourds dans l'eau salée. D'autres expériences portaient sur la chimie et les effets biologiques du pétrole dispersé chimiquement.

Resumen

Este simposio sobre Experimentos Marinos en Ecosistemas Cerrados (MEEE) consistió en nueve trabajos de análisis que describen varios tipos de enclaustramientos ecosistémicos y una serie de trabajos derivados de experimentos con estos enclaustramientos en Xiamen, República Popular de China, y en Sannich Inlet, Canadá. Los estudios incluyen enclaustramientos bentónicos para costas rocosas y arenosas, y los efectos de los contaminantes (fundamentalmente hidrocarburos) sobre bacterias, macroalgas e invertebrados. Los enclaustramientos pelágicos se utilizaron para estudiar el control de la reproducción del fitoplancton, la ingestión y expulsión de substancias orgánicas disueltas y los efectos de pesticidas en los ecosistemas de agua dulce.

Se realizaron seis experimentos en ecosistemas cerrados en China y Canadá, de 1983 a 1987. Algunos de estos experimentos examinaron los efectos que ejercen los sedimentos contaminados, fundamentalmente los metales pesados, sobre bacterias, fitoplancton y zooplancton, y el ciclo y destino final de estos metales pesados en el agua de mar. Otros experimentos estudiaron los efectos químicos y biológicos de los aceites crudos dispersados por medios químicos.

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B. Hydrocarbons

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Use of Enclosed Experimental Ecosystems to Study the Effects of Suspended Sediments on Zooplankton Communities

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Large volumes of natural seawater were enclosed in plastic bags for experimental ecosystem studies in both Xiamen, People's Republic of China, and Saanich Inlet, BC, Canada. At both sites, various concentrations of sediment were added to the experimental containers and changes in resident zooplankton communities were followed. In the Canadian experiment, the added sediment was composed of fine-grained mine tailings that are routinely discharged into the sea from a copper mine. In the People's Republic of China experiment, the added sediment was obtained from dredgings in the discharge area of a Xiamen fertilizer factory. The effects of both sediment types on zooplankton species composition and abundance were compared, paying particular attention to differential effects on larvaceans (appendicularians), which feed on small particle sizes, versus herbivorous copepods, which consume larger food items. Mine tailings at concentrations of 40 and 300 ppm increased total numbers of both larvaceans and copepods over those in the control, possibly by both delaying and increasing primary productivity. On the other hand, dredged polluted sediments at concentrations of 11.2 and 112 ppm appreciably depressed total numbers of copepods compared with controls, but did not produce a consistent pattern with respect to Oikopleura *numbers.*

Enclosed experimental ecosystems have been used to study the effects of various types of suspended sediments on planktonic communities. This paper focuses on the responses of and changes in resident zooplankton in containers when they are exposed to mine tailings that are routinely discharged into the sea from a Canadian copper mine and to sediment obtained from the discharge area of a fertilizer factory in Xiamen, People's Republic of China.

Methods

The first experiment was conducted in three 60-t controlled experimental ecosystems (CEEs) deployed in Saanich Inlet, BC, Canada, as part of a joint research project between the People's Republic of China and Canada. One container

(CEE-1) was a control; CEE-2 and CEE-3 were treated with dredged mine tailings at concentrations of about 40 and 300 ppm.

The second experiment was conducted in Xiamen in 1985. Three enclosures containing about 10 m^3 of seawater were employed as experimental systems and received sediment dredged from the discharge area of a Xiamen fertilizer factory. Containers S1 and S2 received about 11.2 ppm and S3 about 112 ppm of the polluted sediment.

In both experiments, zooplankton in control and experimental containers were routinely sampled using a 20-cm diameter net with 200-µm mesh. The net was towed from near the bottom of each container to the surface (13 m to surface in the Saanich Inlet experiment; 3 m to surface in the Xiamen experiment).

Results and discussion

Species composition of the zooplankton communities in both experiments (Table 1) was remarkably similar given the differences in latitude (ca. 48° N versus 24° N). The dominant herbivorous copepods in both areas were *Paracalanus parvus* and species of *Acartia* (*A. clausi* in Saanich Inlet and *A. pacifica* in Xiamen). *Pseudocalanus minutus* was also an important member of the herbivorous zooplankton community in the Saanich Inlet experiment. The cyclopoid copepod *Oithona similis* was present in both areas, but was much more abundant in Saanich Inlet waters; it is considered to be primarily herbivorous in this study, although it is capable of feeding on a wide size spectrum, which may include smaller zooplankton (e.g., Poulet 1978). Both experiments also included small numbers of the predatory copepod *Corycaeus*, but a major difference involved the presence of a large predator, *Tortanus derjuginii*, in the Xiamen containers. The food habits of *Tortanus* in Xiamen waters have been discussed by Lee (1964); this copepod fed on *Acartia pacifica* in laboratory investigations conducted as part of the present study. Larvaceans (mostly species of *Oikopleura*) were also important zooplankton in both experiments.

