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Introduction

Response of Biogeochemical Cycles and Ecosystem in the East China Sea to Multi-stressors

This editorial article introduces the research progress of IMBER-China Study on "Sustainability of Marine Ecosystem Production under Multi-stressors and Adaptive Management" (MEcoPAM), funded by the Ministry of Science and Technology of China (MoST-China No. 2011CB409800). There are 12 research articles in this Special Issue of Deep-Sea Research II on the "East China Sea", which provide the reader with snapshots of "Impact of Multi-stressors on the Structure and Function of Marine Ecosystems", one of research foci of MEcoPAM in the period of 2011–2015.

Globally, continental margins play an important role in connecting land and ocean, and with strong interactions with atmosphere. This is also an area that has been extensively affected by human being activities particularly since late 18th Century. The future development of continental margins has many unforeseen issues given the complex mechanisms that link between external forcings and ecosystem functions (Glavovic et al., 2015).

The East China Sea is located in the Northwest Pacific Ocean and hugged by the China mainland in the west, the western boundary current, Kuroshio, flows through along the deep Okinawa Trough in the east; ca. 60% of surface area of the East China Sea is represented by a wide shelf (Fig. 1). The East China Sea is connected to the Yellow Sea in the north and the South China Sea through shallow Taiwan Strait.

This region is affected by the East Asian monsoons with dominance of northeasterly winds in winter, and the wind-field turns to be southwesterly in summer. Circulation pattern in the East China Sea is dominated by the yearly round northward flow of Kuroshio, warm and saline water from Taiwan Strait, as well as the influx from various land-sources, notably the Changjiang (Table 1). The influence of Kuroshio on the East China Sea Shelf is mainly through the incursion of sub-surface water in the northeast of Taiwan, meso-scale processes (e.g. eddies and front waves) in the area of shelf slope. Waters from Taiwan Strait affect the hydrography of middle part of the East China Sea Shelf in the upper layers owing to its shallow water depth (i.e. 60–80 m). In summer, the dispersal of Changjiang Diluted Waters (CDW) covers a broad area of shelf and can extend as far as to the Cheju Island. In winter water discharged from Changjiang is considerably reduced, and the effluent off the river mouth is incorporated in the Zhe-Min Coastal Current that flows southward along the east coast of main land of China, stimulated by northerly winds.

From ecosystem point of view, the East China Sea is considered as overstressed because of syndromes that can be related to anthropogenic perturbations, particularly in marginal waters, such as overfishing, pollution, eutrophication and seasonal hypoxia. The future of biodiversity and function of ecosystems of the East China Sea, as well as the services to the human society, depend on how well we understand the structure of ecosystem, the interactions with biogeochemistry, and its change in response to the external forcings, such as climate change and human being activities, which in turn will provide knowledge to the adaptive management at ecosystem-based-level (Fig. 2). Obviously, the sound scientific knowledge that supports the adaptive management requires integrated research activities from hydrodynamics to fishery with cross-link to social and economic dimensions.

In the period of 2011–2015, we have a national research project on "Sustainability of Marine Ecosystem Production under Multi-stressors and Adaptive Management" (MEcoPAM), funded by the Ministry of Science and Technology of China (MoST-China No. 2011CB409800). MEcoPAM has five cross-linked research modules as below:

SP1-Biogeochemical Dynamics of Marine Ecosystems
SP2-Nutrient Cycles and Response to Multi-stressors
SP3-Response of the Hydrodynamics to Multi-stressors and Its Impact on the Supply of Nutrients
SP4-Microbial Loop and Coupling with Biogeochemical Cycles
SP5-Feedback Mechanisms of Ecosystem Structure and Function to Climate Change and Human Activities

MEcoPAM examines physical, chemical, biological and fishery aspects of the East China Sea, towards the understanding of ecosystem function under the multiple and combined natural and anthropogenic forcings and the impact on the human society through a multidisciplinary approach (Fig. 3).

Later in 2013, the MEcoPAM was endorsed by SCOR/IGBP-IMBER Scientific Steering Committee as a national contribution to the Integrated Marine Biogeochemistry and Ecosystem Research of China (i.e. IMBER-China) (http://www.imber.info/index.php/Sci

