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The status of coastal oceanography in heavily impacted Yellow and East China Sea: Past trends, progress, and possible futures

Xiao Hua Wang [a, *], Yang-Ki Cho [b], Xinyu Guo [c], Chau-Ron Wu [d], Junliang Zhou [e]

[a] The Sino-Australian Research Centre for Coastal Management, the University of New South Wales, Canberra, ACT 2610, Australia
[b] School of Earth and Environmental Sciences/Research Institute of Oceanography, Seoul National University, Seoul 151-742, Republic of Korea
[c] Center for Marine Environmental Studies, Ehime University, Japan
[d] National Taiwan Normal University, Taipei, Taiwan
[e] State Key Laboratory of Estuarine and Coastal Research, East China Normal University, Shanghai 200062, China

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ABSTRACT

Coastal environments are a key location for transport, commercial, residential and defence infrastructure, and have provided conditions suitable for economic growth. They also fulfil important cultural, recreational and aesthetic needs; have intrinsic ecosystem service values; and provide essential biogeochemical functions such as primary productivity, nutrient cycling and water filtration. The rapid expansion in economic development and anticipated growth of the population in the coastal zones along the Yellow and East China Sea basin has placed this region under intense multiple stresses. Here we aim to: 1) synthesize the new knowledge/science in coastal oceanography since 2010 within the context of the scientific literature published in English; 2) report on a citation analysis that assesses whether new research topics have emerged and integrated over time, indicate the location of modelling and field-based studies; and 3) suggest where the new research should develop for heavily impacted estuaries and coastal seas of East Asia. The conclusions of the synthesis include: 1) China has emerged as a dominant force in the region in producing scientific literature in coastal oceanography, although the area of publications has shifted from its traditional fields such as physical oceanography; 2) there has been an increasing number of publications with cross-disciplinary themes between physical oceanography and other fields of the biological, chemical, and geological disciplines, but vigorous and systematic funding mechanisms are still lacking to ensure the viability of large scale multi-disciplinary teams and projects in order to support trans-disciplinary research and newly emerging fields; 3) coastal oceanography is responding to new challenges, with many papers studying the impacts of human activities on marine environment and ecology, but so far very few studying management and conservation strategies or offering policy solutions.

1. Introduction

The environmental degradation of the waters of heavily populated coasts such as the Yellow and East China Sea (Fig. 1) is particularly serious because of the multiple environmental pressures facing these regions from rapid growth, coastal erosion, land reclamation, dredging, increased navigation, oil and gas infrastructure development, and sediment/nutrient run-off due to increased human activity in these catchment areas (Dong et al., 2010; Liu et al., 2010; Ding et al., 2011; Hu et al., 2011; Song et al., 2013; Song and Wang, 2013; Zhou et al., 2014; Gao et al., 2014a, 2014b; Chen et al., 2014). Ineffectual coastal management including the lack of linkages between science and policy often escalate these environmental problems (Mee, 2012). Marine environmental conservation and integrated coastal zone management (ICZM) require research that integrates science with economic and social changes beyond the scope of current management regimes to assist in delivering more sustainable development outcomes (Wang et al., 2011b).

This synthesis follows the Special Issue (SI) with its theme: "Impact on coasts and their ecosystems in the Yellow and East China Sea by intensive anthropogenic activities". The contributors to this SI are from countries/region of the Yellow and East China Sea including mainland China (China hereafter), Korea,

* Corresponding author.
E-mail address: hua.wang@adfa.edu.au (X.H. Wang).

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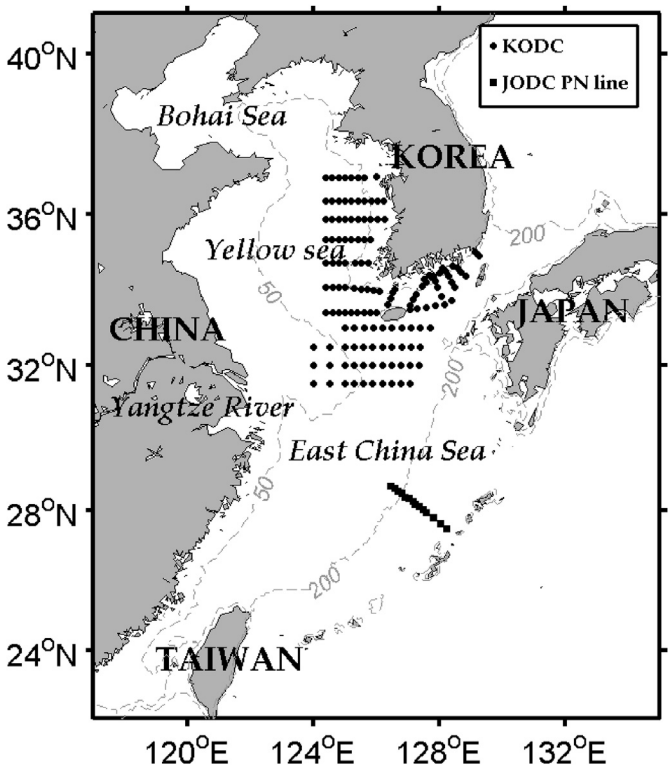

