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Intrusions of the Kuroshio Current in the northern South China Sea affect copepod assemblages of the Luzon Strait

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Abstract

We analyse the influence of the Kuroshio Current on copepod assemblages in the northern South China Sea. The assumption was tested whether predominant current regimes bring marine zooplankton and Copepoda from subtropical and tropical waters to the south of Taiwan. A total of 101 copepod species were identified from 26 families and 48 genera that include Calanoida, Cyclopoida, Harpacticoida and Poecilostomatoida. High copepod abundances in the study area are shown to be caused by both, a year-round Kuroshio Current intrusion and the SW monsoon, prevailing in the South China Sea during summer. *Calanus sinicus* did not appear in the samples, indicating that there was no cold water mass intrusion in the area during sampling. Both, the intrusion of the Kuroshio Branch Current to the Luzon Strait and the South China Sea circulation may play a more important role in shaping copepod assemblages in the region than hitherto expected. The abundance of copepods was higher above the 50 m isoline than at deeper strata. Species number and the Shannon–Wiener diversity index were higher with increasing depth. Copepod assemblage structure changed with different sampling depth and different sampling areas. Copepod abundance and species richness were higher in the northern South China Sea than in the Kuroshio Current area, and higher at lower latitudes than at higher latitudes. Some indicator species are characteristic for the Kuroshio Current and indicate with others that the study area accomodated water masses from the northern South China Sea as well as from the Kuroshio Current.

Keywords: Community ecology; Copepoda; Current regimes; Kuroshio Branch Current; Marine plankton

1. Introduction

Marine life around the island of Taiwan is highly diverse. There are estimates that the marine fauna comprises about 10% of the world's total marine fauna, including a large number of endemic species (Hwang et al., 2000a; Shao, 1998). As for zooplankton and its predominant taxon the Copepoda, Shih and Young (1995) have reviewed the published records of 431 copepod species from the marginal seas of China, including those surrounding Taiwan. The diversity of Taiwan's marine life is enriched by the transport of temperate and subtropical species from the north and tropical species from the south (Chiu and Chen, 1998; Chiu and Hsyu, 1994; Hwang et al., 2000b, 2004a, 2006; Hwang and Wong, 2005; Shih and Chiu, 1998).

Hwang and coworkers (Hwang et al., 2004a,b,c) suggest that oceanic waters of different origin that

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converge at Taiwan are the primary driving forces of enriched marine biodiversity in Taiwan (see also Liu et al., 2003; Wong et al., 2000). The NE monsoon is suggested to bring plankter during winter to the north and west of Taiwan; from the Bohai Sea, the Yellow Sea and the East China Sea (ECS) into the Taiwan Strait (TS) (Chen, 1992; Hwang and Wong, 2005; Hwang et al., 2006). The SW monsoon brings species from the South China Sea (SCS) to the south of Taiwan during summer (Chen, 1992; Hwang et al., 2000b, 2003, 2004a; Liu et al., 2003). To the east of Taiwan, the northward flow of the Kuroshio Current (KC) provides a continuous year-round addition to the marine biodiversity of eastern Taiwan that influences the oceanic regime all year round. To the west, along the TS and the southern edge of the ECS, the water circulation is strongly influenced by monsoon winds.

During the NE monsoon period in winter (September to April), the China Coastal Current (CCC) brings cold water from the Yellow Sea and the ECS into the TS (Lee and Chao, 2003; Liang et al., 2003; Liu et al., 2003; Tseng and Shen, 2003). Water circulation in the TS varies seasonally with changes in wind direction (Jan et al., 1995, 2002; Lee and Chao, 2003; Liang et al., 2003; Tseng and Shen, 2003).

A long-term multidisciplinary project of Kuroshio Edge Exchange Processes (KEEP) was launched in the 1990s to study influences of the KC on the physical, chemical and biological processes of the ECS and its surroundings (Liu et al., 2003; Wong et al., 2000). Data from physical oceanography indicate that the KC intrudes into both, the northern SCS and coastal waters of southern Taiwan via the Luzon Strait, particularly during winter (Jan et al., 1995, 2002). From late autumn to early spring (November to March) the NE monsoon drives water masses from the ECS along the China coast line towards the TS, resulting in the obstruction of the north-flowing KC at the Changyun Ridge. The KC flows over the Changyun Ridge and may impact the northern part of the TS only when the NE monsoon begins to subside in spring. The Luzon Strait, between Taiwan and the Philippines is the most important water passage connecting between the west Pacific KC and the northern SCS. We suppose that the Luzon Strait is an important waterway transporting marine fauna from the KC towards the northern SCS and coastal waters of southern Taiwan.

Zooplankton community composition can provide suitable indication for water mass movements that are otherwise characterized by parameters such as different temperature and salinities (Paffenhoefer and Flagg, 2002; Peterson and Keister, 2003). In Taiwan waters, such attempts are as yet restricted to short term studies on copepods (Hsieh et al., 2004; Hwang and Wong, 2005) and ichthyoplankton (Chiu and Chen, 1997; Chiu and Hsyu, 1994).

Several studies indicated that copepod assemblages in waters of Taiwan have been highly influenced by water masses from ocean currents (Hwang and Wong, 2005; Hwang et al., 2004a, 2006). Hwang and Wong (2005) used *Calanus sinicus* as a biological indicator to trace water movements. They suggested that during the NE monsoon that prevails in winter, *C. sinicus* gets transported from the Bohai Sea, Yellow Sea, and ECS into northern Taiwan waters and along the China coast southwards to the waters of Hong Kong.

Our study area located in the KBC, and the South China Sea Surface Current (SCSSC) is supposed to have a major impact on the abundance and diversity of biotic communities in this region (Hsieh et al., 2004; Hwang et al., 2000b, 2004b; Hwang and Wong, 2005; Lan et al., 2004; Lo et al., 2004b; Shih and Chiu, 1998).

Based on the results of previous studies, we propose and test the following two hypotheses here: (i) the effect of the Kuroshio Branch Current intrusion is substantial for copepod assemblages in the northern South China Sea, and (ii) the copepod composition in coastal areas of southern Taiwan is affected by South China Sea waters. We use data from 3 stations along 2 latitudinal transects in the northern South China Sea to test these hypotheses.

2. Materials and methods

2.1. Zooplankton sampling

Zooplankton samples were collected on board the Ocean Research Vessel I at 6 stations along the KC edge, the Luzon Strait, and the NSCS around the southern tip of Taiwan (Fig. 1). Sea water temperature and salinity were measured on board using SeaBird CTD probes. The study is based on plankton collections by the Taiwan Ocean Research Vessel I during the CR 734 cruise from the 12th to 23rd of October in 2004. Stations along two latitudinal transects were sampled from the northern SCS towards the KC (Fig. 1). These transects are along two latitudinal lines, 21.419 (°N) and 22.164 (°N) respectively. A western group of stations was situated in the NSCS and included stations A, S1, M1 (S1 and M1 are directly influenced by KC intrusion waters) and the KC that included stations S3, S4, S5. Latitude, longitude, sampling depths, and sample numbers of each station during the ORI CR-734 cruise are listed in Table 1. Zooplankton samples were collected down to 4500 m depth by oblique net tows with a modified Norpac zooplankton net (0.45 m mouth diameter, 200 μm mesh).