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Effects of Nuclear Power Plant Thermal Effluent on Marine Sessile Invertebrate Communities in Southern Taiwan

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EFFECTS OF NUCLEAR POWER PLANT THERMAL EFFLUENT ON MARINE SESSILE INVERTEBRATE COMMUNITIES IN SOUTHERN TAIWAN

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Key words: thermal effluent, marine, sessile invertebrate.

ABSTRACT

The present study aimed at determining the impact of cooling water discharge from a Nuclear Power Plant in Kenting, Taiwan on the recruitment patterns of marine invertebrates. Field experiments were conducted over a six-year period in the vicinity of the power plant, with six control sites, five at influent areas, one at reference site, and three experimental sites at effluent areas. In general, among the monitoring sites, polychaetes and bryozoans were the most abundant organisms, and their recruitment on settlement plates was always higher in influent than in effluent areas. Partially as a result of a 5-week accidental shutdown of the power plant in the early spring of 2001, a higher recruitment of both polychaetes and bryozoans, comparable to that in influent areas, was observed in the spring and summer of 2001, but only at site Efflu, one of the three effluent areas. Albeit right nearby, site Efflu2 intriguingly showed no such increase in recruitment, MPT as well. Based on the monitoring results, it is strongly suggested that the different patterns of recruitment in the effluent areas can not just be attributed to thermal effects; on the contrary, other physico-chemical disturbances seem to have been at play.

INTRODUCTION

The biological consequences of cooling discharge have received considerable attention over the last several decades. In areas of discharge, such physical and chemical disturbances as residual chlorine, elevated temperatures, increased suspended matters, decreased chlorophyll a and dissolved oxygen may pose serious threats to aquatic organisms (Perkins, 1974). Among those factors, raised temperature in effluent environments had received much attention. Depending on the design and the operating units of the power plants, after passing through condensers, the water temperature in the effluent sites might raise as much as 8°C (Laws, 1993). In tropical oceans, this circumstance might lead seawater temperatures over 30°C in summer, which may approximate or even exceed the upper limits of the resident organisms (Jokiel and Coles, 1974, Suresh *et al*., 1993, Wright *et al*., 2000). In most cases, motile organisms are able to avoid the unfavorable discharges by swimming away. However, sessile organisms are inevitable from the thermal impacts in the effluent areas, and might be killed easily. For instance, Jokiel and Coles (1974) monitored shallow-water corals at Kahe Point, Oahu, Hawaii, and found the corals were bleached or dead near the power plant drainage, and the entire benthos were killed over a large area of Biscayne Bay, Florida when the water temperatures were 4°C above the ambient (Zieman and Woods, 1975). Not surprisingly, the addition of warm water from cooling drainage may very well lead to substantial adverse effects on the diversity of fouling communities (Sasikumar *et al*., 1993, Suresh *et al*., 1993).

In light of this, the present study was conducted to determine whether the recruitment patterns of sessile invertebrates were indeed affected by the discharges of cooling water from the nuclear power plant located next to the Kenting National Park area in Nanwan Bay in southern Taiwan (Fig. 1).

MATERIALS AND METHODS

To monitor whether the nuclear power plant drainage was altering populations of sessile organisms on temporal and spatial scales, settlement plates were placed at 9 sites, comprising those in influent areas (i.e. Influ-2, Influ-3, Influ-5, Influ-10 and Influ-11) and effluent areas (i.e. Efflu, Efflu2 and Mao-pi-tou (MPT)) as well as at the reference site, Shi-new Shi (SNS), in 5 - 10 meters deep (Fig. 1). The PVC plates (20×20 cm^2) were

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fixed horizontally with three replicates on steel frames at each site, and the plates were collected at the end of each season to determine the respective amounts of recruitment of sessile organisms from 1998 to 2004. The four seasons from spring to winter were defined as January-March, April-June, July-September and October-December, respectively.

The number of sessile organisms in different phyla, i.e. mollusks, tunicates, corals, barnacles, polychaetes and bryozoans, were counted seasonally and expressed in terms of occurrence per cm^2. The Multi-Dimensional Scaling (MDS) method was employed to analyze and compare the recruitment patterns of sessile organisms among different sites.

RESULTS

Although four of the six types of sessile organisms, namely mollusks, tunicates, corals and barnacles, were observed on some of the settlement plates, the number of more than one-half of all plates were zero occurrence per cm^2 during the experimental period. Thus, the analysis only covers polychaetes and bryozoans which are the two most abundant organisms.

