이학박사 학위논문

Spatiotemporal distributions of sedimentary persistent toxic substances and their impacts on macrofaunal community in the coastal areas of the Yellow Sea

황해 연안지역 퇴적물 내 잔류성독성물질의 시공간 분포 및 대형저서동물 군집에 대한 영향

2021년 2월

서울대학교 대학원

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이 논문을 이학박사 학위논문으로 제출함

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윤서준의 이학박사 학위논문을 인준함

2021년 2월

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ABSTRACT

Sediments in the coastal areas of the Yellow Sea have been contaminated by persistent toxic substances (PTSs) over the last 30 years. This study evaluated the spatiotemporal distribution of classic and emerging PTSs in sediment and their impact on the macrofaunal community in the coastal areas of the Yellow Sea. PTSs included polycyclic aromatic hydrocarbons (PAHs), alkylphenols (APs), polychlorinated biphenyls (PCBs), metals, emerging PTS (styrene oligomers (SOs), emerging-PAHs (E-PAHs), and halogenated-PAHs (Hl-PAHs). The distribution of PTSs varied in relation to chemical and station, with that of PAHs being generally high. PAH concentrations in Nantong, Huludao, and Qinhuangdao (China) present potential risks to aquatic organisms. Over the last decade, PAH contamination has declined in Korea, while that of PAHs in general has increased in China. Thus, PTS contamination is likely ongoing with high potential risk, especially in China. Historical records of classic and emerging PTSs over the 100 years showed that contamination of both classic and emerging PTSs was high from the 1970s to 1990s. Fluxes of classic and emerging PTSs showed a similar trend to concentrations of PTSs; however, since the 2000s, the rate of decrease has been relatively low, indicating the continuous input of PTSs to the Yellow Sea. The impact of PTSs has been low, despite the relatively high concentrations of classic and emerging PTSs in hotspots. The macrofaunal community inhabiting the upper intertidal zone, estuaries, and coastal areas was more impacted by salinity, sediment grain size, and chlorophyll-*a*, rather than PTSs. However, the great potential ecological risk of PTSs was found in some areas, which suggested that continuous monitoring is required. Overall, the contamination by sedimentary PTSs in the coastal areas of the Yellow Sea has decreased compared to the past; however, contamination remains high in certain areas. The impacts of PTSs on the macrofaunal community were weak, despite the high PTS concentrations in some areas. In conclusion, This study provides baseline information on PTS contamination and ecological impacts, suggesting that selecting priorities for pollution management and implementation of pollution reduction policies in Korea and China are necessary.

Keywords: Sediments, Contaminants, Coastal pollution, Potential risk assessments, Environmental status, Marine macrozoobenthos

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LIST OF ABBREVIATIONS

Ace	Acenaphthene
Acl	Acenaphthylene
Ant	Anthracene
APEOs	Alkylphenol ethoxylates
APs	Alkylphenols
BaA	Benzo[*a*]anthracene
BaP	Benzo[*a*]pyrene
BbF	Benzo[*b*]fluoranthene
BghiP	Benzo[*g,h,i*]perylene
BkF	Benzo[*k*]flouranthene
Br-PAHs	Brominated-polycyclic aromatic hydrocarbons
BS	Bohai Sea
CA	Cluster analysis
CAP	Canonical analysis of principal coordinates
CBs	Chlorinated biphenyls
CCME	Canadian Council of Ministers of the Environment
Chl-*a*	Chlorophyll-*a*
Chr	Chrysene
Cl-PAHs	Chlorinated- polycyclic aromatic hydrocarbons
Co-PCBs	Coplanar-polychlorinated biphenyls
COD	Chemical oxygen demand
CRS	Constant rate supply
DBahA	Dibenz[*a,h*]anthracene
dbRDA	Distance-based redundancy analysis
Dbthio	Dibenzothiophene
DCM	Dichloromethane
DIN	Dissolved inorganic nitrogen
DistLM	Distance-based linear model
DO	Dissolved oxygen
dw	Dry weight

E-PAHs	Emerging-PAHs
EcoQ	Ecological quality
EQR	Ecological quality ratio
ERL	Effect-range low
ERM	Effect-range median
Fl	Fluoranthene
Flu	Fluorene
GC-MSD	Gas chromatography-mass selective detector
H′	Shannon-Wiener diversity index
Hl-PAHs	Halogenated-Polycyclic aromatic hydrocarbons
IAEA	International Atomic Energy Agency
IcdP	Indeno[*1,2,3*-cd]pyrene
ICP-MS	Inductively coupled plasma mass spectrometer
Indival	Indicator value
ISQG	Interim sediment quality guidelines
LME	Large marine ecosystem
LMW	Lower-molecular weight
MDL	Method detection limit
MOE	Ministry of Environment
Na	Naphthalene
nMDS	Non-parametric multi-dimensional scaling
NOWPAP	Northwest Pacific Action Plan
NP	Nonylphenol
NP1EO	Nonylphenol monoethoxylate
NP2EO	Nonylphenol diethoxylate
OP	4-*tert*-octylphenol
OP1EO	4-*tert*-octylphenol monoethoxylate
OP2EO	4-*tert*-octylphenol diethoxylate
PAHs	Polycyclic aromatic hydrocarbons
PCA	Principal component analysis
PCBs	Polychlorinated biphenyls
PECs	Probable-effect concentrations
PEL	Probable effect levels

PERMANOVA	Permutational multivariate analysis of variance
PERMDISP	Test for homogeneity of multivariate dispersion
Pery	Perylene
Phe	Phenanthrene
PMF	Positive matrix factorization
PTSs	Persistent toxic substances
Py	Pyrene
QA/QC	Quality Assurance/Quality Control
SD1	1,3-diphenylpropane
SD2	cis-1,2-diphenylcyclobutane
SD3	2,4-diphenyl-1-butene
SD4	trans-1,2-diphenylcyclobutane
SOs	Styrene oligomers
SQGs	Sediment quality guidelines
SRM	Standard reference material
SS	Suspended sediment
ST1	2,4,6-triphenyl-1-hexene
ST2	1e-phenyl-4e-(1-phenylethyl)-tetralin
ST3	1a-phenyl-4e-(1-phenylethyl)-tetralin
ST4	1a-phenyl-4a-(1-phenylethyl)-tetralin
ST5	1e-phenyl-4a-(1-phenylethyl)-tetralin
ST6	1,3,5-triphenylcyclohexane
TECs	Threshold effect concentrations
TEFs	Toxic equivalency factors
TN	Total nitrogen
TOC	Total organic carbon
TP	Total phosphorus
VPDB	Vienna Peedee Belemnite
YS	Yellow Sea
YSLME	Yellow Sea Large Marine Ecosystem

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CHAPTER 1.

INTRODUCTION

1.1. Backgrounds

Exposure of coastal environments to direct and indirect anthropogenic pollution over many decades is driving their deterioration; consequently, marine pollution represents a significant and common problem worldwide. Anthropogenic pollution is mainly caused by various human activities, including industrialization and urbanization. The Yellow Sea is one of the most economically and industrially developing regions globally. Historically, coastal regions of the Yellow Sea have been targeted for development in both Korea and China (Hoagland and Jin, 2006; Kong et al., 2015). However, over the last 50 years, the rapid development of Korea and China is threatening the ecosystems of the Yellow Sea through the environmental deterioration of coastal regions. Consequently, scientific effort to assess the ecological conditions of the polluted coastal environments of the Yellow Sea has grown in parallel (Jeppesen et al., 2011; Ryu et al., 2016). The Northwest Pacific Action Plan (NOWPAP) reported key marine ecosystem problems in the Yellow Sea, including: 1) loss of habitat and biological diversity; 2) introduction of invasive species; 3) coastal eutrophication; 4) chemical pollution; and 5) marine litter (NOWPAP POMRAC, 2017). The report showed extensive eutrophication, pollutants, and marine litter in all regions of Korea and China (Figure 1.1). In particular, pollutants (i.e., persistent toxic substances [PTSs]), were the main cause of pollution. Pollution in the Yellow Sea by various PTSs has persisted over the last 30 years (Khim et al., 2018b), representing a major concern for the environmental health of the Yellow Sea.

The Yellow Sea extends about 1000 km from north to south and about 700 km from east to west, covering a total area of about 470,000 km^2. The average depth is about 45 m, and the maximum depth does not exceed 100 m. The Yellow Sea is regarded as a wide semi-enclosed sea or closed shallow ocean. The southern part of the Yellow Sea joins with the East China Sea and the northern part of the Yellow Sea is called the Bohai Sea, which encompasses three bays (Liaodong, Bohai, and Laizhou Bay). The entire region of the Yellow Sea, including the Bohai Sea, has been delineated as the Yellow Sea Large Marine Ecosystem (YSLME), which is one of 66 Large Marine Ecosystems worldwide. The coastline of the Yellow Sea is complex, and water exchange is slow, due to the sea's geographical characteristics. Consequently, 30 years (or more) is required for a complete water exchange to occur in the northern part of the Yellow Sea (including the Bohai Sea) (Luo et al., 2010). Consequently, pollutants, especially PTSs, can easily accumulate in the Yellow Sea, negatively impacting its ecosystem.

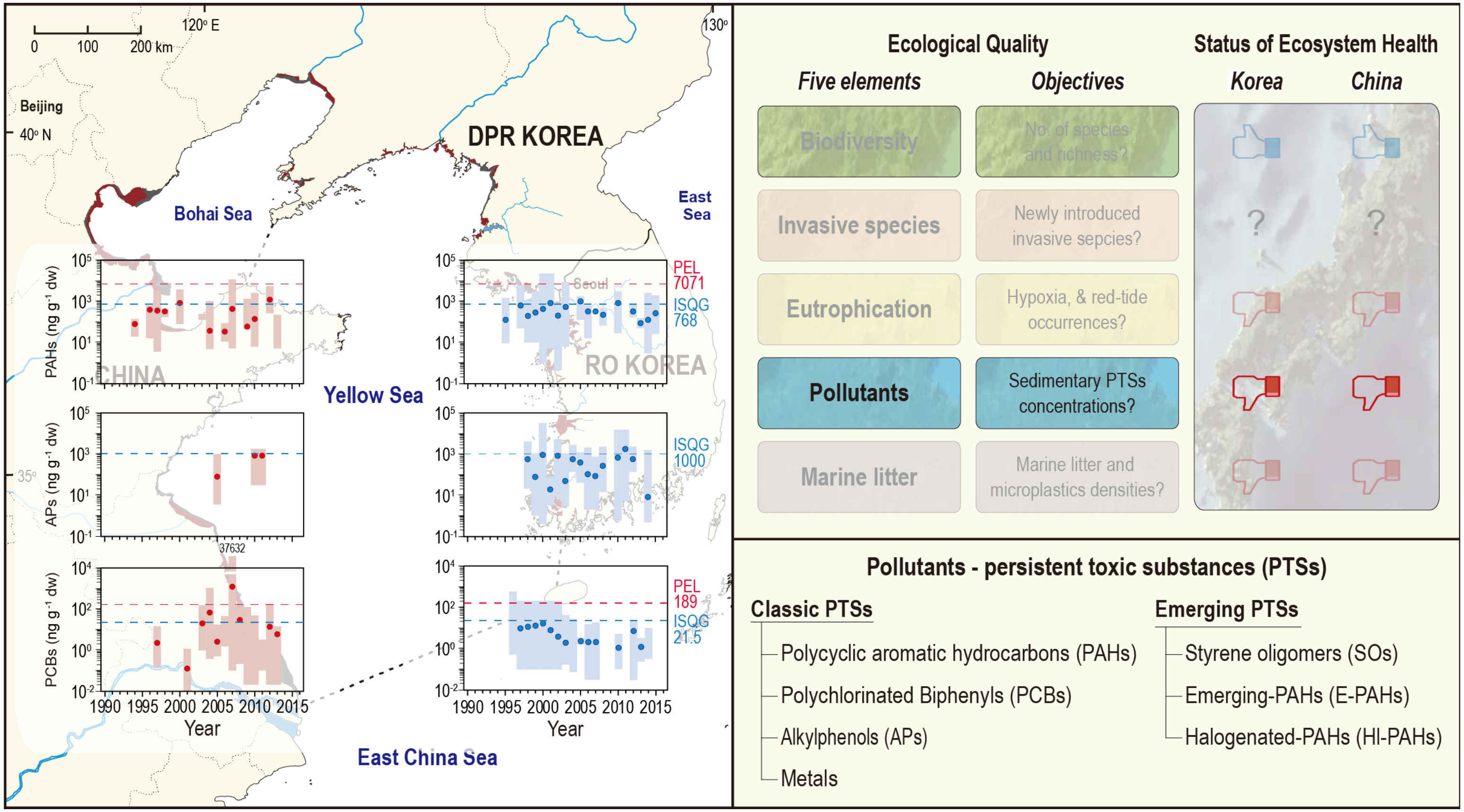

Figure 1.1.
Ecological quality and pollution status of persistent toxic substances in the Yellow Sea over the last 30 years.