Fig. 1. Map of the Yellow and East China Sea with the long term hydrographic observation stations and PN line taken by National Fisheries Research and Development Institute, Korea, and the Japan Meteorological Agency, respectively. The observations are available from the Korea Oceanographic Data Center (KODC) and the Japan Oceanographic Data Center (JODC), respectively.

Japan and Taiwan. The SI aims to examine and document the physical and ecological impacts and the biogeochemical evolution and mechanisms of the coasts in the Yellow and East China Sea region due to intensive human activities and their resultant effects on the coastal ecosystem structures and functions. The SI assesses the influences of human activities on the environmental degradation and sustainable use of the marine resources in these environments; probes into the possible scientific approaches to manage and recover coastal ecological functions; reports whether the discipline has responded to on-going and new issues (such as climate change and eutrophication) and consequently has developed new directions of research. To this end, the paper aims to: 1) synthesize the new knowledge/science since 2010 within the context of the scientific literature published in English; 2) report on a citation analysis that assesses whether new research topics have emerged and integrated over time, indicate the location of modelling and field-based studies; and 3) make suggestions where the new research should develop for heavily impacted estuaries and coastal seas of East Asia.

The papers reviewed were indexed by the *Oceanic Abstracts*, which focuses on worldwide literature pertaining to the marine and brackish-water environment. We culled papers that were not in English even though they had English titles and abstracts listed within the database. We acknowledge the limitation of using one single database which may have led to a non-exhaustive search of entire literature available. However, a total of 670 papers from mainstream English journals reviewed here do represent a snapshot of the current status of coastal oceanography research for the heavily impacted Yellow and East China Sea region from 2010 to date.

2. A historical perspective

2.1. China

Studies of the Yellow and East China Sea during the 1980s and 1990s appear to be dominated by physical oceanography with a particular focus on hydrography and circulation dynamics using in-situ observations, and simple numerical models addressing specific mechanisms (e.g. Su, 1998). In this last decade, the Chinese scientific community has enjoyed a rapid rise in research and development funding. A conservative estimate suggests an investment in the order of CNY300 million (US$50 million, Chen, D.K., personal communication) per year in oceanography/marine science research through major funding schemes such as '973' (Ministry of Science and Technology) and NSFC (National Natural Science Foundation of China). NSFC project management reports (e.g. Ren et al., 2014) suggest that NSFC alone has provided an annual funding of CNY138 million (US$23 million) for marine and polar sciences averaged over a period from 2007 to 2014. This funding growth has been further coupled by an aggressive expansion of oceanography departments and schools among its universities and thus numbers of graduate students. As a result, among its regional neighbours in East Asia, China has published a total of 386 journal articles concerning the Yellow and East China Sea region, the largest number indexed by *Oceanic Abstracts* since 2010 (Table 1). Furthermore, it has boasted an averaged 8% per annum growth in the number of publications on the Yellow and East China Sea region between 2010 and 2014 (Fig. 2), again the fastest growth rate in the region.

Within this period, there are a limited number of review papers including 'Integrated management of nutrients from the watershed to coast in the subtropical region' by Chen and Hong (2012); 'Pollution status of the Bohai Sea: An overview of the environmental quality assessment related trace metals' by Gao et al. (2014b); and 'Marine renewable energy in China: Current status and perspectives' by Zhang et al. (2014b). A special issue on 'Dynamics of Chinese muddy coasts and estuaries' (Wang et al., 2011a) includes a collection of ten papers as case studies of the Changjiang (Yangtze River), Huanghe (Yellow River) and Zhujiang (Pearl River) estuaries, and the Chinese muddy coasts in the Bohai, Yellow, East China and South China Seas. These papers represent the recent advancement in Chinese estuarine and coastal research during the 2000s. A more geographically focused review can be found by Hong et al. (2011) who synthesized the physical, biogeochemical processes and ecosystem dynamics in the Taiwan Strait, and these processes' interconnectivity with El Niño-Southern Oscillation (ENSO) and interannual variability.