On the question of seasonal variations, in the 1st season, the highest recruitment of polychaetes was observed at Influ-5 in 2004, with an average occurrence of 0.94 per cm^2 (Fig. 2), whereas that of bryozoans was at Efflu-2 in 2003, with an average occurrence of 0.99 per cm^2 (Fig. 3). In the 2nd season, the highest recruitment of both polychaetes and bryozoans were at Influ-5, and their respective average occurrence per cm^2 was 0.78 in 2004 and 0.97 in 2001. In the 3rd season, the highest recruitment of both organisms occurred at site Influ-2, with an average occurrence of 0.95 per cm^2 for polychaetes in 1999 and 0.84 for bryozoans in 2002. In the 4th season, polychaetes had the highest recruitment with an average occurrence of 1.00 per cm^2 at Influ-5 in 1998; the highest recruitment of bryozoans with an average occurrence 0.71 per cm^2 was at the same site but in 2003, 5 years later. Additionally, there was no consistent annual pattern in the recruitment of both polychaetes and bryozoans during the experimental period (Fig. 4).

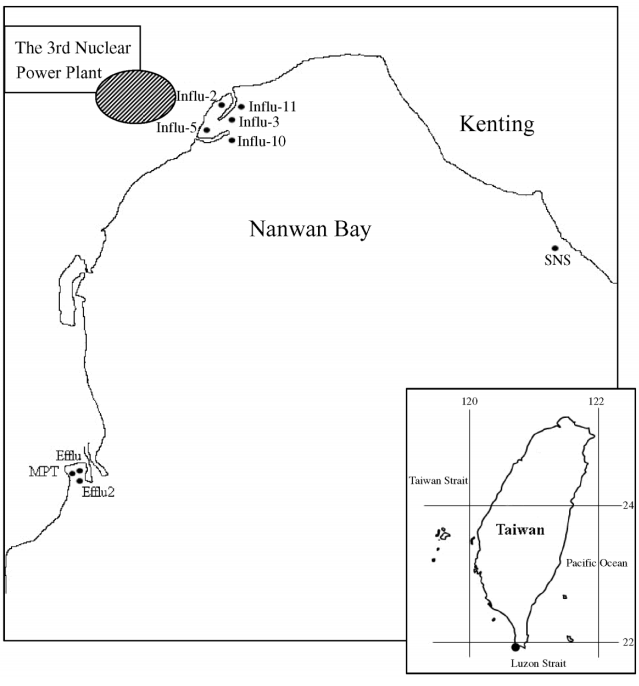

Fig. 1. Detailed map showing the location of the nuclear power plant and the sampling sites.

Turning to spatial variations, the relative abundance of both polychaetes and bryozoans differed in the influent and effluent areas (Figs. 2-4). In general, higher recruitment was found in the influent areas than either in the effluent areas or at the reference site. However, with the power plant having accidentally shut down during the March 18 to April 25, 2001 period, particularly noteworthy is that at Efflu in the 2nd and 3rd seasons, 2001, higher recruitment of polychaetes was found in that year, and it was quite comparable to that in the influent areas (Fig. 2). Worth noting too is that this enhanced recruitment at Efflu was not observed at Efflu2 although the two sites are close to each other. These results were further analyzed following the MDS method.

What became apparent is that during the shutdown period (the 2nd season of 2001), Efflu shifted into the influent group, while in general trend, the influent and effluent areas were separated into two distinct groups (Fig. 5). This difference, moreover, lasted into the next season.

To sum up, on the temporal scale, the amount of recruitment of polychaetes and bryozoans was, by and large, quite similar among seasons. By contrast, on the spatial scale, the recruitment of polychaetes and bryozoans was significantly higher in the influent areas than that in the effluent areas in all seasons ($p < 0.01$, ANOVA test).

DISCUSSION

Clear differences in the recruitment of polychaetes and bryozoans were observed in the influent and effluent areas of the power plant. More specifically, for both polychaetes and bryozoans, recruitment in the influent areas was greater than that in the effluent areas (Figs. 2 and 3).