Classic and emerging PTSs include polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), alkylphenols (APs), metals, styrene oligomers (SOs), emerging-PAHs (E-PAHs), and halogenated-PAHs (Hl-PAHs). These PTSs unintentionally generated during industrial activities, are artificially synthesized or are present in trace amounts in nature (Figure 1.2). Out of monitored PTSs, PAHs, E-PAHs, and Hl-PAHs are mainly generated unintentionally (Lin and Zhu, 2004; Moon et al., 2006; Ghosh et al., 2015). PAHs are globally ubiquitous contaminants that occur everywhere (Lipiatou et al., 1997; Rogers, 2002). E-PAHs and Hl-PAHs are emerging PTSs that are receiving increasing focus (Horii et al., 2008; An et al., 2020). PCBs, APs, metals, and SOs are industrially used in dielectric fluids, detergents, paints, alloys, plates, and plastic materials (White et al., 1994; Brivik et al., 2004; Giesy et al., 2010; Hosoda et al., 2014; Kim et al., 2020). PCBs were appointed as a major persistent organic pollutant (POP) by the Stockholm Convention (UNEP, 2001). APs are used in nonionic surfactants and are being increasingly recognized as priority PTSs to combat. Metals are representative contaminants that are discharged to the coastal environment, globally. SOs have been recently identified as degraded products of polystyrene plastic materials. Although the use of certain PTSs (PCBs and APs) is currently banned, developing countries continue to use some PTSs, with environmental regulations lacking on emerging-PTSs and unintentional products (Hornbuckle and Robertson, 2010). PTSs also negatively impact aquatic ecosystems through their toxicity, having carcinogenic and estrogenic effects that cause feminization and increased infertility (Neff, 1979; Giesy and Snyder, 1998; Ohyama et al., 2001; Neff, 2002; Tatarazako et al., 2002; Dassenakis et al., 2003; Christophoridis et al., 2009; Chen and Yen, 2013). PTSs are introduced into the environment through various sources, including pyrogenic, petrogenic, leaks of products, wastewater, sewage, and mining (Lin and Zhu, 2004; Li et al., 2013; Ghosh et al., 2015; Xu et al., 2016). Most PTSs originate from land sources, circulating in the atmosphere, rivers, estuaries, oceans (Witt, 1995). Ultimately, they sink to and accumulate in sediments, due to their hydrophobic properties, adversely affecting the benthic community (Gewurtz et al., 2000; Engraff et al., 2011; Bastami et al., 2015; Singh and Kumar, 2017, Yoon et al., 2019).

Chemical	Usage	Origin	Source	Toxicity	Remark
PAHs	-	Unintentional, natural	Pyrogenic, petrogenic	Carcinogen	Classic PTSs
PCBs	Dielectric fluids	Unintentional, artificial	Pyrogenic, leaks of product	Carcinogen	Classic PTSs
APs	Detergents, paints	Artificial	Wastewater	Environmental estrogens	Classic PTSs
Metals	Alloy, plating	Natural	Mining, wastewater	Carcinogen	Classic PTSs
SOs	Plastic meterials	Artificial	Wastewater	Environmental estrogens	Emerging PTSs
E-PAHs	-	Unintentional	Pyrogenic	Carcinogen	Emerging PTSs
HI-PAHs	-	Unintentional	Pyrogenic	Carcinogen	Emerging PTSs

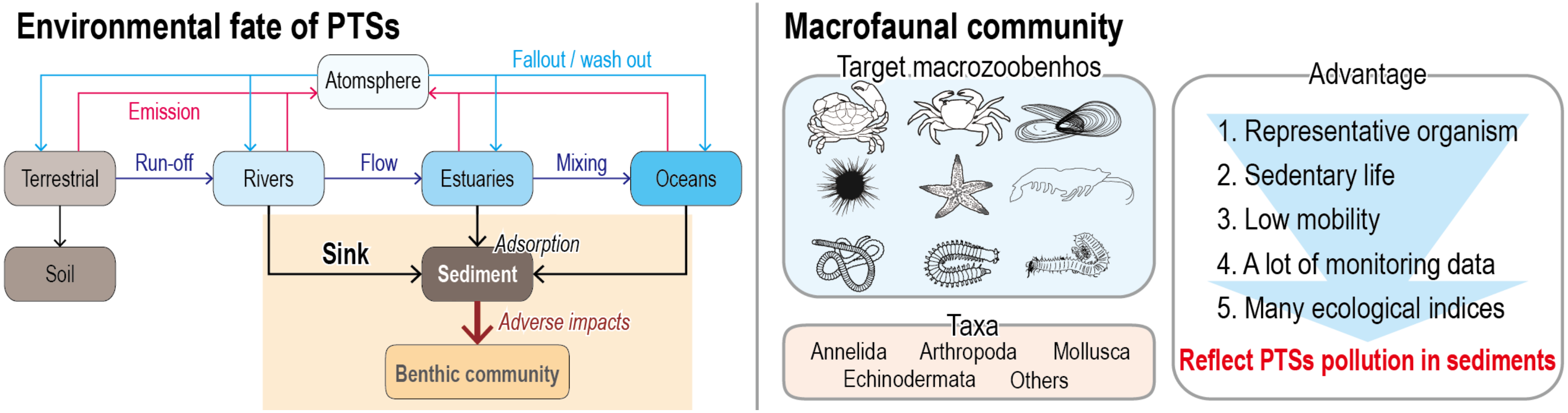

Figure 1.2.
Characteristics of persistent toxic substances and advantages in using the macrofaunal community as indicators of pollution.

Benthic macrofauna are the most abundant taxa among benthic organisms, and play important roles in benthic ecosystems (Herman et al., 1999). Benthic macrofauna are well adapted to the surrounding environments because of their low mobility (Gray et al., 1992). In addition, various feeding types, dominant species, opportunistic species, and indicator species of macrofauna also facilitate the ability of the macrofaunal community to reflect the benthic environment. Consequently, their life-history traits and sedentary lifestyles make them suitable indicators of the ecological quality of benthic environments. Thus, studies on macrofauna are possible to collect large quantities of data and generate many ecological indices (Figure 1.2) (Gray et al., 1992). Distributions of the benthic macrofauna are often affected by various environmental parameters, such as PTSs, organic matter, nutrients, salinity, turbidity, dissolved oxygen, suspended sediments, chlorophyll-*a*, wave exposure, pH, temperature, illumination, aerobic/anaerobic condition, grain size, permeability, and pore water gases (Hyland et al., 2005; Sandrini-Neto et al., 2016; Bae et al., 2018, Kim et al., 2020) (Figure 1.3). Environmental parameters that originated from anthropogenic pressure, not a natural phenomenon, strongly impacts macrofauna, because of a weak tolerance of macrofauna to sudden specific events. In particular, PTSs that are adsorbed to sediments and bioaccumulated in biota often adversely affect the structure and function of the macrofaunal community, potentially altering macrofaunal assemblages. The response of the macrofaunal community to chemical pollution (including various PTSs) has been well reported (Zheng et al., 2011; Wetzel et al., 2012; Ryu et al., 2016; Egres et al., 2019). However, limitations exist to compare responses to various PTSs and assess potential impacts of PTSs with environmental variables, simultaneously. In addition, the response of the benthic macrofaunal community to PTSs was not sufficient, while studies on how benthic communities respond to PTSs have mainly focused on microbial communities. Overall, the previous studies on PTSs and their impacts on the macrofaunal community in the Yellow Sea were limited in the aspects of compounds evaluated, timeframe, and space (Khim and Hong 2014; Meng et al., 2017; Kim et al., 2020) (Figure 1.4).

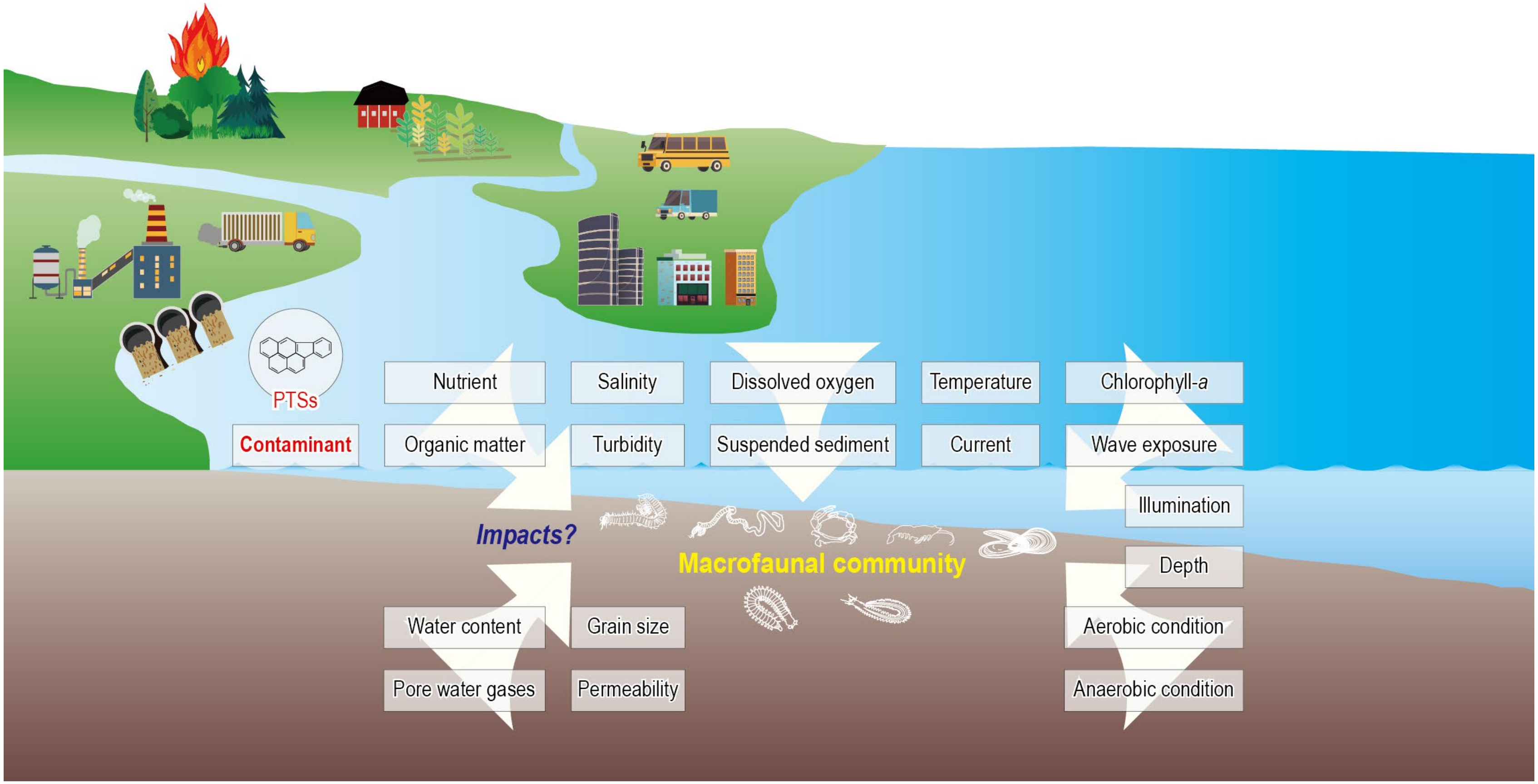

Figure 1.3.
Major environmental factors affecting the structure and function of the macrofaunal community.

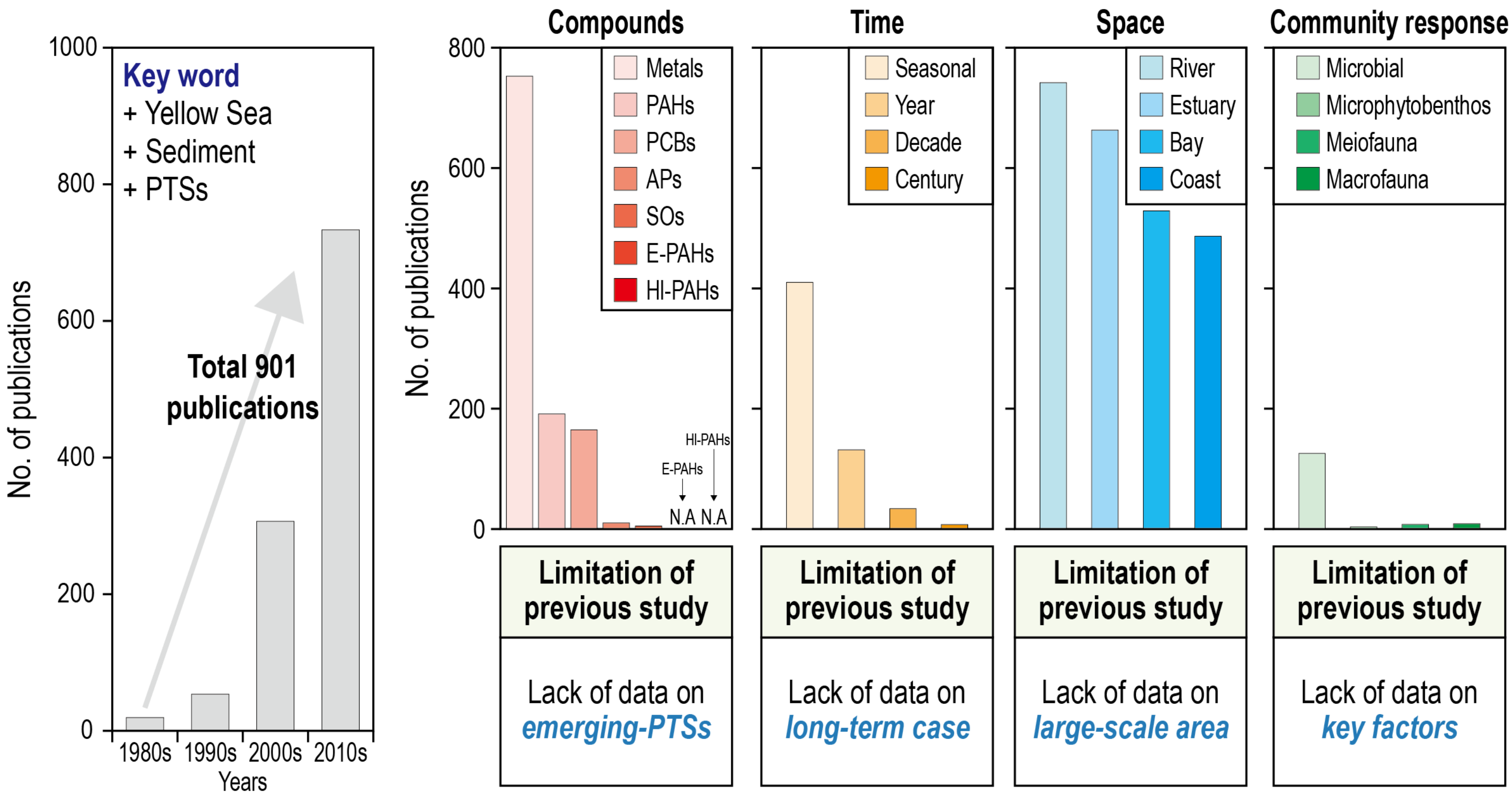

Figure 1.4.
Overview of previous studies of sedimentary persistent toxic substances to target compounds, time, space, and community responses in the Yellow Sea.