In biogeochemistry, extensive research has been conducted on nutrient dynamics (Guo et al., 2012; Hung et al., 2013; Chen et al., 2015), eutrophication and associated algal and jellyfish blooms (Dong et al., 2010; Cui et al., 2012; Huo et al., 2013; Dai et al., 2014), and molecular biology of bloom formation. Coastal pollution is a historical research area with a focus on heavy metals (Jiang et al., 2014), which has been enriched by the more recent efforts in organic pollution research, including pesticides, hydrocarbons (Deng et al., 2013; Hu et al., 2014), chlorinated compounds (Hu et al., 2011; Duan et al., 2013), polybrominated diphenyl ethers (Fan et al., 2014), and the emerging pharmaceuticals and personal care products (Yan et al., 2013; Zhang et al., 2013).

Table 1
The number of publications by countries/region between 2010 and 2015 focussing on the Yellow and East China Sea region.

China	Korea	Japan	Taiwan
393	119	39	117

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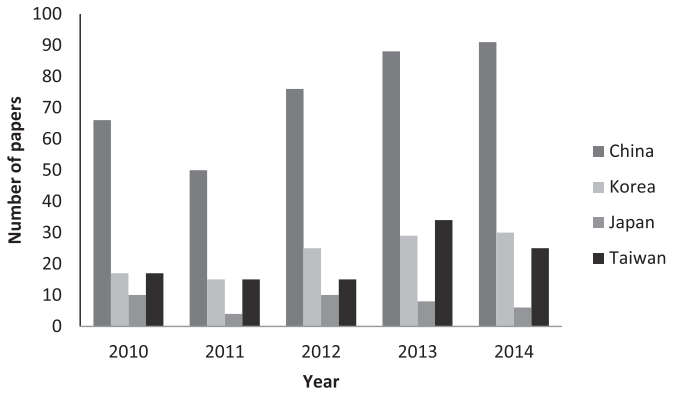

Fig. 2. Number of publications by the countries/region between 2010 and 2014 indexed in *Oceanic Abstracts* focussing on the Yellow and East China Sea region.

2.2. Korea

Reclamation, coastal erosion, red tides and pollution have been challenging issues for the coastal area of Korea. The Ministry of Oceans and Fisheries, Korea was established in 1996 to meet the nation's increasing demand on ocean environments, construction of ports, maritime shipping, and fisheries.

About 2400 km^2 was reclaimed for agricultural and urban areas in Korea from 1970 to 2008 (Koh and de Jonge, 2014). Sea dykes have been constructed to prevent intrusion of seawater into most estuaries of the Korean peninsula. Sea dykes have resulted in weak tidal currents, strong stratification and sea level changes in the estuaries (Byun et al., 2004; Cho et al., 2004).

Geologists have shown an interest in studying sediment transport along the coast of the Yellow Sea. The movements of sediments in the Yellow Sea are caused by the winds and waves in the winter monsoon (Lee, 2014).

A total of 1330 red tide events occurred along the Korean coasts from 1972 to 2011. The annual red tide events dramatically increased from 1 to 9 in 1970s to 15–35 in 1980s. The annual red tide events increased to 25–109 in 1990s but decreased to 12–83 in 2000s (Lee et al., 2013). It is noticeable that the red tides have mostly occurred offshore in the south of Korea rather than in the estuaries or bays. The Changjiang diluted water might play some role in occurrence of the red tides in the south sea of Korea (Lee, 2008). The recent rapid increase of dissolved inorganic nitrogen in the coast of Korea has been attributed to increasing dissolved inorganic nitrogen in the Changjiang River (Kim et al., 2013b).

The MV *Hebei Spirit* accident in December 2007 resulted in the largest oil spill ever recorded in the Yellow Sea (Kim et al., 2013a). About 10,500 metric tons of crude oil was spilt into the sea. As a result, more than 70 km of coastline was polluted. After the accident, oil spills were a matter of urgent concern for research in Korea.

2.3. Japan

Studies on the East China Sea and Yellow Sea in Japan have a long history. Regular monitoring (4 times in a year) of physical, chemical, and biological variables have been conducted by the Japan Meteorological Agency for more than 50 years along a section (PN line, Fig. 1) from the Kuroshio to the offshore area of Changjiang estuary (Hinata, 1996; Guo et al., 2012; Lui et al., 2014). In addition, other regular observations have been led by the Fisheries Research Agency and other agencies in Japan for more than 50 years along a section at 31.5°N (Siswanto et al., 2008).