The drainage from the power plant has monitored for its ecological impact over a considerable length of time, and as a result, it has been firmly concluded that since drainage draws large amounts of water to cool condensers, large volumes of pelagic organisms and

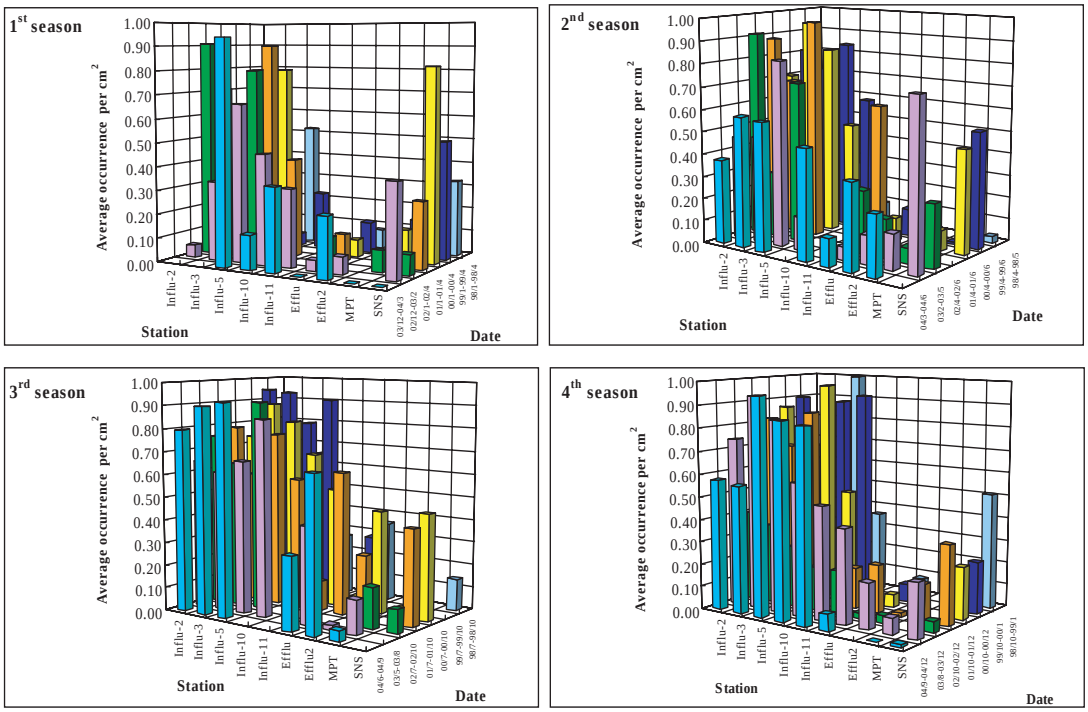

Fig. 2. Recruitment of polychaetes by season from 1998 to 2004, with the colored bars indicating the observation periods.

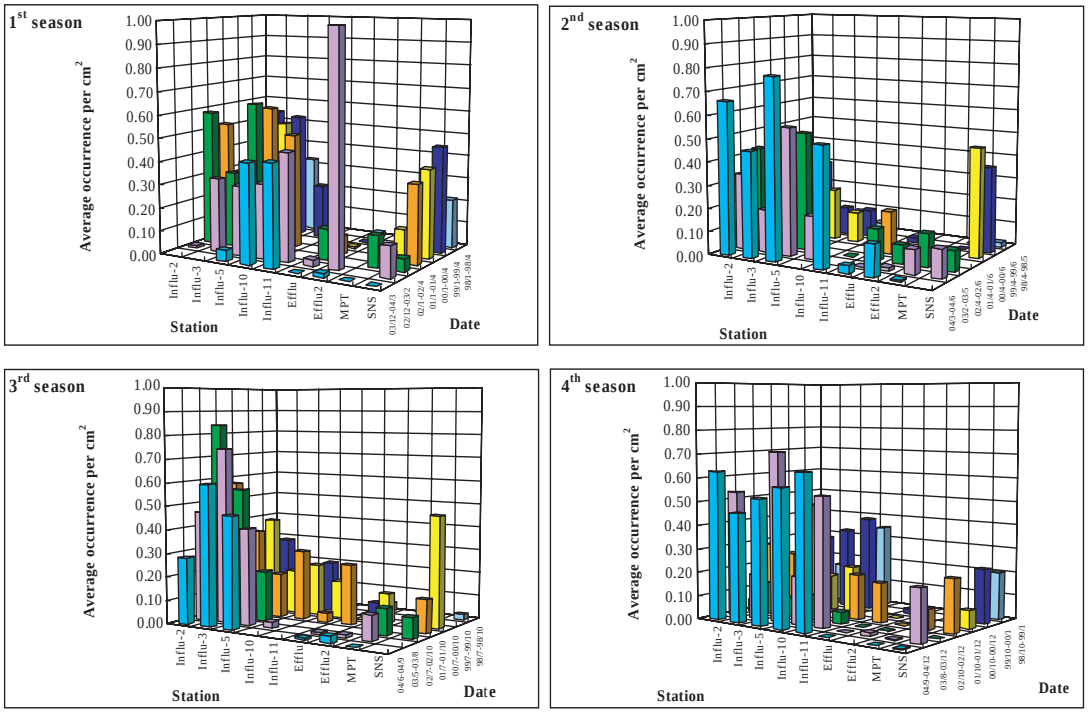

Fig. 3. Recruitment of bryozoans by season from 1998 to 2004, with the colored bars indicating the observation periods.