1.2. Objectives

This dissertation aimed to address the limitations of existing studies, and improve the current understanding of contamination status and ecological impacts of PTSs in the Yellow Sea. The spatiotemporal distribution of sedimentary persistent toxic substances and their impact on the macrofaunal community were investigated in the coastal areas of the Yellow Sea through chapters 2 to 6. The specific objectives and structuring of the present study include (Figure 1.5):

1. **Chapter 2**

   Determining the distribution and sources of PTSs and sedimentary organic matter, and characterizing macrobenthic community responses to sedimentary contamination in the Geum River estuary.

2. **Chapter 3**

   Characterizing the spatiotemporal distribution patterns of PTSs and macrofaunal assemblages, and evaluating key factors influencing spatiotemporal changes to macrofaunal communities in the Geum River estuary.

3. **Chapter 4**

   Measuring the concentrations of PTSs in sediment, assessing potential ecological risks posed by PTSs, evaluating long-term changes (past 10 years) in sedimentary contamination, and identifying key factors controlling the macrofaunal community.

4. **Chapter 5**

   Reconstructing historical deposition and fluxes of classic and emerging PTSs over the last 100 years, and identifying the composition and sources of classic and emerging PTSs.

Finally, Chapter 6 (concluding section) includes a summary of the key findings, the environmental implications and associated limitations of PTSs, and suggested future research directions.

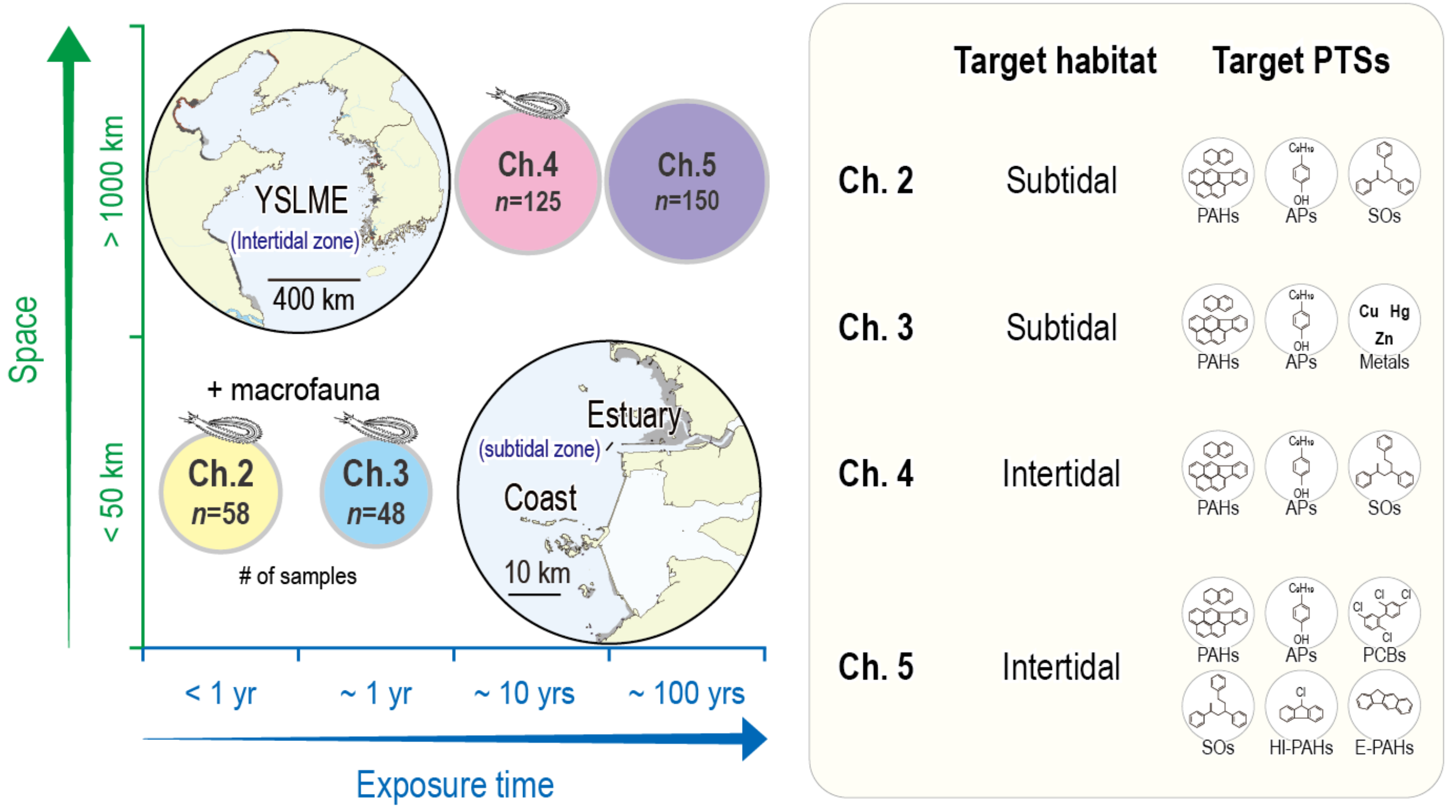

Figure 1.5.
Schematic of present study conditions. Through four case studies, this thesis evaluated the spatiotemporal distribution of PTSs (including PAHs, APs, PCBs, SOs, E-PAHs, HI-PAHs, and HMs) and their impact on the macrofaunal community in the coastal areas of the Yellow Sea.

CHAPTER 2.

DISTRIBUTIONS OF PERSISTENT ORGANIC CONTAMINANTS IN SEDIMENTS AND THEIR POTENTIAL IMPACT ON MACROBENTHIC FAUNAL COMMUNITY OF THE GEUM RIVER ESTUARY AND SAEMANGEUM COAST, KOREA

This chapter has been published in Chemosphere.
Yoon, S.J., Hong, S., Kwon, B.-O., Ryu, J., Lee, C.-H., Nam, J., Khim, J.S., 2017. Distributions of persistent organic contaminants in sediments and their potential impact on macrobenthic faunal community of the Geum River estuary and Saemangeum coast, Korea. *Chemosphere* **173**, 216-226. https://doi.org/10.1016/j.chemosphere.2017.01.031

2.1. Introduction

The Geum River Estuary has been subject to major changes since the construction of a sea dike in 1990 and the establishment of the Gunsan-industrial complex in 1992 (Kim et al., 2006). Likewise, the Saemangeum Coast located to the south of the Geum River Estuary undergone major changes following the construction of the Saemangeum sea dike between 1991 and 2010 (Lee and Ryu, 2008; Lie et al., 2008). Gunsan is a major city in southwestern Korea that is located near the Geum River Estuary and Saemangeum Coast. Over the years, this city has expanded to support a manufacturing industry and an international trade port (Yi and Ryu, 2015), which might cause local contamination with persistent organic contaminants (POCs) (Hong et al., 2012). Moreover, dike construction and reclamation induced erosion and change to surface sediments (Lie et al., 2008). These activities might alter the biogeochemical conditions of particulate organic matter in coastal areas and benthic environments (Lee et al., 2012).

Toxic chemicals, such as polycyclic aromatic hydrocarbons (PAHs), alkylphenols (APs), and styrene oligomers (SOs) have been found near industrial complexes and in waste from cities and large harbors in Korea (Khim et al., 1999; Koh et al., 2006; Hong et al., 2016). PAHs are ubiquitous POCs in various environments, particularly intensively used areas, such as dockyards, harbors, estuaries, and shallow coastal zones exposed to anthropogenic effects (Lipiatou et al., 1997; Rogers, 2002). PAHs are generally accumulated with relatively great concentrations in sediments due to their hydrophobic nature. PAHs can have also a high degree of biota-sediment accumulation factors by being accumulated in coastal benthic organisms (Gewurtz et al., 2000). PAHs have long been considered as one group of major toxic contaminants found in coastal sediments to cause adverse effects on aquatic wildlife (Neff, 1979, 2002). Alkylphenol ethoxylates (APEOs), which include nonylphenol polyeothoxylates (NPEOs) and octylphenol polyeothoxylates (OPEOs), are extensively used as nonionic surfactants (White et al., 1994). APEOs can be degraded into products such as nonylphenol and octylphenol through biological and photochemical degradation (Li et al., 2013). However, the degradation products, endocrine disruptors, have harmful effects, including population decrease and the feminization of several aquatic species (Giesy and Snyder, 1998; Chen and Yen, 2013).

SOs have been reported as new pollutants in highly developed coastal areas (Hong et al., 2016). SOs are known decomposition chemicals that originate from polystyrene plastic materials, and have been listed as new contaminants of increasing concern; yet, few studies have reported the distribution of SOs (Saido et al., 2014; Kwon et al., 2015; Hong et al., 2016). SO analogues originate from the thermal decomposition of polystyrene at temperatures of 240–300 °C (Kwon et al., 2014). SOs have been reported to cause estrogenic effects *in vitro* and reproduction toxicity on daphnids (Ohyama et al., 2001; Tatarazako et al., 2002). Thus, sedimentary SOs may cause potential adverse effects on the ecosystem, but effects on the benthic community are not well known. Altogether, a study on the occurrences and distributions of PAHs, APs, and SOs in sediments and benthic community responses would remain in question.

In general, sediment organic carbon (SOC) is positively correlated with organic contaminants (Warren et al., 2003). The SOC content and origin of organic matter are affected by inputs of freshwater. The origin of organic matter is generally determined by using the SOC to sediment nitrogen (SN) ratio and stable carbon isotopes (Sampei and Matsumoto, 2001; Meksumpun and Meksumpun, 2002). It is important to determine the origin because terrestrial organic matter is connected with an increase in macrofaunal community biomass and density (Hermand et al., 2008). However, there have been few studies on organic contaminants, the sources of organic matter, and factors affecting the benthic macrofaunal community inhabiting the sediment of the Geum River Estuary and Saemangeum Coast.

Thus, the objectives of the present study were to: (1) determine the distribution of PAHs, APs, and SOs, (2) identify sources by analysis of chemical compositions, (3) address sources of sedimentary organic matter by use of carbon stable isotope ratio, and finally (4) characterize macrobenthic community responses against sedimentary contamination.

2.2. Materials and Methods

2.2.1. Sampling areas and strategy

The Geum River Estuary and Saemangeum Coast are located in the southwestern part of Korea. These areas are affected by three watergates. The inner part of the Saemangeum sea dike is influenced by freshwater originating from the Mangyeong and Dongjin Rivers. The Geum River Estuary and the Saemangeum Coast surround the industrial and domestic areas of the cities of Gunsan and Seocheon. Fifty-eight sediment samples were collected from the Geum River Estuary and Saemangeum Coast (Figure 2.1). Thirty sediment samples were collected from the Saemangeum Coast in September 2014. The other samples were collected from the Geum River Estuary in December 2014. Surface sediments were collected for chemical analysis by use of Van Veen grab sampler. Upper 2 cm of the sediments were collected. All sediment samples for chemical analyses were transported with dry-ice and stored at -20 °C until analysis. For the macrofaunal community, duplicate sediment samples were collected at each site. Macrofauna was separated by using a 1 mm mesh sieve on-site and were fixed with 5% buffered formalin.

2.2.2. Analyses of PTSs and carbon stable isotope ratio

The PTSs including PAHs, APs, and SOs and stable carbon isotope ratio ($\delta^{13}C$) in sediment were determined using a gas chromatograph equipped with a mass-selective detector (MSD, Agilent Technologies, Santa Clara, CA) and Elemental Analyzer (EA)-Isotope Ratio Mass Spectrometer (IRMS, Elementar, Hanau, Hesse). Detailed information on instrumental conditions were presented in Table 2.1 and Table 2.2.