Because of their important role in fisheries and marine environments, the East China Sea and the Yellow Sea are two important study fields for oceanographers in Japan. Based on field observations and numerical models, Japanese scientists have published numerous papers on the East China Sea and the Yellow Sea in last century with most of them included in two review papers (Ichikawa and Beardsley, 2002; Isobe, 2008).

The 2011 earthquake off the Pacific coast of Tōhoku forced most funding and oceanographers in Japan to shift to the issues related to this disaster. Although there are still some projects on the East China Sea based on personal interests and funding from the Japan Society for the Promotion of Science (JSPS), there is no national project designed for the East China Sea. Consequently, there has been a reduction in the number of papers published by Japanese scientists from the studies on the East China Sea. As an apparent example, there were only 39 papers since 2010 from Japan in the *Oceanic Abstracts* database searches concerning issues of the Yellow and East China Sea. That was the smallest number amongst the papers for the region from China, Korea, Japan and Taiwan (Table 1).

2.4. Taiwan

Taiwan is blessed to be surrounded by the rich natural resources of the ocean. Continuous investigations and studies of the East China Sea have been conducted in the past decades. However, most investigations have been individual endeavours, and lacked linkages amongst studies. During 1989–2000, an integrated project, the Kuroshio Edge Exchange Processes (KEEP), made significant advances in biogeochemical and hydrodynamic processes in the East China Sea (Liu et al., 2003). Researchers have focused on in-situ observations rather than numerical modelling.

Following KEEP, the Long-term Observation and Research of the East China Sea (LORECS), another inter-disciplinary project which was initiated in 2000 and completed in 2012, surveyed routinely the East China Sea shelf between Changjiang Estuary and Taiwan. The achievements from this project have been fruitful and have improved the knowledge of the ocean dynamics and biogeochemistry in the East China Sea. Modelling efforts were also involved in the project. The numerical models developed from the project have been used not only for process studies to uncover dynamics and mechanisms, but also (in conjunction with field data) to help analyze and explain observations for ocean predictions.

3. Main disciplines

3.1. China

The papers searched from the *Oceanic Abstracts* database were divided into traditional disciplines of physical oceanography, marine geology, biology and chemistry (Table 2). Physical oceanography had the least number of papers (23); whereas marine chemistry had the largest number (120). Marine ecology as an emerging and environmental focused discipline had a total of 88 papers. There were 36 papers on cross-disciplinary studies containing at least one biological, chemical or geological subdisciplinary field.

Table 2
The number of publications by discipline between 2010 and 2015 focussing on the Yellow and East China Sea region.

	China	Korea	Japan	Taiwan
Physical oceanography	23	54	16	52
Marine geology	46	5	0	8
Marine chemistry	120	32	9	42
Marine biology	44	36	8	33
Marine ecology	88	48	0	18

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For biogeochemical papers, trace elements, heavy metals, nutrients and sediments are still being widely published among the marine chemistry and environmental researchers. Increasing numbers of such environmental papers deal with coastal pollution from organic pollutants such as pesticides, polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), organochloride pesticides, polybrominated diphenyl ethers (PBDEs), and pharmaceuticals. This is a strong reflection of the increasing levels of human impacts on coastal seas, the rapid development and availability of highly sensitive analytical facilities in the Asia Pacific countries, and the rapid rise in research funding in the region.

From above, it can be observed that marine chemistry has become a dominant discipline in coastal oceanography. Marine ecology has emerged strongly covering the study areas including ecosystem dynamics (50), phytoplankton/red tides/green tides (39). Cross-disciplinary study involving biogeochemistry has also become a feature in physical process papers. Interestingly, physical oceanography was a strong traditional area in the studies of China Seas (Su, 1998), but it has now become the smallest discipline with most of the papers focussing on circulation and currents (17), less than its counterparts from Korea (54) and Taiwan (52).

3.2. Korea

The papers published by Korean scientists were grouped into the disciplines of physical oceanography, marine geology, marine biology, and marine chemistry. The discipline of physical oceanography had the largest number of published papers (54), whereas the marine geology discipline had the least numbers published (23). Marine ecology and the marine chemistry discipline had a total of 48 and 32 papers, respectively.

The major research areas of physical oceanography were circulation (21), climate change (17) and river plume (9) based on the published papers. Algae bloom was a dominant study area in marine biology on the basis of 13 published papers.

Marine biology has wide range of study areas including primary production, taxonomy, biomass, feeding mechanism, and jelly fish. Most papers were on pollution (23) in marine chemistry, and sedimentation (16) in marine geology, respectively.