larvae are also gathered up in the process (Perkins, 1974). Thus, an abnormally high recruitment rate in the intake areas is resulted from such concentrating effect. In addition, on account of the high velocity of water flow in the drainage areas, as a rule, the local environment is more than likely highly affected. In support of

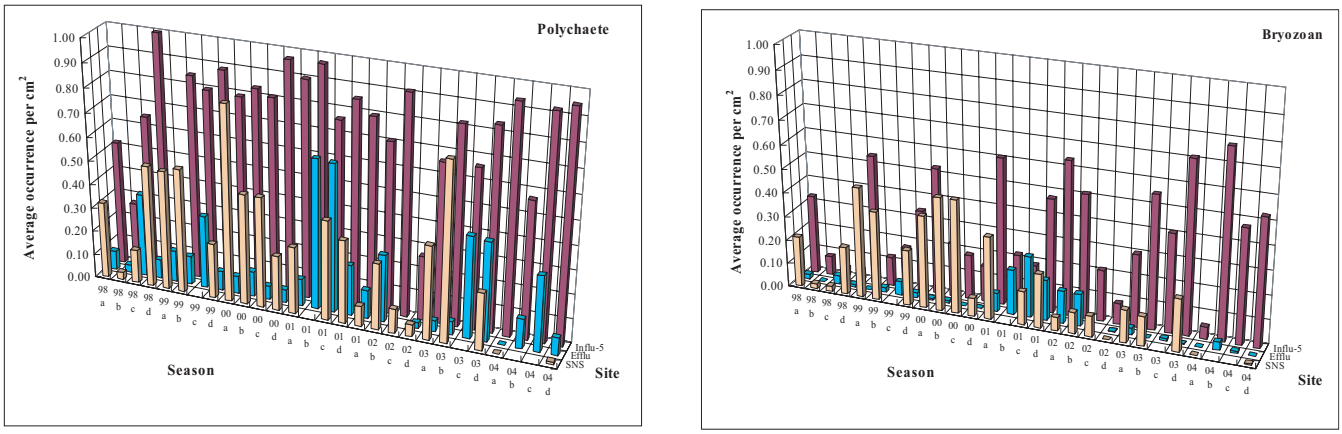

Fig. 4. **The recruitment of polychaetes and bryozoans by season from 1998 to 2004, with the colored bars indicating the observation sites of Influ-5, Efflu and SNS. a: Spring (January-March); b: Summer (April-June); c: Fall (July-September); and d: Winter (October-December).**