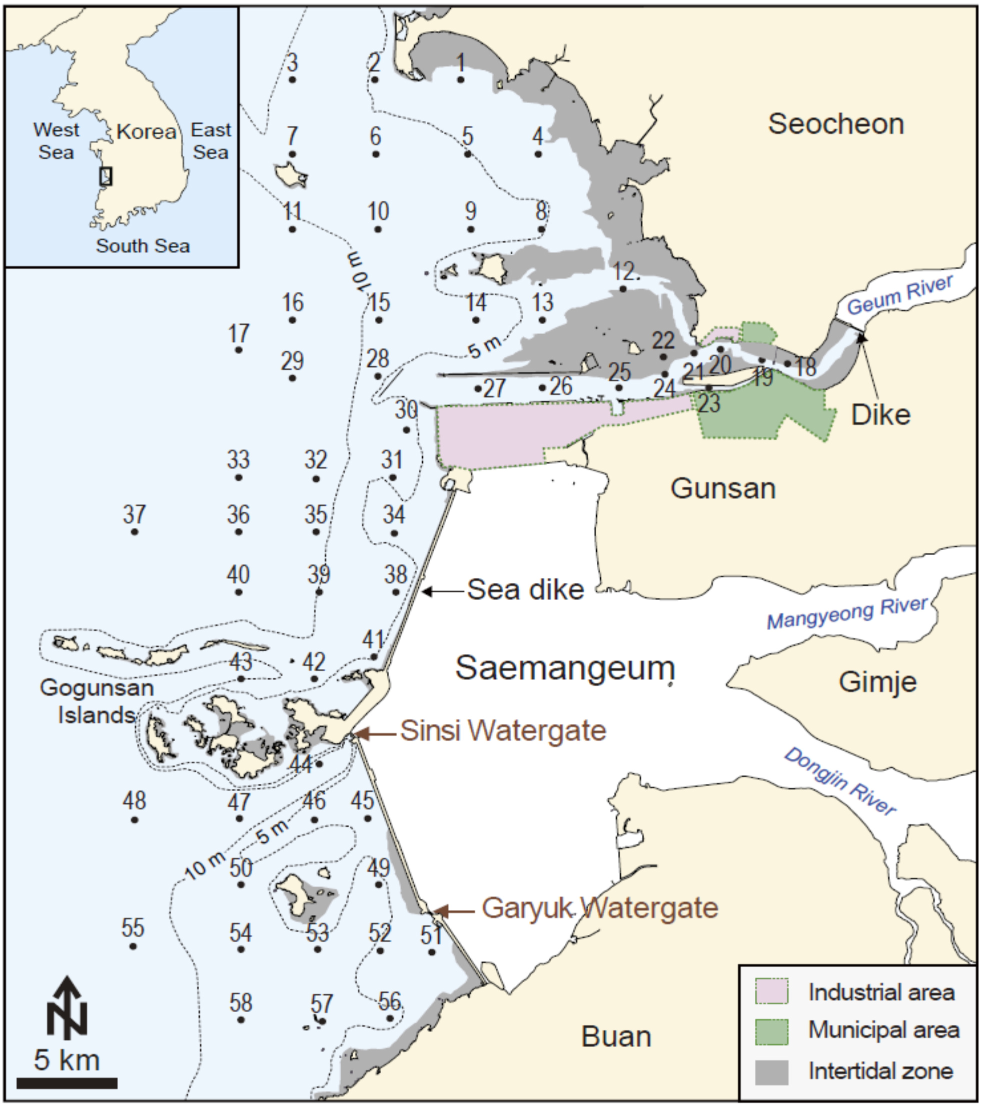

Figure 2.1.
Map showing the sampling sites of the surface sediment at the Geum River Estuary and the Saemangeum Coast.

Table 2.1.
GC/MSD instrumental conditions for PAHs and SOs analyses.

GC/MSD system	Agilent 7890A GC and 5975C MSD
Column	DB-5MS (30 m long, 0.25 mm i.d., 0.25 μm film thickness)
Gas flow	1 mL/min He
Injection mode	Splitless
Injection volume	2 μL
MS temperature	180 °C
Detector temperature	230 °C
Oven temperature	60 °C hold 2 min Increase 6 °C/min to 300 °C 300 °C hold 13 min
Target PAHs, alkyl-PAHs and SOs	Naphthalene (Na), 2-Methylnaphthalene (2-Na), 1-Methylnaphthalene (1-Na), 1,3-Dimethylnaphthalene (1,3-Na), Acenaphthylene (Acl), Acenaphthene (Ace), Fluorene (Flu), 1-Methylfluorene (1-Flu), Phenanthrene (Phe), 3-Methylphenanthrene (3-Phe), 2-Methylphenanthrene (2-Phe), Anthracene (Ant), Fluoranthene (Fl), Pyrene (Py), Benzo[*a*]anthracene (BaA), Chrysene (Chr), 3-Methylcrysene (3-Chr), Benzo[*b*]fluoranthene (BbF), Benzo[*k*]fluoranthene (BkF), Benzo[*a*]pyrene (BaP), Perylene (Pery), Indeno[*1,2,3-cd*]pyrene (IcdP), Dibenz[*a,h*]anthracene (DbahA), Benzo[*g,h,i*]perylene (BghiP), 1,3-Diphenylproane (SD1), *cis*-1,2Diphenylcyclobutane (SD2), 2,4-Diphenyl-1-butene (SD3), 2,4,6-Triphenyl-1-hexene (SD4), 2,4,6-Triphenyl-1-hexene (ST1), 1e-Phenyl-4e-(1-phenylethyl)-tetralin (ST2), 1a-Phenyl-4e-(1-phenylethyl)-tetralin (ST3), 1a-Phenyl-4a-(1-phenylethyl)-tetralin (ST4), 1e-Phenyl-4a-(1-phenylethyl)-tetralin (ST5), and 1,3,5-Triphenylcyclohexane (isomer mix) (ST6)

Table 2.2.
GC/MSD instrumental conditions for APs analysis.

GC/MSD system	Agilent 7890A GC and 5975C MSD
Column	DB-5MS (30 m long, 0.25 mm i.d., 0.25 μm film thickness)
Gas flow	1 mL/min He
Injection mode	Splitless
Injection volume	1 μL
MS temperature	180 °C
Detector temperature	230 °C
Oven temperature	60 °C hold 5 min Increase 10 °C/min to 100 °C Increase 20 °C/min to 300 ° C
Target Alkylphenols	300 °C hold 6 min 4-tert-Octylphenol (OP), 4-tert-Octylphenol monoethoxylate (OP1EO), 4-tert-Octylphenol diethoxylate (OP2EO), Nonylphenol (NP), Nonylphenol-monoethoxylate (NP1EO), and Nonylphenol diethoxylate (NP2EO)

2.2.3. Macrobenthic fauna analysis

After transferring the macrofauna to the laboratory, the samples were re-sieved using a 1 mm screen to rinse away formalin before analysis. The macrofaunal samples were sorted, identified to the species level, and counted using a dissection microscope.

2.2.4. Quality assurance and quality control

Method detection limit (MDL) was calculated as 3.707 x standard deviation of standard. The MDLs of PAHs, SOs, and APs ranged from 0.23 to 1.4 ng g^{-1}, from 0.28 to 0.94 ng g^{-1}, and from 0.09 to 0.97 ng g^{-1}, respectively. The mean recoveries of five SS were generally within the acceptable range (78-111% for PAHs and SOs; 75% for APs; detailed in Table 2.3). In the carbon and nitrogen stable isotope analysis, the analytical precision of the IAEA-CH-3 and IAEA-CH-6 were 0.2‰ and 0.1‰, respectively.

2.2.5. Data analysis

In this study, 24 PAHs, 6 APs, 10 SOs, organic carbon, nitrogen, and stable carbon isotope were investigated in the surface sediments (full names of the chemicals and abbreviations are shown in Tables 2.1 and 2.2). Principal component analysis (PCA) was performed using the normalized values of the environmental parameters and macrofaunal community data. SPSS 23.0 (SPSS INC., Chicago, IL) and SigmaPlot 13.0 software were used for the statistical analyses.

Table 2.3.
QA/QC data for sedimentary PAHs, SOs, and APs measured in the present study.

Compounds	Abbreviations	Method detection limit (ng g dw^{-1}, n = 7)	Surrogate recovery (%, n = 58)
PAHs and SOs			
Naphthalene	Na	0.43	
2-Methylnaphthalene	2-Na	0.80	
1-Methylnaphthalene	1-Na	0.78	
1,3-Dimethylnaphthalene	1,3-Na	0.65	
Acenaphthylene	Acl	0.85	
Acenaphthene	Ace	0.84	
Fluorene	Flu	0.80	
1-Methylfluorene	1-Flu	1.40	
Phenanthrene	Phe	0.79	
Anthracene	Ant	0.41	
3-Methylphenanthrene	2-Phe	0.28	
2-Methylphenanthrene	3-Phe	0.73	
Fluoranthene	Fl	0.78	
Pyrene	Py	0.90	
Benzo[a]anthracene	BaA	0.60	
Crysene	Chr	0.72	
3-Methylchrysene	3-Chr	0.24	
Benzo[b]fluoranthene	BbF	0.69	
Benzo[k]fluoranthene	BkF	0.71	
Benzo[a]pyrene	BaP	0.59	
Perylene	Pery	0.66	
Indeno[1,2,3-cd]pyrene	IcdP	0.43	
Dibenz[a,h]anthracene	DbahA	0.27	
Benzo[g,h,i]perylene	BghiP	0.33	
1,3-Diphenylproane	SD1	0.34	
cis-1,2-Diphenylcyclobutane	SD2	0.65	
2,4-Diphenyl-1-butene	SD3	0.94	
trans-1,2-Diphenylcyclobutane	SD4	0.28	
2,4,6-Triphenyl-1-hexene	ST1	0.57	
1e-Phenyl-4e-(1-phenylethyl)-tetralin	ST2	0.53	
1a-Phenyl-4e-(1-phenylethyl)-tetralin	ST3	0.30	
1a-Phenyl-4a-(1-phenylethyl)-tetralin	ST4	0.49	
1e-Phenyl-4a-(1-phenylethyl)-tetralin	ST5	0.32	
1,3,5-Triphenylcyclohexane (isomer mix)	ST6	0.34	
Acenaphthene-d10	Ace-d12		77.9 ± 19.1[a]
Phenanthrene-d10	Phe-d10		111.3 ± 28.2
Crysene-d12	Chr-d12		93.6 ± 20.6
Perylene-d12	Pery-d12		85.9 ± 20.4
APs			
4-tert-Octylphenol	t-OP	0.09	
Iso-Nonylphenol	NPs	0.97	
4-tert-Octylphenol-mono-ethoxylate	t-OP1EO	0.10	
Iso-Nonylphenol-mono-ethoxylate	NP1EOs	0.49	
4-tert-Octylphenol-di-ethoxylate	t-OP2EO	0.10	
Iso-Nonylphenol-di-ethoxylate	NP2EOs	0.88	
Bisphenol A-d16	BPA-d16		74.8 ± 18.7

2.3. Results and Discussion

2.3.1. Spatial distribution of persistent organic contaminants

The concentrations of organic contaminants in the sediments is shown in Table 2.4 and Figure 2.2. The mean concentration of PAHs, APs, and SOs ranged from 39.6, 9.46, and 14.3 ng g^{-1} dry weight (dw) respectively. Looking for the distributions of POCs, most of the target compounds were concentrated (top 20%) in the mouth of the Geum River Estuary to the Gogunsan Islands along the Saemangeum sea dike, indicating hot spots along this line probably due to the industrial and municipal activities from Gunsan area (Figure 2.2). The mean PAHs concentrations of top 10%, top 10-20%, and < top 20% were 129 ng g^{-1} dw, 80 ng g^{-1} dw, and 23 ng g^{-1} dw, respectively. The concentrations of detectable PAHs varied among the sites and regions, while APs showed narrow groupings in terms of the range of concentrations (top 10%, top 10-20%, and < top 20%; 25 ng g^{-1} dw, 14 ng g^{-1} dw, and 6.9 ng g^{-1} dw, respectively). The range of SOs concentrations was also relatively small (top 10%, top 10-20%, and < top 20%; 87 ng g^{-1} dw, 19 ng g^{-1} dw, and 4.2 ng g^{-1} dw), in general. Relatively smaller concentrations of POCs were detected at several long-distanced sites from the coastline. These results indicated that the industrial and municipal activities were the main sources of POCs, and seemed to cause relatively great accumulation in nearby bottom sediments (Ashley and Baker, 1999). The greater POCs concentrations in some remote sites may be affected by geological hydrodynamic conditions and resuspension by dredge activity for the port (Chen et al., 2006). Overall, spatial distributions of POCs indicated that POCs were mainly accumulated in sediments of adjacent sources due to point-sources and could be transported to a limited area.

Table 2.4.
Overview of the results for chemical and ecological analyses in the sediments of the Geum River Estuary and the Saemangeum Coast, Korea.