3.3. Japan

Among the 39 papers from Japan, physical oceanography had the largest number (16), while marine chemistry and marine biology had almost the same number (9 and 8, respectively). Collaboration between physical oceanography and marine chemistry as well as that between physical oceanography and marine biology contributed to two and three papers, respectively.

The topics given by papers from physical oceanography were circulation (8), ocean mixing (4), air-sea interaction (4). The papers for air-sea interaction in the East China Sea were a part of a national project focussing on the coupled ocean atmosphere variability over Monsoonal Asia (http://www.atmos.rcast.u-tokyo.ac.jp/hotspot/index_eng.html).

3.4. Taiwan

There were 117 papers published by scientists from Taiwan. Similar to Korean and Japanese scientists, physical oceanography had the largest number (52), while marine geology the least number (8). There were also 28 papers on cross-disciplinary studies between physical oceanography and other fields of the biological, chemical or geological disciplines.

Circulation was the dominant sub-discipline for physical oceanography. In addition, the other sub-disciplines of physical oceanography included tides (9), river plume (8), and waves (4). The sub-disciplines of ecology included phytoplankton (15), ecosystem (12), and dynamics (4).

4. Locations of research

4.1. China

The research location was grouped by their geographical orientation. Most of papers were on the Yellow Sea (255), followed by the East China Sea (229), and Bohai Sea (47). In the presence of several large rivers (such as rivers of Changjiang, Huanghe and Zhujiang) that deliver a large amount of freshwater, nutrients and sediments to the Yellow and East China Sea, China has one of the most turbid and eutrophic marine environment in its coastal seas and estuaries. Despite this, there were only 82 papers researching ‘estuaries’ and ‘bays’. This number is only one third of the publications that studied the Yellow Sea.

4.2. Korea

The most researched location was the Yellow Sea (86) and the East China Sea (51). The East China Sea includes the south sea of Korea. Some papers included both the Yellow Sea and the East China Sea simultaneously. The circulation of the Yellow Sea is the traditional study area. Tidal flats and their reclamation has been an emerging issue for the Yellow Sea.

4.3. Japan

Due to the geographical limitation, most research in Japan is naturally on the East China Sea. Collaboration with scientists from other countries contributed two papers on the Yellow Sea and one paper on estuaries.

4.4. Taiwan

The most dominant research area for Taiwan scientists is the East China Sea. Dependent on the distance from Taiwan, most of the research focused on the East China Sea (101), followed by the Yellow Sea (22), and then the Bohai Sea (5). In addition, there were 25 papers researching estuaries or bays.

5. Research collaboration

5.1. China

The China–Italy collaboration was established to develop and improve the basic research in the field. Italian and Chinese researchers have shared common interests on many issues such as studying the conditions and characteristics of the China, Adriatic and Ionian seas.

The China–Australia collaboration was established via the Sino-Australian Research Centre for Coastal Management (SARCCM). SARCCM is a Research Centre of the University of New South Wales (UNSW) Australia with a multidisciplinary/multi-faculty focus. It has worked closely with the Ocean University of China in research on coastal science and management. SARCCM was launched at UNSW in 2010.

In 2009, China and Russia established a partnership to build an international marine ecological safety monitoring demonstration station in Qingdao, China. This station was designed as a base for monitoring the marine ecological environment and carrying out research in the Yellow Sea.

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5.2. Korea

There is little cooperation of Korea in this study area except with China. The China–Korea Joint Ocean Research Centre funded by the governments of China and Korea was established in 1995 to enhance exchange and cooperation on ocean science and environment in Qingdao, China.

Six hydrographic cruises were taken by the cooperation between the First Institute of Oceanography, China, and the Korea Ocean Research and Development Institute, Korea, covering the whole Yellow Sea from 1996 to 1998. These observations enabled a better understanding of the hydrography and its seasonal evolution.

Two regional workshops on Asian Marginal Seas including the Yellow and the East China Sea have been held every two years. PAMS (Pacific–Asian Marginal Seas) began in 1981 as a regional meeting on the North Pacific Ocean and its other marginal seas. The PEACE (Program of the East Asian Cooperative Experiments) workshop has provided opportunities for international cooperative research on regional oceanography in the East Asian Sea.

Despite strong Korea-China collaboration in 1990s, there are currently no collaborative projects on-going between these two nations.