Table 1. Comparison of dominant zooplankton species in enclosed experimental ecosystem experiments conducted in Saanich Inlet, BC, Canada, and Xiamen, People's Republic of China.

Saanich Inlet	Xiamen
Copepoda	Copepoda
Paracalanus parvus	*Paracalanus parvus*
Pseudocalanus minutus	
Acartia clausi	*Acartia pacifica*
Oithona similis	*Oithona similis*
Corycaeus anglicus	*Corycaeus affinis*
	Tortanus derjuginii
Larvacea	Larvacea
Oikopleura dioica	*Oikopleura* sp.
Fritillaria borealis	

Note: Data supplied by C. Lalli, Lin Jinmei, and Chen Xiaolin.

There was also considerable similarity in the numbers of zooplankton and in changes in their population densities in control containers in both the Saanich Inlet and Xiamen experiments (compare controls in Figs 1 and 2). Copepods attained maximal numbers late in the experiments, reaching densities of about 2 000 individuals·L^{-1} in Saanich Inlet and about 3 000 individuals·L^{-1} in Xiamen controls. In both cases, maximal numbers of larvacea in controls were attained in less than a week and differed by less than 100 individuals·L^{-1} (i.e., 378 individuals·L^{-1} in Saanich Inlet versus 473 individuals·L^{-1} in Xiamen).

The addition of mine tailings increased maximal numbers of both larvaceans and herbivorous copepods in each of the experimental containers compared with the control during the 3-week posttreatment period (Fig. 1). *Corycaeus*, a predatory copepod, followed the same response curve as the herbivorous copepod species, increasing in numbers in both experimental containers compared with the control. This enhancement of zooplankton densities may be attributed to a delay in the onset of primary production caused by decreases in the depth of the euphotic zone and to a subsequent increase in total primary production that resulted in better coupling between phytoplankton and zooplankton (Parsons et al. 1986). There was a clear separation between peak numbers of larvaceans, which appeared earlier in the experiment, and maximal numbers of copepods, which developed later. This may have been a reflection of differences in feeding habits — larvaceans feed on small-sized particles, such as bacteria and microflagellates, whereas copepods prefer larger food items. This temporal separation may also have resulted from the faster generation times of larvaceans versus copepods.

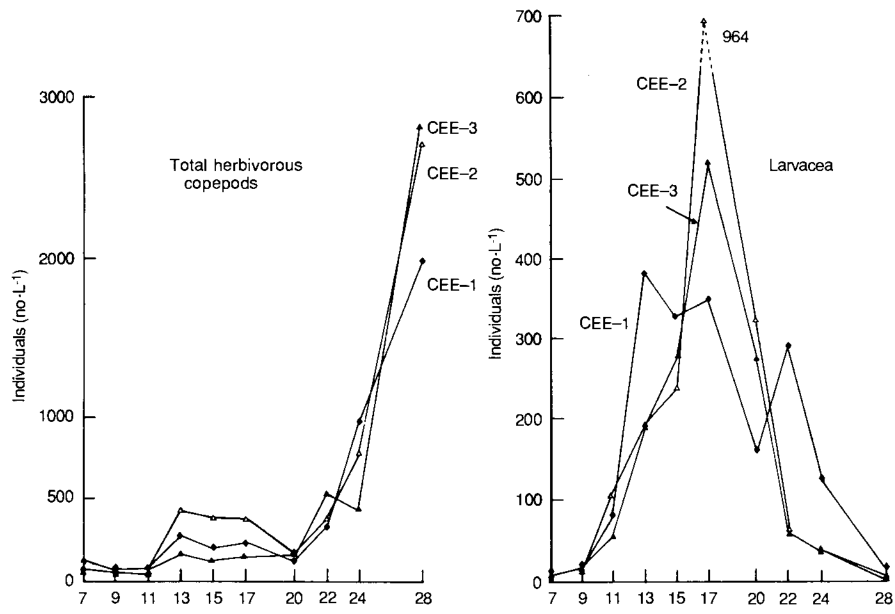

Fig. 1. Zooplankton densities in enclosed marine ecosystem experiments conducted in Saanich Inlet, BC, Canada, during 1984. CEE-1 = control; CEE-2 = 40 ppm mine tailings; and CEE-3 = 300 ppm mine tailings.