Analysis		Unit	Range	Sediment (n = 58)
Sediment property	Mud content	%	Min.– Max.	2.4 – 99
			Mean	29
Persistent Organic Chemicals	PAHs[a]	ng g^{-1} dw	Min.– Max.	2.9 – 158
			Mean	39
	APs[b]	ng g^{-1} dw	Min.– Max.	0.6 – 46.0
			Mean	9.5
	SOs[c]	ng g^{-1} dw	Min.– Max.	0.3 – 261
			Mean	14
Organic matter	Sediment organic carbon	%	Min.– Max.	0.1 – 1.3
			Mean	0.3
	Sediment nitrogen	%	Min.– Max.	0.01 – 0.15
			Mean	0.03
	Carbon stable isotope ratio ($^{13}C/^{12}C$)	‰	Min.– Max.	- 19.9 – - 23.9
			Mean	- 21.6
Macrofunal community	Total species number	number	Min.– Max.	3 – 51
			Mean	11
	Total density	indiv/m^2	Min.– Max.	15 – 2350
			Mean	569
	Total biomass	g WW/m^2	Min.– Max.	0.3 – 1266
			Mean	101

[a] Concentration of PAHs was used the sum of 16 parent PAHs, 2-Na, 1-Na, 1,3-Na, 1-Flu, 3-Phe, 2-Phe, 3-Chr, and perylene.
[b] Concentration of APs was used the sum of OP, OP1EO, OP2EO, NP, NP1EO, and NP2EO.
[c] Concentration of SOs was used the sum of SD1, SD2, SD3, SD4, ST1, ST2, ST3, ST4, ST5, and ST6.

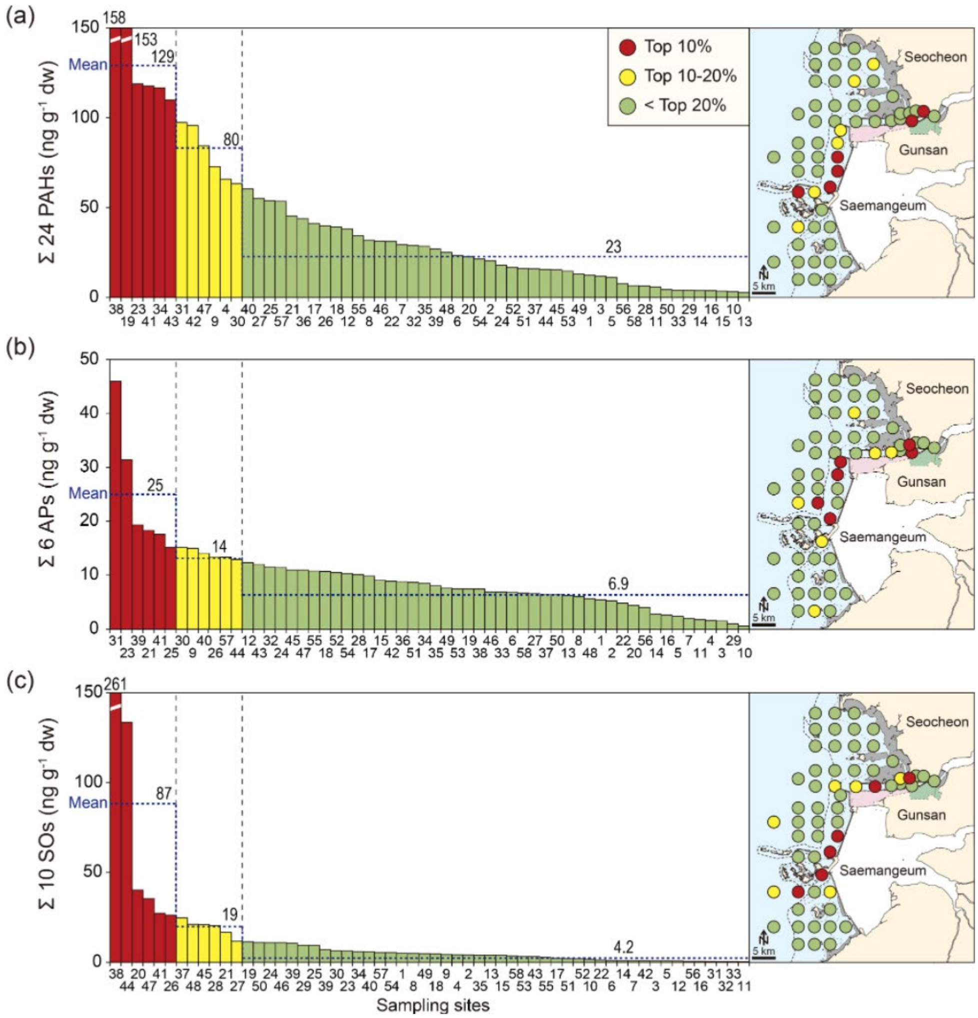

Figure 2.2.
Spatial distributions of (a) 24 PAHs, (b) 6 APs, and (c) 10 SOs in sediments of the Geum River Estuary and Saemangeum Coast. Red, yellow, and green areas mean the top 10%, between the top 10 and 20%, and below the top 20%, respectively.

The distribution pattern of POCs was similar to those of SOC and mud content. The mud content was positively correlated with POCs (r = 0.27–0.67, p < 0.05). The SOC was significantly correlated with PAHs and APs (r = 0.31–0.70, p < 0.01). Unlike PAHs and APs, no significant correlation was observed between SOs concentration and SOC (r = 0.02, p = 0.74). Correlation between $\delta^{13}C$ and POCs was not significant (r = 0.04–0.22, p > 0.05). PAHs and APs were highly correlated with SOC (Xu et al., 2006; Liu et al., 2013), but the correlation between SOs and SOC was not found probably due to lack of data on measured SOs (10 chemicals) at this time. This result indicated that concentrations of POCs were not affected by the origin of organic matter. Of note, the concentration of SOs was correlated with sediment grain size rather than SOC. The major reason for the lack of correlation between POC and $\delta^{13}C$ might be attributed to POC sources being located in the outer region of the estuary. Due to limited information of SOs in sediment, further characterization of SOs accumulation would remain in question. In anyhow, the overall distributions of POCs in the Geum River Estuary and Saemangeum Coast were collectively affected by general sediment characteristics, particularly the organic matter.

The concentrations of PAHs, APs, and SOs in the sediments of the present study area were compared with the results of previous studies in the coastal areas affected by industrial complexes and domestic areas of Korea. Overall, similar or less concentrations of PAHs and APs were detected in the sediments of the Geum River Estuary and the Saemangeum Coast compared to reports for sediments in other coastal areas, such as Gyeonggi Bay Kwangyang Bay, Masan Bay, and Yeongil Bay (Koh et al., 2005; Koh et al., 2006; Moon et al., 2008; Hong et al., 2009). Moreover, the greatest concentrations of PAHs and APs in the sediments of the Geum River Estuary and Saemangeum coasts were below the Interim marine sediment quality guidelines (CCME, 2001). Thus, the contamination level of PAHs and APs in the sediments at the present study area was much lower compared to other coastal sediments in Korea. In SOs (10 chemicals), only one study has been previously conducted in Korea in Gyeonggi Bay (Hong et al., 2016). The concentrations of SOs obtained in the present study were similar to those obtained in the previous study. Thus, the contamination level of PAHs, APs, and SOs in the Geum River Estuary and Saemangeum Coast was moderate to low compared to other areas in Korea. These results indicated that the sediment conditions of the areas assessed by the present study were better compared to other coastal areas in Korea.

2.3.2. Composition and sources of persistent organic contaminants

The composition of PAHs in the sediments of the Geum River Estuary and Saemangeum Coast differed among samples (Figure 2.3a). Out of all sites, the top 10% and top 10–20% contained PAHs of high molecular weight (HMW), representing 75% of total PAHs in both groups. However, HMW accounted for about 59% of sites below the top 20%. HMW PAHs (4–6 rings) appeared to be affected by pyrogenic sources (Gschwend and Hites, 1981; Budzinski et al., 1997). Low molecular weight PAHs (2-3 rings) might be derived from the air-water exchange and atmospheric deposition, due to their relatively high volatility (Tobiszewski and Namieśnik, 2012). Thus, this composition indicated that the industrial complex was the main source. To analyze the sources of PAHs, diagnostic ratios were used as the principal method (Fig 2.4). The results suggested that the sources of PAHs in the study area primarily originated from pyrogenic sources. These results correspond with the dominance of HMW PAHs, which are affected by pyrogenic sources. Pyrogenic sources might originate from the surrounding activities. Consequently, the PAHs in the sediment layer of the Geum River Estuary and Saemangeum Coast were affected by pyrogenic sources originating from sources in the surrounding area, such as the industrial complex.

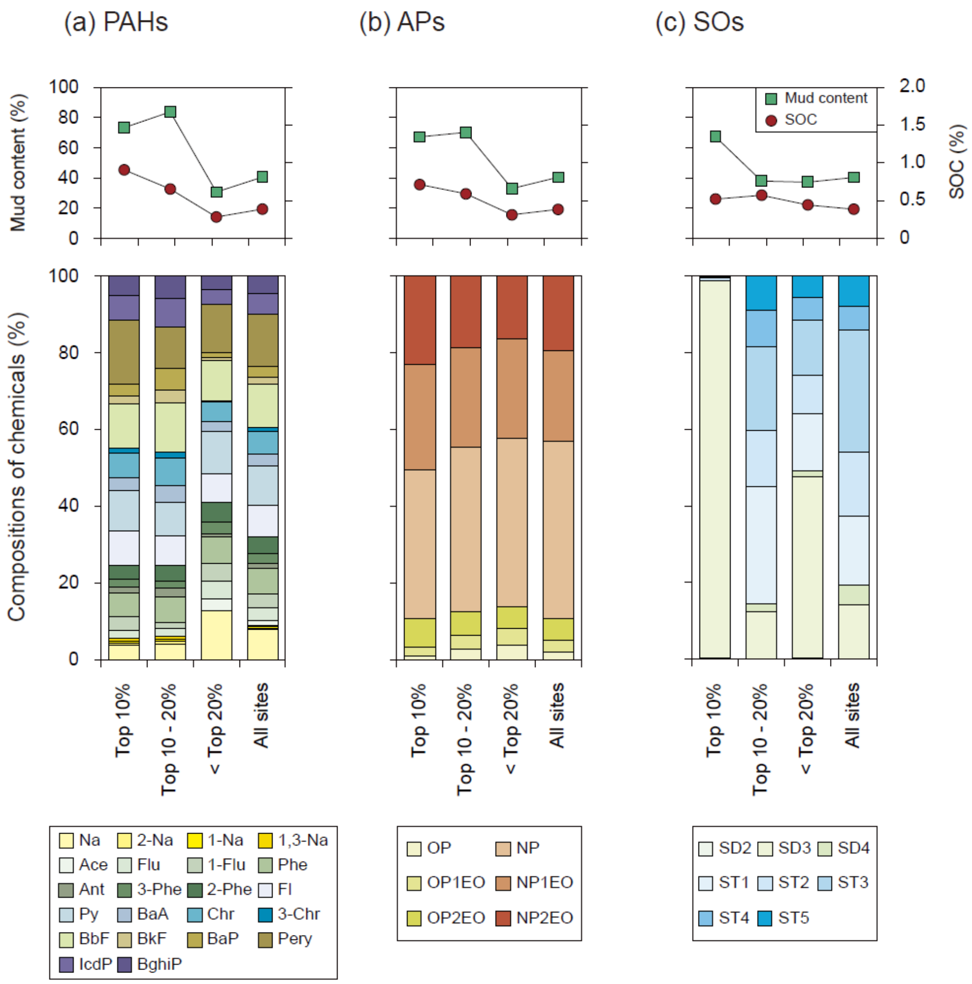

Figure 2.3.
Relative compositions of (a) PAHs, (b) APs, and (c) SOs in sediments of the Geum River Estuary and the Saemangeum Coast. The mud contents and SOC contents were given.

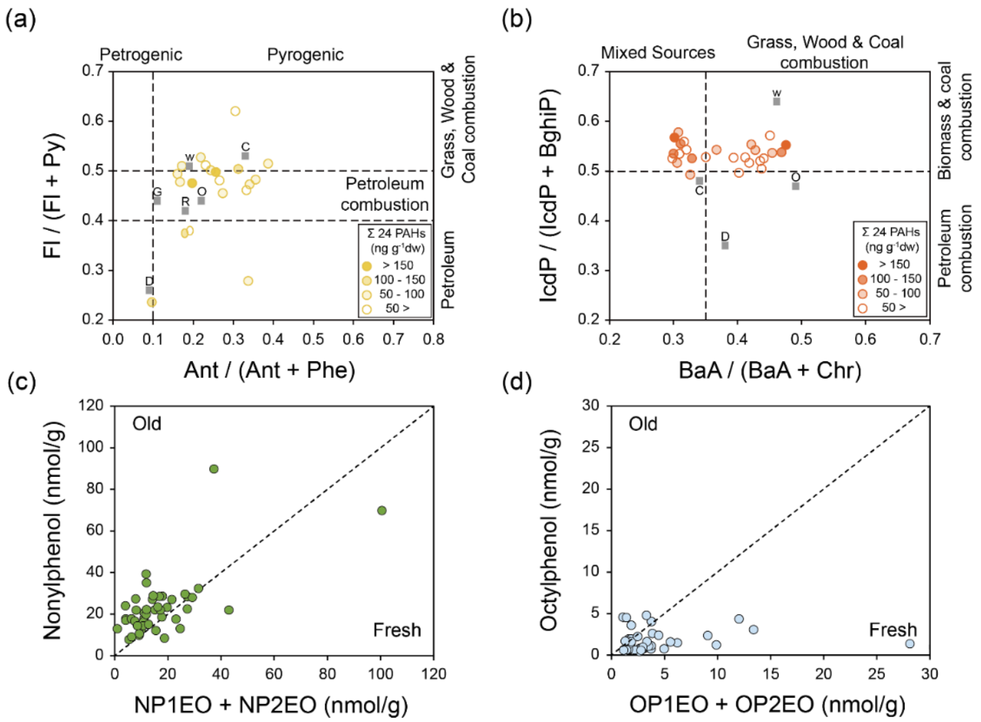

Figure 2.4.

