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Jellyfish assemblages are related to interplay waters in the southern east China Sea

Li-Chun Tseng [a], Chi Chou [b], Qing-Chao Chen [c], Jiang-Shiou Hwang [a,d,*]

[a] Institute of Marine Biology, National Taiwan Ocean University, Keelung, Taiwan
[b] Department of Pathology, Mackay Memorial Hospital, Danshuei District, New Taipei City, Taiwan
[c] South China Sea Institute of Oceanography, Academia Sinica, Guangzhou, China
[d] Department of Biomedical Science and Environmental Biology, Kaohsiung Medical University, Kaohsiung 80708, Taiwan

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ABSTRACT

Zooplankton communities are affected by spatial and temporal factors, as well as by general weather conditions, monsoons, and ocean currents. Present study examined the effects of typhoons, monsoons, and interplay waters on jellyfish assemblages in the complex hydrosystem in the coastal areas of the southern East China Sea. The species and composition of jellyfish and their seasonal succession in the coastal areas of northern Taiwan were investigated through 6 research cruises between October 2007 and January 2009. Among the samples obtained during these cruises, 23 jellyfish species from 2 classes, 7 orders, 13 families, and 19 genera were identified. The 3 most abundant jellyfish species were *Nausithoe punctata* (relative abundance, RA: 91.72%), *Aglaura hemistoma* (RA: 4.20%), and *Diphyes chamissonis* (RA: 1.13%). The species *A. hemistoma* exhibited the highest occurrence ratio (OR, 52.78%), and only this species was observed during all 6 research cruises. The abundance of *Corymorpha bigelowi* and *Lensia multicristata* correlated significantly and positively with seawater temperature, indicating that these species are brought to northeastern Taiwan by the warm Kuroshio Current. The formation of an *N. punctata* bloom yielded a density of 543.25 individuals/m^{-3} in October 2008, indicating that the jellyfish assemblage was influenced by a typhoon event and exhibited a clear pattern of seasonal succession. However, the interplay waters of the China Coastal Current and Kuroshio Current had a greater influence in shaping the jellyfish assemblage structure than did either typhoons or monsoons.

1. Introduction

The structure of jellyfish assemblages is affected by various environmental factors, such as physical processes (Yoon et al., 2008) and changes in hydrographic conditions (Lo et al., 2008, 2014), including spatial (López-López et al., 2013), temporal changes (Li et al., 2012, 2013), monsoons (Hsieh et al., 2013; Lo et al., 2014), typhoons (López-López et al., 2012), and inter-annual variation in jellyfish abundance and quantifying. These inter-annual and long-term changes are also important issues (Lynam et al. 2011). Thus, the composition of jellyfish assemblages can be used to monitor the environment, specifically because their diversity is sensitive to changes in hydrological characteristics (Chen, 1992; Lo et al., 2008; Dong et al., 2010; López-López et al., 2012).

Jellyfishes belong to a taxon of zooplankton with the largest body size. The body of a jellyfish is predominantly water (> 95%) with a low proportion of carbon (< 1%), enabling them to grow faster and larger than other species of zooplankton (Pitt et al., 2013). Because of their size, jellyfish play a crucial role in marine ecosystems in terms of transferring energy and material from small species of zooplankton to other species at the upper trophic level (Arai, 2005; Houghton et al., 2006). For example, larval fish (e.g., jack mackerel, *Trachurus japonicus*, Masuda et al., 2008), oceanic sea birds (e.g., gray-headed Albatross, *Thalassarche chrysostoma*, Catry et al., 2004), and sea turtles (e.g., leatherback turtle, *Dermochelys coriacea*, Houghton et al., 2006) are predators of jellyfish. Moreover, jellyfish consume fish roe and larvae, thus having a marked influence on fishery production and ecological structure (Greve, 1994; Yan et al., 2004; Brotz et al., 2012). In the East China Sea (ECS), jellyfish play a key role among zooplankton communities (Tseng et al., 2012a, 2012b). Several jellyfish species are an essential form of seafood with a high commodity value in China (Hsieh et al., 2001; Purcell et al., 2007). Recently, the abundance of giant jellyfish (Kawahara et al., 2006; Uye, 2008, 2010; Yoon et al., 2008) and macrojellyfish (Yan et al., 2004; Cheng et al., 2005) has increased in east Asian waters, including the ECS. Jellyfish blooms have caused considerable financial loss to fisheries (Yan et al.,

* Corresponding author at: Institute of Marine Biology National Taiwan Ocean University Keelung, 202, Taiwan. Fax: +886 2 24629464.
E-mail address: jshwang@mail.ntou.edu.tw (J.-S. Hwang).

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2004; Uye, 2008; Dong et al., 2010; Nastav et al., 2013), as well as damage the fishing equipment (Yan et al., 2004; Brotz et al., 2012) and the water intakes of power plants situated in coastal areas (Henager et al., 1985; Masilamani et al., 2000). Jellyfishes are characteristically sensitive to environmental change (Cheng et al., 2005). Therefore, the dynamic of jellyfish assemblages serves as an indicator of the water masses movements (Cheng et al., 2005), global warming (Purcell et al., 2007; Richardson et al., 2009), and eutrophication (Mills, 2001; Liu and Diamond, 2005). Thus, monitoring changes in the structure of jellyfish assemblages is a critical issue worldwide.