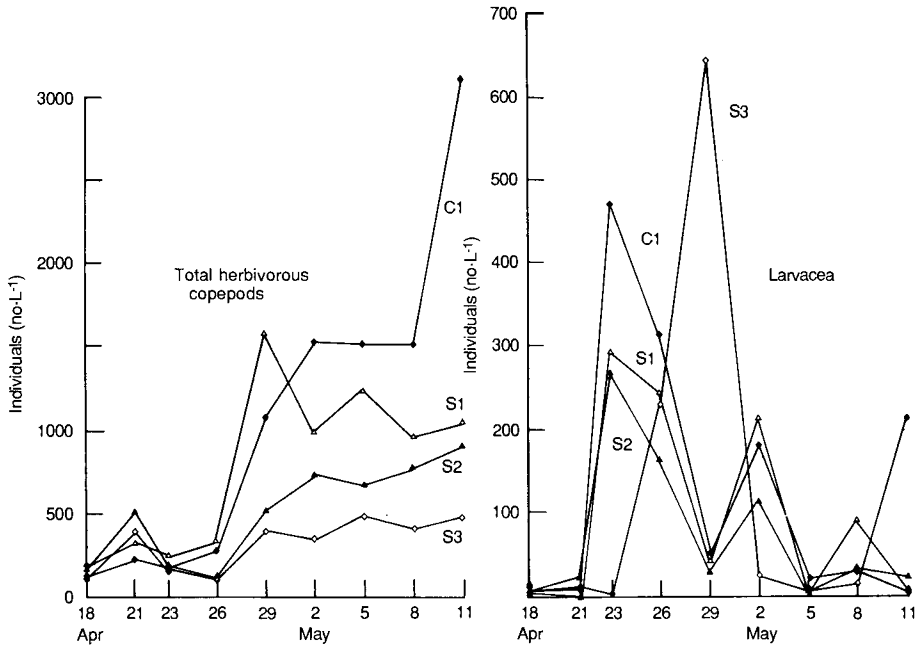

Fig. 2. Zooplankton densities in enclosed marine ecosystem experiments conducted in Xiamen, People's Republic of China, during 1985. (Data supplied by C. Lalli, Lin Jinmei, and Chen Xiaolin.) C1 = control; S1 = 11.2 ppm polluted sediment; S2 = 11.2 ppm polluted sediment; and S3 = 112 ppm polluted sediment.

In the Xiamen experiment, additions of polluted sediment did not enhance zooplankton numbers. The highest levels of sediment (112 ppm in S3) appreciably depressed numbers of total copepods; this effect was particularly noticeable after 29 April (day 11), when maximal numbers were consistently present in the control (C1) and lowest in S3. The two containers with lower levels of sediment (11.2 ppm) developed copepod densities that were intermediate between those of the control and S3. The effects of suspended polluted sediment on larvacea were not as clear. The development and decline of populations in S1 and S2 were similar to the control pattern, but peak numbers of larvaceans were somewhat lower in these experimental enclosures. The highest sediment levels delayed the bloom of larvaceans in S3 by about 6 d, a result comparable to that obtained in experiments using suspended mine tailings. Carnivorous copepods (*Tortanus* and *Corycaeus*) reached maximal densities during the first 3 d (highest value = 94 individuals·L^{-1}), then they declined rapidly and generally remained below 30 individuals·L^{-1} in all bags.

Conclusions

Changes in zooplankton densities or species composition, or both, can be used as indicators of environmental changes. It is important to stress that only dominant species need to be identified in the communities and that knowledge of their general biology is as important as taxonomic identification. Separation of zooplankton into trophic groups (e.g., herbivores versus carnivores; bacterial/flagellate feeders versus diatom grazers) allows one to analyze more accurately the changes in population densities of particular species or groups and to link these with changes in microbial and phytoplankton ecology. Similarly, separation of groups with different generation times (e.g., larvacea versus copepods) permits better analysis of population dynamics. Total zooplankton numbers mask simultaneous declines and increases of two or more groups and will usually not provide much information on biological or ecological changes occurring in either enclosed experimental ecosystems or in natural environments.

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Poulet, S.A. 1978. Comparison between five coexisting species of marine copepods feeding on naturally occurring particulate matter. Limnology and Oceanography, 23, 1 126–1 143.