Diagnostic ratios for prediction of sources of chemicals between (a) Ant/(Ant+Phe) and Fl/(Fl+Py), (b) BaA/(BaA+Chr) and IcdP/(IcdP+BghiP), (c) NP1EO+NP2EO and NP, and (d) OP1EO+OP2EO and OP in sediments of the Geum River Estuary and Saemangeum Coast.

Unlike PAHs, the composition of APs was similar across sites of great and less concentrations (Figure 2.3b). Overall, NPs and nonylphenol monoethoxylate (NP1EO) were the dominant compounds accounting for 43% and 26% of APs in all sites, respectively. This result supports previous studies (Duan et al., 2014; Dong et al., 2015). NP and OP were the degradations of chemicals of NP and OP polyethoxylates. In this study, more NP was detected compared to NP1EO + nonylphenol diethoxylate (NP2EO); however, lower OP was calculated compared to octylphenol monoethoxylate + octylphenol diethoxylate (Figure 2.4). Thus, fresh input consists of OP derivatives; but, concentrations were negligible. Lesser NP1EO and NP2EO concentrations might have been influenced by their limited uses in household products being banned since 2002 in Korea. Overall, NP derivatives were dominant, with fresh inputs of OP derivatives being detected. This result indicated that although a small quantity of fresh input was detected, regulation of their uses seemed to be effective in more recent years.

The compositions of SOs in the sediments of the Geum River Estuary and Saemangeum Coast varied among sites, mostly because of site 38 (top 1) (Figure 2.3c). At site 38, SD3 (98%) was the dominant chemical. However, for other sites in the top 10%, ST1 (26%) was the dominant chemical, followed by ST3 (25%), ST2 (16%), and SD3 (11%). Likewise, in sites top 10-20%, ST3 was the dominant chemical with 26%, followed by ST1 (22%), ST2 (18%), and SD3 (11%). In sites below the top 20%, a similar pattern was found. The great concentration of SD3 found at site 38 might be affected by adjacent industrial sources, because the greatest concentration of PAHs was also found at site 38. SD1 and ST6 were not detected in all sites. A relatively great composition of STs may indicate a fresh input of SOs because styrene monomer would be detected after decomposition of polystyrene (Kwon et al., 2014). Thus, this result might indicate that fresh input of SOs would exist in the study area. A recent study performed by Hong et al. (2016) first investigated 10 SOs in the lake and coastal sediments (same as the present study) with relatively great contributions of SDs. However, the current study found that STs were the predominant chemical group among the SOs. This difference in SOs composition might be explained by the sources, i.e., by direct inputs (Hong et al., 2016) and/or specific decomposition mechanism of polystyrene at nearby sources.

Overall, the lack of reports on the 10 SOs in the sediment means that more studies are required on their composition and distribution in coastal sediments.

2.3.3. Sources and distribution of organic matter

The $\delta^{13}C$ values in the sediments of the Geum River Estuary and Saemangeum Coast ranged between -23.9‰ and -19.9‰, with a mean value of -21.6‰ (Table 2.1 and Fig 2.5). The $\delta^{13}C$ values of marine organic matter and terrestrial organic matter clearly differ. Previous studies reported lower $\delta^{13}C$ values for the organic matter of terrestrial origin compared to the $\delta^{13}C$ values for marine origin. Terrestrial organic matter had a $\delta^{13}C$ value ranging between -27‰ and -25‰ (Schubert and Calvert, 2001; Lehmann et al., 2002). In comparison, the value for marine organic matter ranges between -22‰ and -20‰ (Peters et al., 1978; Meyers, 1994). The mouth of the Geum River, Site 42, and 46 (located near Shinsi-watergate) had relatively lighter $\delta^{13}C$ values (< -22.0‰). Relatively heavier $\delta^{13}C$ values were detected at other sites. In the West Sea, Korea, benthic particulate organic matter and suspended particulate organic matter were found to range between -22‰ and -13‰ (Suh and Shin, 2013). These results indicate that the organic matter of the sediments in sites near to freshwater inputs is of terrestrial origin (DeLaune, 1986; Chmura et al., 1987). In Saemangeum Coast, the marine origin of organic matter prevailed which could be explained by the weak freshwater input as well as seawater circulation at Sinsi- and Garyuk Watergates. The difference in hydrodynamics on water flow followed by the spatial variations of organic matter between Geum River Estuary and Saemangeum Coast seemed to cause dissimilar species composition of macrozoobenthos between two regions, in general (Hermand et al., 2008). Overall, the organic matter in the coastal area of the Geum River Estuary and Saemangeum Coast was mostly of marine origin; however, the organic matter of some sites located near the watergate was of terrestrial origin.

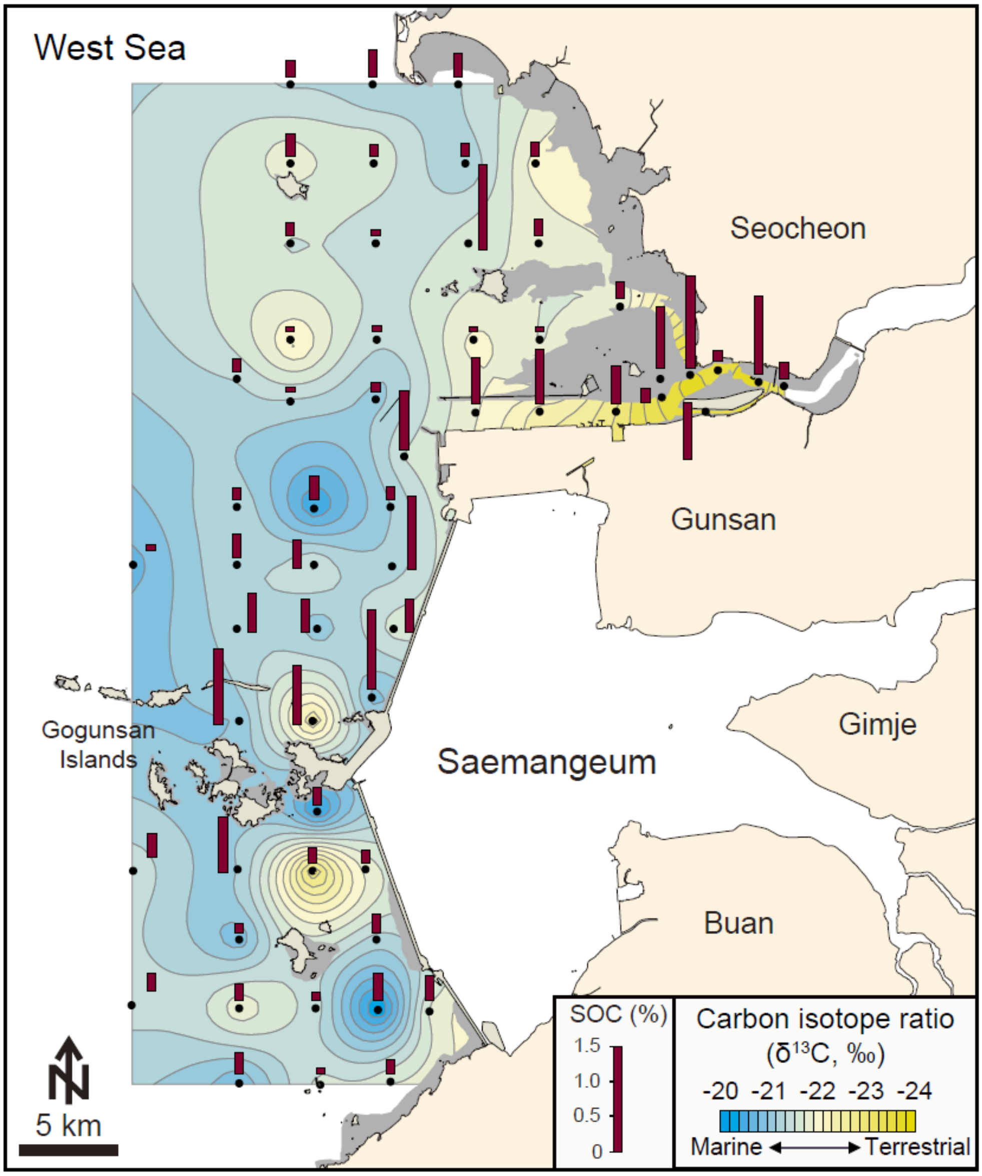

Figure 2.5.
Spatial distributions of δ^{13}C values and total organic carbons in sediments of the Geum River Estuary and the Saemangeum Coast.

The SOC and SN contents ranged between 0.06% and 1.27% (mean: 0.38%) and 0.01% to 0.15% (mean: 0.04%), respectively (Table 2.1, Figure 2.5, and Figure 2.6). High SOC contents were detected at sites located along the domestic and industrial area, from within the Geum River Estuary to the Gogunsan Islands. Lower SOC contents were detected at all other sites, except site 9 located near an island. The distribution of SN was a similar pattern as SOC and organic chemical concentrations across sites. Previous studies reported that organic carbons tend to contain smaller particles (Guo et al., 2009), with similar results being obtained for sites with a high composition of mud content in our study (Figure 2.3). Sedimentation conditions might be affected by the complex hydrodynamic and water current conditions of the study area. Overall, the SOC and SN contents in the study area appeared to be correlated with sediment grain size.

The SOC/SN ratios ranged from 4.15 to 17.93 (mean: 9.53; Fig 2.6). The SOC/SN ratios indicated that most organic matter (81%) was of marine origin (SOC/SN between 4 and 12), while only a small percentage (19%) was of terrestrial origin (SOC/SN > 12) (Holligan et al., 1984; Stein, 1991). The highest SOC/SN values (> 12) were detected in the mouth of the Geum River Estuary and the vicinity of the watergate of the Saemangeum sea dike. This result was consistent with the $\delta^{13}C$ value, indicating that the sedimentary organic matter in the Geum River Estuary and Saemangeum Coast is partially affected by terrestrial inputs.

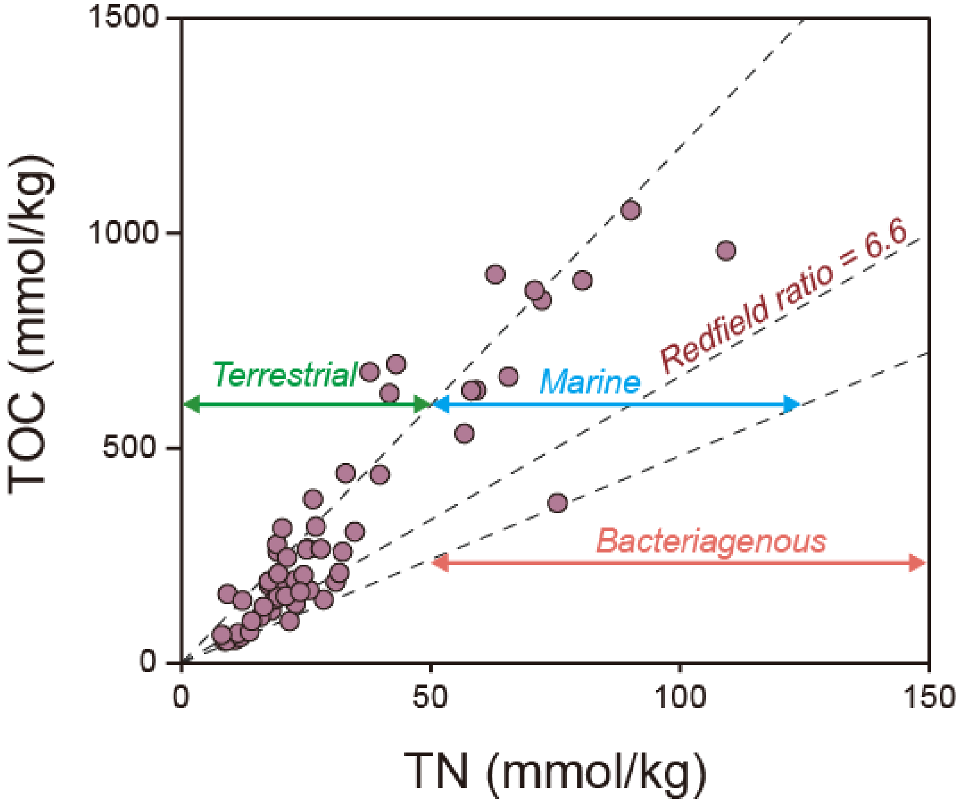

Figure 2.6.
Scatter plots of sediment organic carbon and nitrogen contents for prediction of sources of organic matter in sediments of the Geum River Estuary and the Saemangeum Coast.