5.3. Japan

There were two important joint projects between Japan and China on the Kuroshio and the East China Sea in the last century. One is the Japan–China Joint Research Programme on the Kuroshio (JRK) from 1977 to 1998 while the other is Material Cycling in the East China Sea-MASFLEX Program from 1992 to 1997. The understanding from the former project on the physical aspect of the Kuroshio and its influences on the East China Sea has been summarized by Su et al. (1990) and Guan and Fang (2006). The latter focuses on the biogeochemical cycles of carbon, nitrogen and other substances in the East China Sea and its connection to global change. A special issue from this project has been published by Japanese scientists (Tsunogai et al., 2003).

The bilateral cooperation between Japan and China in recent years has been shifted from fundamental research to environmental and fisheries issues in the East China Sea. One example is the migration of the *Nemopilema nomurai* from the East China Sea to Japan Sea (Uye, personal communication).

5.4. Taiwan

Taiwan-sponsored participation in the World Ocean Circulation Experiment (WOCE) deployed the moored current meter array east of Taiwan (PCM-1) for the period of September 1994 to May 1996. This moored data has been used to derive estimates of the Kuroshio transport at the entrance to the East China Sea.

Recently, a series of Taiwan-USA joint projects, such as the Quantifying, Predicting, and Exploiting Uncertainty (QPE) Project, were established to explore the variability, dynamics, and acoustics of the Kuroshio, East China Sea, and South China Sea.

6. Development of research methodology

6.1. China

Three areas of research methodology have been examined. In-situ observation appears to dominate the methodology with a total of 161 papers. There were 88 papers using Satellite/remote sensing. Satellite imageries from space-borne sensors such as MODIS, SeaWIFS, AVHRR, SAR and QuickScat were the most commonly used to study topics such as suspended particular matters, harmful algae blooms, water mass characteristics, and ocean circulation (e.g. Cui et al., 2012). Papers using modelling approaches remain popular and there were 27 papers involved in numerical studies using community ocean models such as MOM (Modular Ocean Model) and ROMS (Regional Ocean Modeling System).

6.2. Korea

Observations were the dominant methodology. There were 72 papers published on observational data. Modelling (26) and satellite/remote sensing (23) papers are increasing with time. Hydrographic observation has been bimonthly conducted by National Fisheries Research and Development Institute (NFRDI), Korea since 1960. The region of this observation is shown in Fig. 1. A nationwide red tide monitoring network was started in 1995. This data is valuable to the understanding of long-term changes in the Yellow and East China Sea. Quantitative measurements of sediment transport were attempted in Korea with the introduction of a self-contained benthic tripod (Lee, 2014). Hydrodynamic parameters including water depth, current velocities, waves, suspended sediment concentrations and bed-level fluctuations were recorded in a time-series. Heat flux across the surface of the macro tidal flat was estimated based on in-situ observations on a tidal flat (Kim and Cho, 2009).

The number of papers using satellite data has greatly increased due to its free accessibility. Remotely sensed sea surface temperature (SST) by satellites was compared with in-situ SST in the seas around the Korean Peninsula from 1981 to 2013 (e.g. Park et al., 2015). Comparison with in-situ SST shows that the satellite SST in the Yellow Sea has a warm bias in early 1980s and a cold bias in early 2010s (Kwak et al., 2015). The GOCI (Geostationary Ocean Color Imager) was launched to observe ocean-color around the Korean Peninsula in June 2010. The spatial resolution of the GOCI is about 500 m and the range of the target area is about 2500 km × 2500 km centered on Korean Peninsula. It takes eight images per day. The high frequency resolution images of the GOCI have enabled scientists to resolve intra-diurnal variation of suspended sediment, chlorophyll a, and algae patches.

Although the total number of papers published on modelling was less than those on observation, the number of papers in this area has been increasing recently. For example, ROMS is used widely to study circulation in marginal seas. The FVCOM (Finite-Volume Coastal Ocean Model) and EFDC (Environmental Fluid Dynamics Code) have been adapted for coastal area and estuarine systems, respectively.

6.3. Japan

Being the same as for Korea, field observation is the major method for Japanese scientists to work with the East China Sea. Among the 39 papers from Japan, 27 papers were based on field observations. Research vessels and their usage system is one of the fundamental conditions for such studies in Japan.

There were 9 papers from numerical modelling and 3 papers from satellite/remote sensing. Eight papers based on numerical modelling still use the Princeton Ocean Model (POM) although other models (ROMS and FVCOM) have been widely used for marginal seas over the world. The satellite/remote sensing papers are based on ocean-color data.