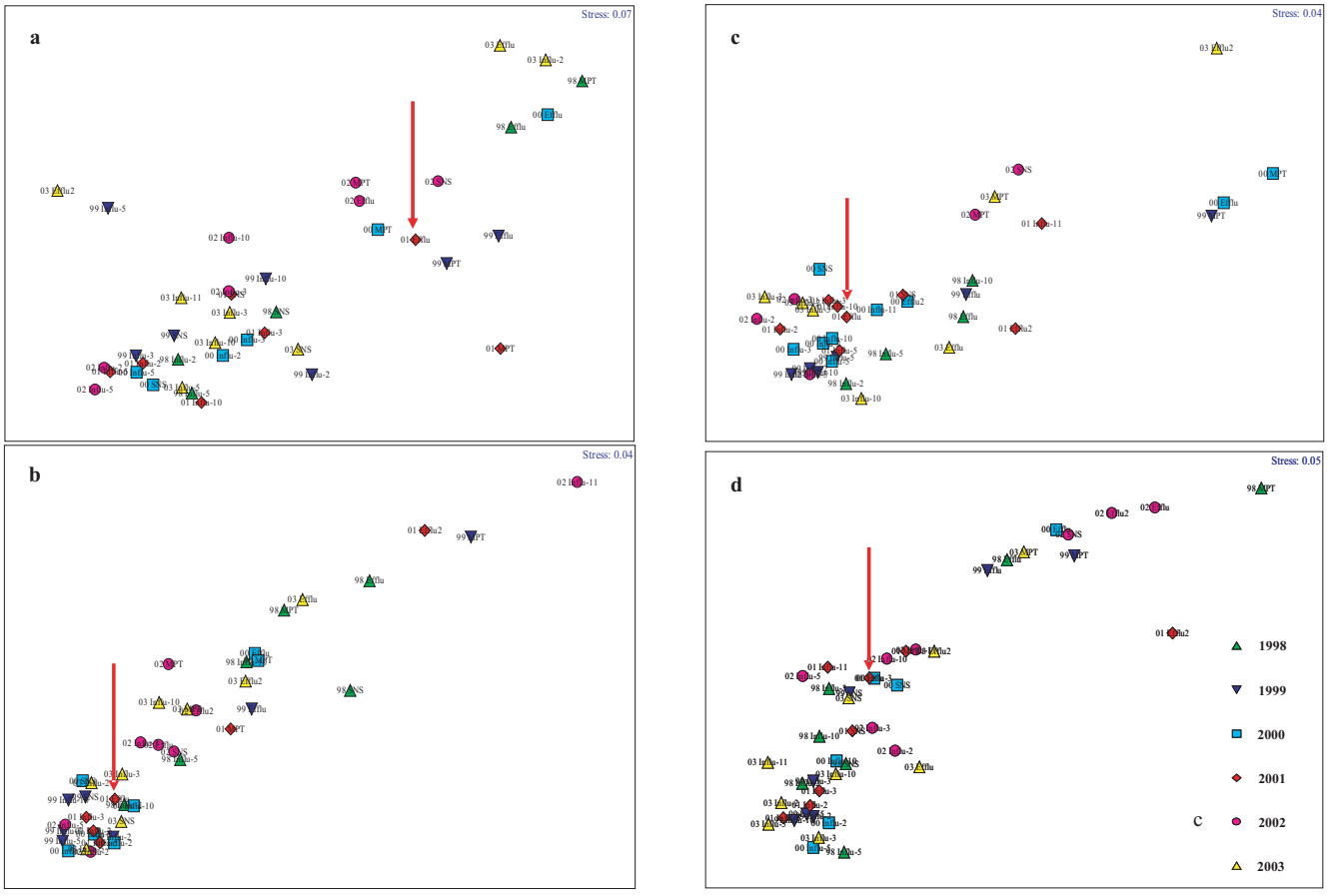

Fig. 5. **The MDS analyses of the six types of sessile organisms (i.e. mollusks, tunicates, corals, barnacles, polychaetes and bryozoans) in the influent and effluent areas and at the reference site in the four seasons (1998-2003). a. Spring (January-March); b. Summer (April-June); c. Fall (July-September); and d. Winter (October-December); ↓: Efflu (2001).**

this, Crisp (1959) contended that water flows supply large quantities of food for sessile organisms and enhance egg production in barnacles. It is also possible that the greater recruitment of polychaetes and bryozoans in the influent areas in the present study is also water flow related as Crisp stated [4].

A long term monitoring on the marine communities has been started in 1979 which was coped with the construction and operation of the nuclear power plant. During the period of 1980-1990, at fixed stations, the impact of warm water from the drainage the succession of benthic invertebrates was insignificant (Jan *et al*., 1994). Based on the experiments of tracing the warm water mass, it was suggested that the monitoring sites were beyond the influenced area (Su *et al*., 1988, Hung, 1989). However, a serious event of coral bleaching occurred near the water discharge outlet in parallel to 4-5°C increase of water temperature in 1987 (Hung *et al*., 1998). As follows, the global warming event during 1998-99, a wider scale of coral bleaching occurred in the local waters.

It should be kept in mind that the effluent areas in this study were more complex than the influent ones. The impact of the addition of warm water from the drainage of the Nuclear Power Plant aside the effluent areas here were located in the recreational area of Kenting National Park which attracts many tourists for diving activities all year round (Chung *et al*., 2002). The low recruitment in the effluent areas, therefore, may have resulted from many other disturbances, such as sewage discharge, diving pressure and so on; thus, further study is necessary to evaluate the effects of all the potentially destructive factors.

Since recruitment was higher than normal at Efflu during the shutdown period, the water flow from the drainage might have played a prominent role in altering the recruitment of sessile organisms. If the water flow changed, however, then it follows those local environmental factors, e.g. maximum upper temperatures, the range in temperature fluctuations, residual chlorine and the flow itself may have also contributed, though probably to varying degrees, to the disparities in the recruitment of these sessile organisms. Given that the only site affected by the shutdown event in spring 2001 was Efflu (Fig. 5), factors other than those related to temperature itself must have also been important in resulting in such a phenomenon. Never before, however, have any of these factors been investigated in this study area.

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