2.3.4. Association of POCs contamination to the macrofaunal community

The present study detected 10,878 individuals from 186 macrofaunal species belonging to four major taxonomic groups. In all sites, Polychaeta was the main group (51%), followed by Arthropoda (26%), Mollusca (17%), and Echinodermata (3%). Polychaeta was well known as an opportunistic and indicator of organic enrichment (Martínez-Lladó et al., 2007; Seo et al., 2014). *Heteromastus filiformis* was the single most abundant species of all counted individuals (18.9%). The next dominant species was *Sinocorophium sinensis* (4.7%), followed by *Chaetopterus* sp. (4.0%), *Spiochaetopterus costarum* (3.7%), and *Photis brevipes* (3.7%). *Heteromastus filiformis, Sinocorophium sinensis,* and *Spiochaetopterus costarum* are opportunistic species that are used as indicators of organic pollution (Pearson and Rosenberg, 1978; Hong et al., 1997). The presence of these species indicates that the sediments of the Geum River Estuary and Saemangeum Coast have been subject to organic enrichment. Thus, the present study focused on identifying the factors that control the macrofaunal community in the Geum River Estuary and Saemangeum Coast.

Principal component analysis (PCA) was performed to identify the factors controlling the macrofaunal community, by using all available parameters (macrofaunal community, POCs, organic matter, and mud content) (Table 2.1 and Figure 2.7). The PCA divided the sites into two groups. The first group included the industrial and domestic area, the area near the sea dike, and the Gogunsan Islands. These sites had greater concentrations (top 10%) of POCs, larger species ranges, and a greater density of macrofauna. The second group was characterized by sites that had relatively high species numbers and density, as well as high δ^{13}C values. The results indicated that the parameters of the macrofaunal community were more strongly affected by δ^{13}C compared to POCs, mud content, SOC, or SN. However, PC1 and PC2 only explained 51% of the variance; thus, the high correlation factors with the macrofaunal community should be treated with caution.

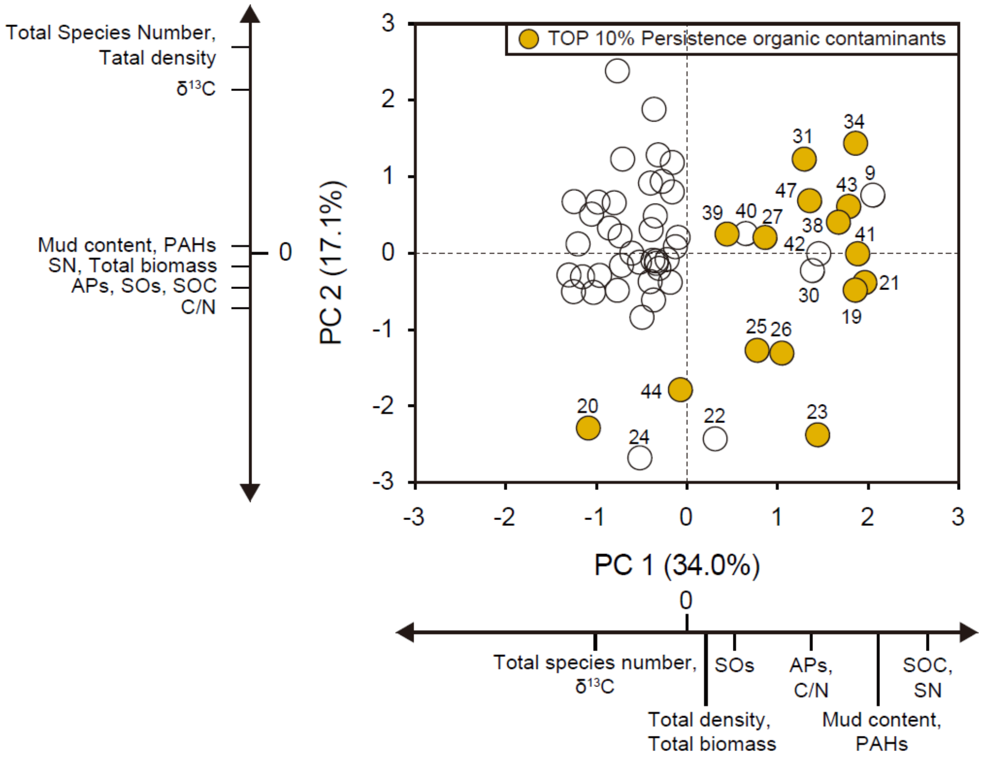

Figure 2.7.
Principal component analysis (PCA) for factors controlling the macrofaunal community.

The correlation of the macrofaunal community with environmental parameters was used to determine the coefficient of determination and *p*-value (Table 2.5). The total number of species was significantly correlated with $\delta^{13}C$ ($r = 0.72$, $p < 0.01$); however, there was only a low correlation with the other parameters. The total density and biomass were poorly correlated with all parameters, except for total biomass and $\delta^{13}C$ ($p < 0.05$). In the macrofaunal community, the number of Polychaeta species was highly correlated with $\delta^{13}C$ ($r = 0.67$, $p < 0.01$), followed by Arthropoda and Mollusca (Figure 2.8). Although only stable carbon-stable isotope ratio was used as the main environmental factor in this study, the most influential factor in the environment may be salinity caused by freshwater inflow. The same researchers analyzed the spearman correlation between the salinity obtained near the sites and $\delta^{13}C$ showed a significant positive correlation ($r = 0.47$, $p < 0.01$). This result indicated that the inflow of fresh water changes the physical environment first and at the same time transports terrestrial origin organic matter. Overall, the macrofaunal community (particularly Polychaeta) was more highly correlated with $\delta^{13}C$ compared to all other parameters.

The distribution of the macrofaunal community was affected by $\delta^{13}C$ along the Geum River Estuary (between sites 17 and 30), and differed with increasing distance from the mouth of the estuary (Table 2.6). High numbers of species were found that contained heavier $\delta^{13}C$ values and that were located far away from the mouth of Geum River Estuary (Site 17, 29, 28, 30, and 27). But, the numbers of individuals and biomass were similar, or lower, further away from the mouth when compared to closer to the mouth. A low number of species was detected at sites, which were supplied with terrestrial organic matter ($\delta^{13}C < -23$). But, high biomass was detected near dike due to *Potamocorbula amurensis*, which is an invasive species (Lowe et al., 2000). This high biomass dominated because the estuarine area was highly affected by the river input of terrestrial phytodetritus (Hermand et al., 2008). Many Polychaeta species were dominated in sites affected by terrestrial organic matter because they exploit terrestrial organic matter (Darnaude et al., 2004). Furthermore, opportunistic species and organic pollution indicator species (such as *Spiochaetopterus costarum*, *Sigambra tentaculata*, *Sinocorophium sinensis*, and *Prionospio membranacea*) dominated at the sites affected by terrestrial organic matter. Thus, the input of terrestrial organic matter caused an enriched environment and influenced the macrobenthic faunal assemblages in the given area. Therefore, in general, the origin of sedimentary organic matter was an important factor controlling the macrofaunal community at this time.

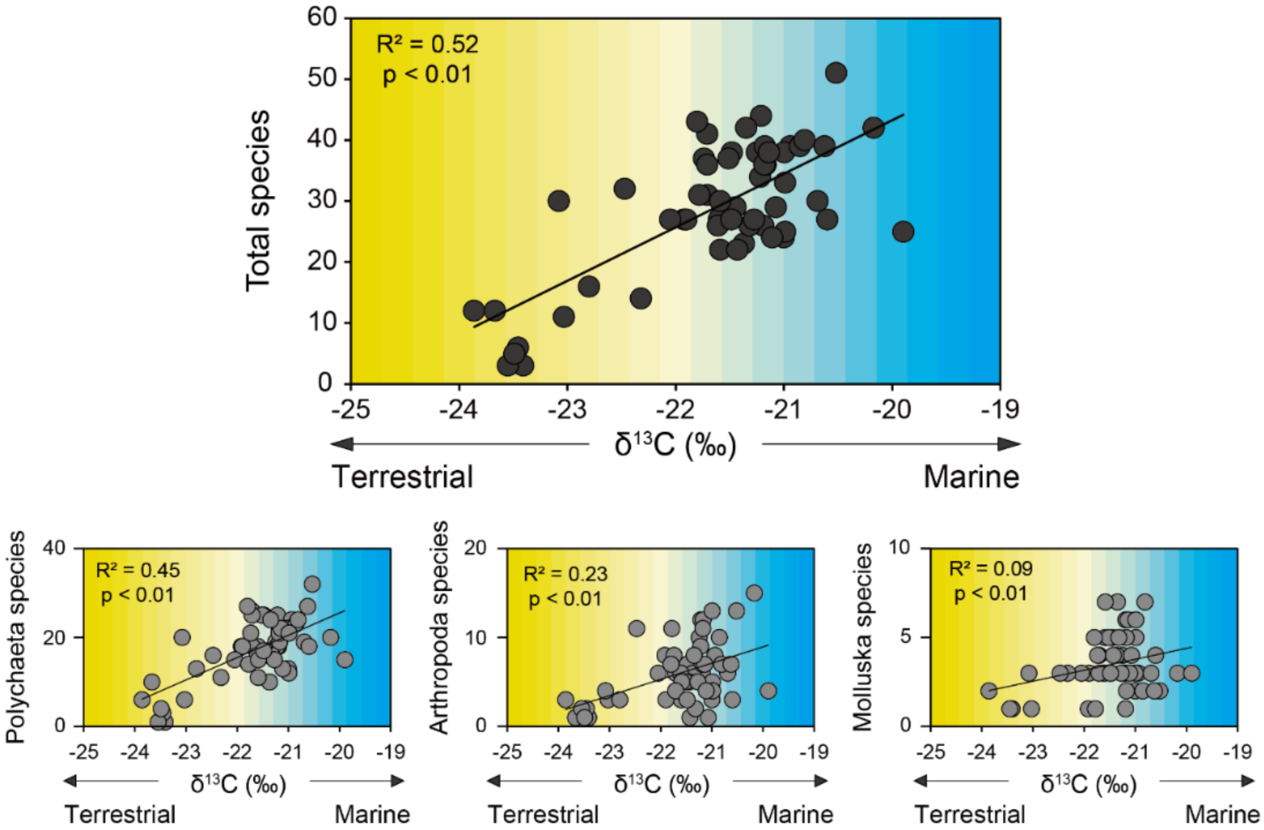

Figure 2.8.
Correlations between the macrofaunal community and $\delta^{13}C$ values in sediments of the Geum River Estuary and Saemangeum Coast.

Table 2.5.
Correlation between environmental parameters and the macrofaunal community.

Environmental parameters	Species number (number)		Density (individual/m^2)		Biomass (g wet weight/m^2)	
	r^2	p-Value	r^2	p-Value	r^2	p-Value
PAHs (ng g^{-1})	0.01	0.41	0.03	0.24	0.05	0.09
APs (ng g^{-1})	0.01	0.49	0.01	0.69	0.01	0.41
SOs (ng g^{-1})	0.01	0.64	0.01	0.40	0.01	0.90
TOC (%)	0.06	0.07	0.01	0.57	0.01	0.42
TN (%)	0.03	0.21	0.03	0.20	0.03	0.23
C/N	0.06	0.08	0.05	0.09	0.06	0.07
δ^{13}C (‰)	0.52	$<0.01^{**}$	0.05	0.11	0.10	0.01^{*}
Mud content (%)	0.01	0.73	0.06	0.07	0.01	0.46

Table 2.6.

Characteristics of sites 17 to 30 classified based on their environmental parameters and macrofaunal community.

Sites	17	29	28	30	27	26	25	22	24	21	23	20	19	18
Environmental parameters														
$\delta^{13}C$ (‰)	-21.2	-21.2	-20.9	-21.4	-21.8	-22.3	-22.8	-23.5	-23.5	-23.7	-23.6	-23.4	-23.9	-23.0
Total organic carbon	0.2	0.1	0.1	0.8	0.6	0.8	0.5	0.8	0.2	1.3	0.8	0.1	1.1	0.3
Polycyclic aromatic hydrocarbons	41.3	4.0	6.4	63.4	55.2	39.9	53.9	31.2	18.1	45.3	119.0	22.6	153.1	39.3
Alkylphenols	9.8	1.0	10.1	15.1	6.6	13.4	15.1	4.8	11.4	18.3	31.4	4.4	7.5	10.7
Styrene oligomers	2.3	9.5	20.4	6.3	11.7	26.2	9.5	1.2	11.0	16.7	6.3	40.3	11.5	4.7
Macrofaunal community														
Total species number	44	36	39	22	30	14	16	6	5	12	3	3	12	11
Total individuals	463	243	349	144	181	107	77	18	17	413	3	23	284	212
Total biomass (g wet weight)	29.2	1.7	4.7	2.3	3.0	3.7	1.3	0.4	4.2	1.8	0.1	52.9	253.2	117.5
Dominant species[a] (%)														
(P) *Chaetopterus* sp.	**34.6**	-	-	-	-	-	-	-	-	-	-	-	-	-
(A) *Gammaropsis japonicus*	9.9	-	-	-	-	-	-	-	-	-	-	-	-	-
(A) *Photis brevipes*	**20.7**	2.5	2.3	-	**29.8**	-	-	-	-	-	-	-	-	-
(P) *Spiochaetopterus costarum*[b, c]	-	**36.6**	**47.3**	-	-	-	-	-	-	-	-	-	-	-
(A) *Urothoe brevicornis*	1.5	**23.5**	4.0	-	-	-	-	-	-	-	-	-	-	-
(P) *Sigambra tentaculata*[b]	-	0.8	0.3	7.6	-	3.7	-	-	-	0.20	-	-	-	-
(M) *Hydatina albocincta*	0.2	2.1	2.9	3.5	0.6	1.9	-	-	-	-	-	-	-	-
(P) *Heteromastus filiformis*[b, c]	1.1	3.7	5.4	**53.5**	4.4	**52.3**	18.2	**44.4**	**47.1**	8.5	-	-	3.5	1.4
(P) *Nectoneanthes multignatha*	0.2	0.4	0.9	0.7	19.3	-	11.7	-	-	-	-	-	0.4	-
(P) *Sternaspis scutata*	-	-	0.3	0.7	-	9.3	11.7	-	-	0.2	-	-	-	-
(M) *Theora fragilis*	-	-	-	-	-	13.1	-	-	-	-	-	-	-	-
(A) *Sinocorophium sinensis*[c]	-	-	-	-	-	-	**20.8**	-	-	**86.4**	-	13.0	15.1	**43.9**
(P) *Glycinde* sp.	-	-	-	0.7	-	4.7	14.3	-	-	1.0	-	-	1.1	-
(P) *Glycera chirori*	0.4	1.2	2.3	-	4.4	-	5.2	11.1	**35.3**	0.5	-	-	0.4	0.5
(P) *Neanthes japonica*[d]	-	-	-	-	-	-	-	-	-	0.5	-	-	1.4	0.5
(P) *Prionospio membranacea*[c]	-	-	-	-	-	-	-	-	-	0.2	**33.3**	13.0	-	**22.6**
(M) *Potamocorbula amurensis*	-	-	-	-	-	-	-	-	-	-	-	**73.9**	**27.5**	**22.2**
(A) *Cirripedia* sp.	-	-	-	-	-	-	-	-	-	-	-	-	**47.9**	4.7

[a] Species in bold indicate > 20% individuals in all species and acronyms: (P) Polychaeta, (A) Arthropoda, and (M) Mollusca.