6.4. Taiwan

Field survey is also the main methodology for the papers published by Taiwan scientists. There were 82 papers in total using in-

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situ measurements to conduct their studies on the East China Sea. In-situ observation of the ocean is limited to narrow areas and it is virtually impossible to fully comprehend the ocean process and dynamics. Thus, contribution to these studies from numerical modeling and remote sensing efforts is increasing. Taiwan scientists have developed numerous models with different integration domains and resolutions to study the East China Sea and the western North Pacific Ocean (e.g. Wu et al., 2008). There were 50 papers published using numerical modelling as their major methodology. In addition, 26 papers from Taiwan were based on satellite remote sensing data.

7. Trends in management and conservation

7.1. China

To investigate whether coastal research had incorporated integrated coastal zone management, all papers in the database were evaluated in terms of their contribution to coastal management. There were 6% (22) and 2% (7) of papers that emphasized 'management' and 'conservation', respectively, in their titles or abstracts. Within these papers, two used the concept 'integrated coastal zone management', one reviewed nutrient variation and the associated aquatic ecosystem responses in the subtropical region (Chen and Hong, 2012). They attributed imbalanced and modified ratio and flux of nutrients delivered to aquatic ecosystems to three major causes: 1) human activities in the catchment areas; 2) climate perturbations; and 3) changes in land use and damming. To address these issues, authors proposed institutional arrangements to be developed and coordinated across multiple government agencies and other stakeholders from the watershed to the coast. They argued that the framework should integrate inter-disciplinary scientific approaches with adaptive principles regarding nutrient management.

7.2. Korea

Very limited papers were directly related to management (2) and conservation (2). However, many papers had addressed the environmental changes after coastal development such as reclamations and sea dykes. Large reclamation projects in the Yellow Sea have been undertaken in Korea during a rapid economic development period. It seemed to be an economic way to provide land for building cities and factories. The management and the conservation of the tidal flats have been debated for a decade following many reclamation projects in Korea. Strong opposition has led to a decline in such large reclamation projects (Koh and de Jonge, 2014).

7.3. Japan

There was no paper from Japan paying attention to management and conservation in the East China Sea and Yellow Sea. This is partly because the area of the East China Sea freely observed by Japanese scientists is mainly affected by the Kuroshio and is far from the coast where human activities are important to the marine environment. However, there were many papers from Japan considering the management and conservation of inland seas and bays. In addition to traditional approach for the management and conservation, a new concept called 'Sato-Umi', which is defined as "high productivity and biodiversity in the coastal sea area with human interaction", has been proposed and gradually accepted by the community (Yanagi, 2008, p. 351).

7.4. Taiwan

Only a few of the research papers for Taiwan placed emphasis on issues concerning management (2), conservation (1), and policy (1). Although the East China Sea has often caught the policy maker's attention, their marine development still lacks an understanding of the ocean processes. Studying the oceanic features can provide the basis for an improved understanding of the ocean's interplay with the climate, the earth and its species. With a better knowledge of the ocean dynamics in the region, numerous effects caused by weather and disasters, as well as economic, fishery, and environmental problems can be ameliorated.

8. Towards the future

The coastal environments are zones of major economic growth and are the location for most of the transport, commercial, residential and defence infrastructure. They also fulfil important cultural, recreational and aesthetic needs, have intrinsic ecosystem service values and provide essential biochemical functions such as primary productivity, nutrient cycling and water filtration. The anticipated growth of the population in the coastal zones along the Yellow and East China Sea basin will make a coastal observing and forecasting systems an even higher priority than they are today for environmental protection and coastal hazard management. Development and support of long-term coastal research sites, both in heavily impacted eutrophic coastal environments (e.g. Changjiang estuary) and the oligotrophic offshore region (e.g. The PN-line) will lead to an identification of quantitative relationships between physical and biological processes and their response to anthropogenic stressors and these processes can be represented within predictive models. Observation and prediction on sea fog in the coastal area of the Yellow Sea is one of challenging issues for the future (Cho et al., 2000).

Future climate change projections must be dynamically downscaled to the coastal zones of the Yellow and the East China Seas from global climate models (Seo et al., 2014). Forecasting capability that informs event detection, provision of information can assist disasters (e.g. oil spills, storm surges and harmful algae bloom events), to prepare readiness and response to extreme events, or to explore scenarios particularly those relating to the evaluation of risk management. Capability development to provide access to better information, including near real-time data processing and forecasting, can facilitate anticipatory and responsive decision-making, guidelines, and community networks.