The southern and southeastern ECS are complex hydrographic systems (Hwang et al., 2006; Tseng et al., 2013). Two major annual water currents influencing these areas are the China Coastal Current (CCC), which brings cool water from the Yellow Sea and the Bo-Hai Sea, and the Kuroshio Current (KC), which brings warm water from eastern Taiwan. The interplay between these 2 currents creates a dynamic environment supporting diverse marine biota in the southern ECS (Hwang et al., 2006; Chou et al., 2012; Tseng et al., 2013). Annually, the climatic influence of the northeast (NE) monsoon prevails during April–September, and that of the southwest (SW) monsoon prevails during October–March. Typhoons occur near Taiwan from June to September during the summer–autumn period. In the western Pacific Ocean, global warming has led to changes in the marine environment, and the frequency and power of typhoons in the area have increased (Xu et al., 2011). Thus, studying the effects of typhoons on zooplankton communities has gained importance. Previous studies have indicated that the southern ECS is a suitable area for evaluating how monsoons, typhoons, and interplay waters affect the zooplankton community.

Brotz et al. (2012) reported the population trends of jellyfish species and revealed a marked increase in the number of invasive jellyfish species in the region of the western Pacific Ocean. Currently, the effects of such complex environmental factors on jellyfish assemblages in the coastal areas of the southern ECS remain unclear. Therefore, present study was conducted to collect samples from different environments of the southern ECS to evaluate the effects of monsoons, typhoons, and interplay waters on the diversity and assemblage structure of jellyfish (major class Hydrozoa and Scyphozoa) to provide baseline data in northern Taiwan.

2. Material and methods

2.1. Study area and field sampling

Present study is the first to investigate the effects of the seasonal successions of jellyfish on the abundance and composition in northern Taiwan. Six sampling stations were selected: one in Shen-Aou Bay and 5 in Fan-Zai-Aou Bay in northeastern Taiwan, located near the southern edge of the ECS in the vicinity of Keelung City, Taiwan, between 25°07′–25°09′N and 121°48′–121°50′E (Table 1 and Fig. 1).

Six sampling cruises were conducted between October 2007 and March 2009. Prior to conducting the plankton tow, the onboard salinity and temperature were measured at all of the selected stations. Zooplankton samples were collected using surface net tows (0–5 m) with a standard North Pacific zooplankton net (mouth diameter 45 cm, length 1.8 m, and mesh size 333 μm) for approximately 10 min. at a vessel speed of 2 knots. A flowmeter (Hydrobios, Germany) mounted at the center of the net opening. Following on-board retrieval, the samples were immediately preserved in 5% buffered seawater formaldehyde solution.

Table 1
Location of the sampling stations of the 6 research cruises in Northern Taiwan.

Station	Latitude (° N)	Longitude (° E)
St01	25°7.44′	121°49.18′
St02	25°8.15′	121°49.27′
St03	25°8.70′	121°48.45′
St04	25°8.14′	121°49.33′
St05	25°8.43′	121°48.24′
St06	25°8.22′	121°49.30′

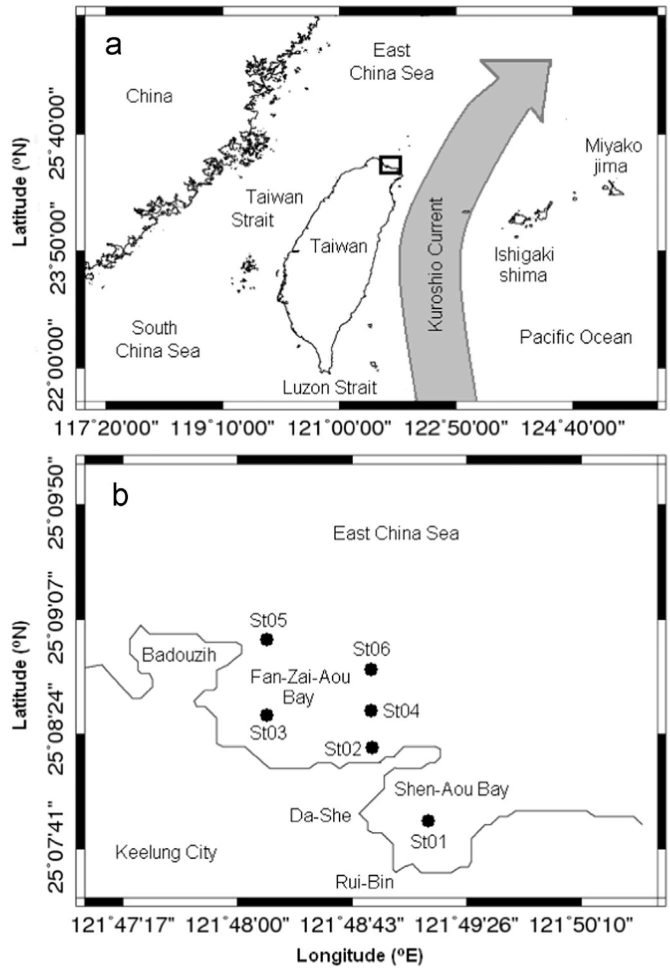

Fig. 1. Map of the research area (a) and location of the sampling stations (b) in Northeastern Taiwan and the Southern East China Sea from October 2007 to March 2009.

2.2. Identification and enumeration of zooplankton

In the laboratory, a Folsom splitter was used to split the zooplankton samples into subsamples until each subsample contained approximately 300 specimens. Jellyfish were categorized and identified at the species level according to the keys proposed by Yamaji (1996) and Chihara and Murano (1997). The number of jellyfish belonging to each taxon was recorded as individuals/m^{-3} (ind/m^{-3}). A jellyfish (siphonophores) was included in the sample whenever its nectocalyx (anterior nectophore) was present. Jellyfish that were broken to pieces were ignored during the identification process.

2.3. Statistical analysis

To evaluate similar jellyfish distribution patterns, the data of 36 samples comprising 23 jellyfish species were analyzed using