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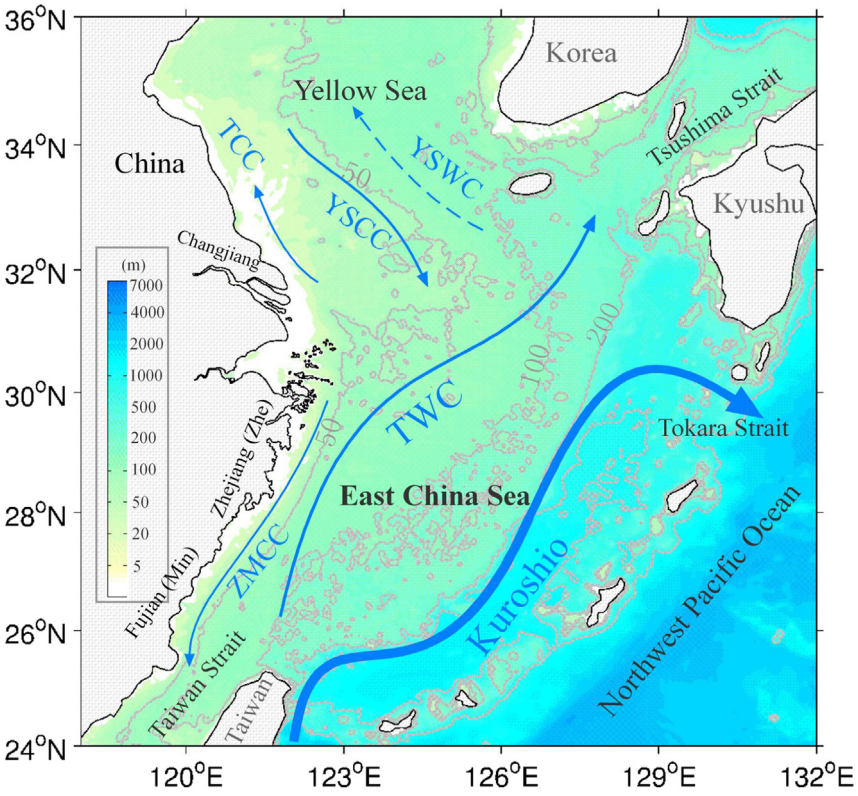

Fig. 1. Geographic location of the East China Sea with bathymetry and major components of circulation. TWC, ZMCC, TCC, YSCC and YSWC represent Taiwan Warm Current, Zhe-Min Coastal Current, Tidal-induced Coastal Current, Yellow Sea Coastal Current and Yellow Sea Warm Current, respectively.

Table 1
Major characters of circulation and the chemical property of different waters in the East China Sea.

Water sources	Characters
Kuroshio	Surface water is depleted in nutrients, but sub-surface water is nutrient enriched, with high temperature and salinity
Taiwan Strait Warm Water	High temperature, salinity and low nutrients
Zhe-Min Coastal Current	Turbid waters in the coastal area in winter, with low temperature and moderate nutrient levels
Changjiang Diluted Water	High nutrient concentration and low salinity (< 30), temperature is high in summer but low in winter

ence/Endorsed-Projects/MEcoPAM-June-2013). Within MEcoPAM, six cruises were carried out across the East China Sea, from the Changjiang Estuary eastwards to the Okinawa Trough and from Taiwan Strait northward to the Southern Yellow Sea (Table 2).

With limited space of this introductive manuscript, it is beyond the ability of steering group of MEcoPAM to reach up a synthesis of how the ecosystem functions of marginal seas respond to the combined external forcings, rather the Special Issue of Deep-Sea Research II, illustrate results of "Impact of Multi-stressors on the Structure and Function of Marine Ecosystems" using the East China Sea as target area for an integrated and multi-disciplinary oceanographic study, which is one of research foci of IMBER-China strategy and needs coupling of five research modules (i.e. SP1–SP5) in implementation shown in Fig. 3. In the following paragraphs, research articles in this special issue provide scientific community with a snapshot of success and lessons learnt from MEcoPAM in 2011–2015.

The current on the shelf of the western East China Sea is dominated by its alongshore component and is primarily along local isobaths with the constraint of bottom bathymetry. In contrast, the cross-shelf current is rather weak and less is known regarding its spatial and temporal variations. However, the cross-shelf current plays a fundamental role in material transport across the shelf and it is a focus of MEcoPAM. Huang et al. (2016a) used the four ADCPs data along a cross-shelf section in the western part of East China Sea to investigate the winter circulation and its response to wind field. The analysis of data obtained revealed the coherent spatial structure and temporal variation of currents, in particular the intrinsically coupled synoptic variation of the weak cross-shore currents to the apparent alongshore currents. That is, the SE offshore cross-shore flow is associated with the NE alongshore current, and the NW onshore cross-shore flow is associated with the SW alongshore current. The synoptic variation of current is modified by the wind-induced sea level difference and is modified by the surface and bottom frictions.

In Gan et al. (2016), bioavailable dissolved organic carbon (DOC) in the East China Sea was quantified and proved to be a significant factor in regulating carbon cycle. EEMs (Excitation-emission-matrix Spectra) is used to evaluate the bioavailability of DOC, and accumulation of refractory organic matter during degradation of bioavailable DOC was examined by EEMs, which sheds lights on the important function of microbial loop in the carbon cycle at regional scale.

Based on the cruise observations in May 2011, Ren et al. (2016) were able to identify the transformation of chemical speciation for arsenic (i.e. from As (V) to As (III)) in the surface waters of East China Sea through mechanisms like biological mediation. In the East China Sea behavior of antimony is rather conservative regardless of other chemical properties of different water masses. Using the existing knowledge a preliminary box model was