Many existing community ocean models have integrated physical and biogeochemical models to investigate coastal ecosystem dynamics. However, there is a need to improve the performance of these models for the extremely turbid coastal oceans such as the Yellow and East China Sea, where the light climate in the water column in general and the time-depth-dependent PAR (photosynthetically available radiation) profile in particular is tightly controlled by the mechanisms of sediment dynamics. Therefore, these sediment processes affecting the water column light physics will need to be represented more accurately in these models. Commonly-used empirical equations for calculating downward PAR irradiance (including single and double exponential forms) will need to be modified in order to identify a more theoretically-sound parameterization for application to physical and biogeochemical models for this region. There is also a need to improve the biogeochemical models to address the issue of finding an adequate conversion term to compute the attenuation coefficients from carbon biomass.

Routine measurements from space-borne sensors have been combined and used together with model-based operational ocean

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forecasting systems. Space- and air-borne observation with high resolution capability will be useful to capture small scale variability in coastal areas. There is a research need to bridge the gap of the current capacity for utilizing satellite/remote sensing measurements in such systems designed for the estuaries and coastal environments. Complex coastal topography and rougher sea states hinder the applications of recent region based satellites (e.g. HJ1A, B and C; Haiyang 1 and 2; GOCI). Remote sensing algorithms need to be developed and improved to retrieve ocean data such as suspended sediment concentration, chlorophyll as well as coastal altimetry. An example of the latter involves estimation of sea level anomalies within 5 km from the coastline using optimal waveform retracking through a fuzzy multiple retracking system (e.g. Idris et al., 2014).

Coastal infrastructure developments such as dredged navigation channels and land reclamation may result in changes in storm surges, tides and mean sea level, which in turn affect coastal erosion, sedimentation and flooding patterns (Aucan and Ridd, 2000; Winterwerp, 2011; Song et al., 2013; Pelling et al., 2013; Li et al., 2014b; Feng et al., 2015). Systems of modeling, in-situ observation and remote sensing provide us with the capability to answer the questions concerning the likely impacts and effects of infrastructure construction on the coastal environments. For example, coastal flooding may be assessed through refinements of the likelihood of information to establish the return period of storm surges of different intensities under changed tides and mean sea level. The extent of flooding and associated economic losses should be calculated for different thresholds of storm surges. Hence, probabilistic and dollar value information may be provided for decision-makers with treatment options to manage the risks of coastal flooding in terms of the "statistically expected" costs and/or fatalities.

Experience in participatory and multidisciplinary research in coastal management situations show that ICZM needs to incorporate various actors (e.g. coastal communities, coastal scientists and engineers, marine policy and law experts, government agencies and industries) in order to inform decisions and ensure the compatibility of development and conservation (Official Journal of the European Union, 2009). Use of modelling and stakeholder participation can improve the adaptive capacity of the ICZM. New methodological approaches such as the Sato-Umi model (Yanagi, 2007, 2008) need to be developed and/or adopted to identify, map, explore and enable the local actors to help manage conflict and sustainability issues in the region. The integrated observing and forecasting system should be used as a quantitative tool in social learning to inform and discuss with stakeholders the social and policy options (as recommended by the *National Framework for Marine Research and Innovation*, OPSAG, 2009).

We also call for renewed efforts to conduct government sponsored bi- and/or multi-lateral collaborative research into the issues of the Yellow and East China Sea among the oceanography communities in China, Korea, Japan and Taiwan. The historical and ongoing international collaborations such as Japan–China JRK and PAMS has produced high impact research outcomes (e.g. Su et al., 1990) as well as active research communities (e.g. PAMS). The environmental and fisheries issues in the Yellow and East China Sea facing our communities have no boundaries. Thus to address them effectively, close cooperation with combined efforts from these nations/region is urgently required.

9. Contributions made by this special issue

This Yellow and East China Sea Special Issue is a collection of 15 papers from the authors of China, Korea, Japan and Taiwan. The SI addresses many of the gaps and opportunities outlined above. Unlike traditional research during 1990s, most of papers have evaluated physical, environmental and ecological impact of land use and reclamation (Suh et al., 2014; Lee et al., 2014; Wang et al., 2014; Gao et al., 2014a; Chen et al., 2014; Sin et al., 2015), channel dredging, bridging (Hayami et al., 2015; Zhao et al., 2015) and damming (Kwak et al., 2014; Zhang et al., 2014a) on its coastal seas and estuarine environment. Others have emphasized biogeochemical processes including: a review of PAR parameterization in current ecosystem dynamics models (Byun et al., 2014), and field-based studies of phytoplankton growth, hypoxia, eutrophication and metal toxicity (Kim and Kim, 2014; Li et al., 2014a; Lui et al., 2014; Baek et al., 2015).

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