[b] Opportunistic species.

[c] Organic polluted or enriched indicators.

[d] Brackish water species.

2.4. Summary

The ecological impacts of PTSs on the macrofaunal community were evaluated based on community structure with the origin of sedimentary organic matter. The pollution level of PTSs in the Saemangeum coast and Geum River estuary was generally low. Although concentrations of PTSs were generally below the Canadian sediment quality guidelines, relatively greater concentrations of PTSs were found at some sites adjacent to industrial complexes and the estuarine area. The most dominant taxon was Polychaeta in Saemangeum Coast and Geum River Estuary. Some sites near watergate had about 2 to 3‰ lighter $\delta^{13}C$ values compared to other areas, indicating that these sites are affected by terrestrial organic matter. *Heteromastus filiformis*, which is a potential indicator of accumulation of organic matter, was the most dominant species. The macrofaunal community was mainly affected by the origin of organic matter, especially on the number of species and density, while the PTSs did not show a distinct effect. Relatively low species and density were found in the area with the terrestrial origin of organic matter, and species and populations increased in sediments of marine origin of organic matter. Thus, the origin of sedimentary organic matter could be controlling the macrofaunal community.

CHAPTER 3.

MACROZOOBENTHIC COMMUNITY RESPONSES TO SEDIMENTARY CONTAMINATIONS BY ANTHROPOGENIC TOXIC SUBSTANCES IN THE GEUM RIVER ESTUARY, SOUTH KOREA

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3.1. Introduction

The estuary is a dynamic and productive environment, but one of the most threatened coastal ecosystems primarily due to its geographical feature (McLuski and Elliot, 2006). Various substances are introduced to estuaries, via rivers from the land as a direct or indirect result of human activities, that accumulate in the sediment as major sinks for particle matter (Witt, 1995). Along with freshwater, organic matters, nutrients, and persistent toxic substances (PTSs) are introduced to estuaries, altering the environment. Metals, metalloid (As), polycyclic aromatic hydrocarbons (PAHs), and alkylphenols (APs) are widely reported sediment PTSs in contaminated coastal regions, and thus could adversely affect aquatic wildlife and human health (Tian et al., 2020; Yoon et al., 2020). These PTSs originate from both anthropogenic activities and natural sources, entering estuaries through various routes, such as sewage, industrial wastewater, surface runoff, and atmospheric deposition (Lin and Zhu, 2004; Li et al., 2013; Ghosh et al., 2015; Xu et al., 2016). PTSs that accumulate in sediment have high toxicity, persistence, bioaccumulation, and non-biodegradable (White et al., 1994; Bastami et al., 2015; Singh and Kumar, 2017, Yoon et al., 2019), posing potential ecological threats to aquatic organisms.

Benthic macrofauna has an important role in the dynamics of benthic ecosystems, resulting in their being representative taxa (Herman et al., 1999). Benthic macrofauna is sedentary for most of their lives. Because of this low mobility, they must adjust to the surrounding environmental conditions over long timeframes (Gray et al., 1992). Thus, the benthic community serves as a suitable indicator for evaluating the ecology of the benthic environment, facilitating observations of various feeding patterns, life-history, and dominant species (Dauvin et al., 2010; Patrício et al., 2012). Opportunistic species and indicator species often appear in organically enriched and contaminated environments; thus the emergence of specific species is important for interpreting the ecological situation appropriately (Ugland et al., 2008; Pelletier et al., 2010).

The distribution of macrofaunal communities is influenced by a wide variety of factors by anthropogenic and natural disturbances (including pollution by toxic contaminants and organic enrichment, changes to grain size, hypoxia, and seasonal variation) (Hyland et al., 2005; Sandrini-Neto et al., 2016; Bae et al., 2018, Kim et al., 2020). Many studies have used the benthic macrofauna community to evaluate responses to disturbance, with particular emphasis on the distribution of contaminants of anthropogenic origin (Hyland et al., 2005; Sandrini-Neto et al., 2016; Bae et al., 2017). The responses of the macrozoobenthic communities to contaminated areas have been studied in relation to the distribution of various pollutants, including metals and PAHs, as well as organochlorine pesticides, organotins, polychlorinated biphenyls (PCBs), and polybrominated diphenyl ethers (PBDEs) (Zheng et al., 2011; Wetzel et al., 2012; Ryu et al., 2016; Egres et al., 2019). Although many studies have evaluated how the benthic community responds to contaminants, most only investigate individual pollutants and/or simple relationships (or correlations) between contaminants and diversity indices (Ryu et al., 2011; Rumisha et al., 2012; Bae et al., 2017; Egres et al., 2019).

The Geum River Estuary in South Korea has been subject to continuous development since the construction of the estuary dam in 1990, and the completion of the Gunsan National Industrial Complex in 1992. Gunsan is a city located near the estuary that is a representative city of southwestern Korea. The manufacturing industry of this city continues to grow, in parallel to it being an international trade port. Consequently, the ecosystem of the Geum River Estuary has been impacted by a combination of changes to the physical, geological, and chemical environment, including decreased tidal cycles, changes to seabed topography, the irregular inflow of freshwater, deterioration of water quality, and contamination by PTSs (Lee et al., 1999; Kwon et al., 2001; Kim et al., 2006; Seo and Park, 2007; Shin et al., 2013; Yoon et al., 2017). Some studies on PTSs in this area demonstrated that, although contamination levels were not high, the degree of contamination in the inner part of the estuary was relatively high (Jeon et al., 2017; Yoon et al., 2017). Meantime, several studies documented the impacts of environmental changes on marine ecosystems, terrestrial origin organic matter on macrobenthos (Yoon et al., 2017), and eutrophication on phytoplankton in the given estuary (Shin, 2013). Of note, however, those earlier studies were limited to survey in a single season and of only a few parameters. Hence, it is necessary to evaluate how the seasonal and spatial distribution of PTSs and benthic communities change with freshwater discharge and the temporary influx of matter of terrestrial origin across all seasons.

The specific aims of the present study were to: (1) determine the spatiotemporal distribution of PTSs, (2) identify sources and fresh input of PTSs, (3) characterize spatiotemporal patterns of macrofaunal assemblages, and (4) evaluate key factors influencing the spatiotemporal changes in macrofaunal communities. This study will serve as one of few exercises reporting seasonal variations of PTSs and benthic macrofaunal communities, addressing the ecosystem response to anthropogenic activities in a typically closed estuary of the Yellow Sea.

3.2. Materials and Methods

3.2.1. Study area and sampling

The Geum River Estuary was specifically targeted for this study. The estuary is located in the southwestern part of Korea, representing a typical estuary area forming where the Geum River meets the Yellow Sea (Figure 3.1a). Of note, this estuary has been severely impacted by the construction of an artificial dam. The inner part of the estuary (stations 1 to 3) is surrounded by industrial and urban areas and ports, and the estuary dam. The Geum River Estuary is subjected to higher wave energy in the winter (February and December) compared to the summer (June and August). The water temperature differs by about 20 °C or more between summer and winter, which is one critical environmental feature representing a dynamic oceanographic setting. A salinity gradient also exists due to the irregular discharge of freshwater from the estuary dam (Figure 3.1b). Altogether, the very estuary shows a dynamic environment in which water quality parameters are directly/indirectly affected by these distinct seasonal differences and/or episodic event of freshwater input to the offshore.

Sediment and benthic macrofauna samples were collected from the bottom water and sediment at eight stations every two months (February, April, June, August, October, and December) during 2015. Bottom water samples were collected using a Niskin bottle for water parameters (temperature, salinity, pH, dissolved oxygen [DO], chemical oxygen demand [COD], suspended sediment [SS], chlorophyll-*a* [Chl-*a*], nitrate [NO_3^-], nitrite [NO_2^-], ammonium [NH_4^+], dissolved inorganic nitrogen [DIN, a sum of NO_3^-, NO_2^-, and NH_4^+), total nitrogen [TN], phosphates [PO_4^-], total phosphorus [TP], and Silica [SiO_2]). Undisturbed sediment samples were collected using a Van Veen grab sampler. These samples were used to analyze PTSs, sediment properties, and macrofaunal assemblages. All samples collected for laboratory analyses were stored using polyethylene bottles and glass bottles in an icebox with ice or dry ice. Macrofauna samples were collected after sieving sediment and fixed using buffered formalin. Water temperature, salinity, pH, and DO were measured in situ using YSI 556 Multiprobe System (YSI, Yellow Springs, OH).

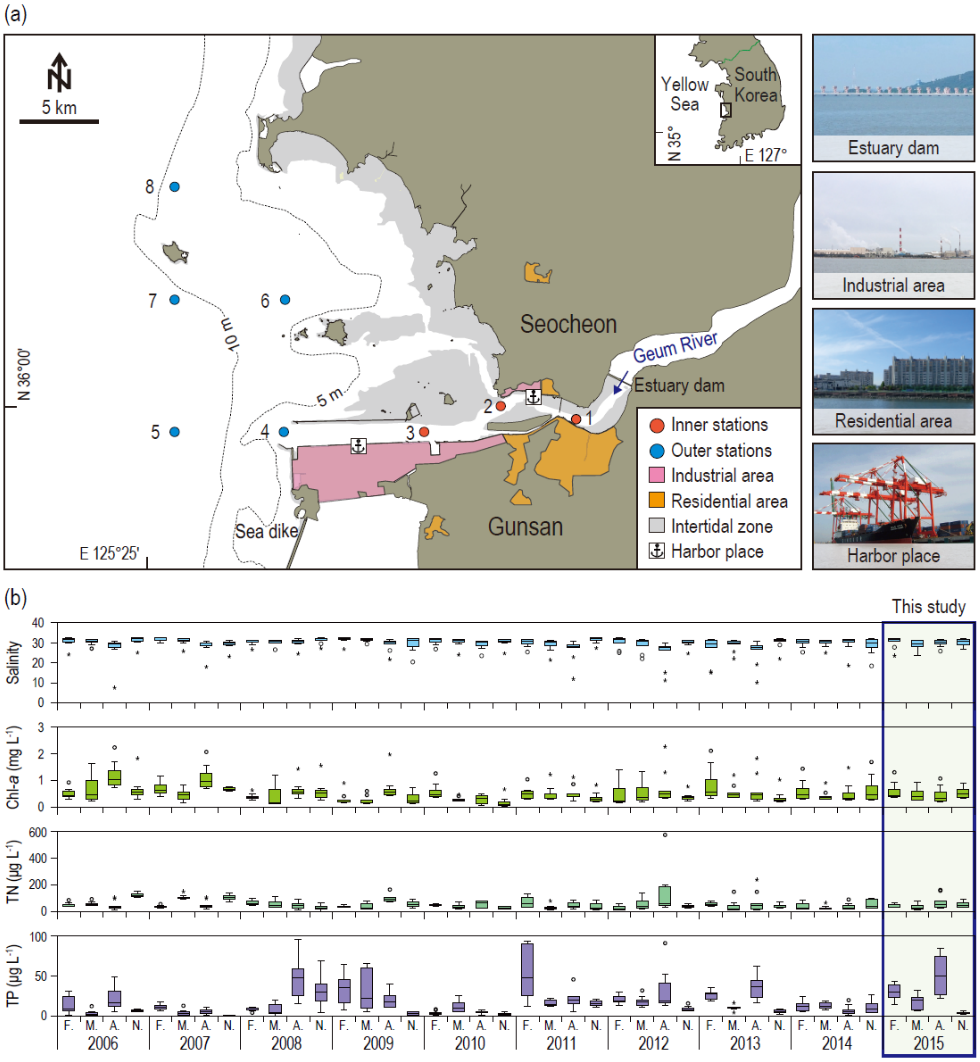

Figure 3.1.
(a) Map showing the study area and sampling stations in the Geum River Estuary, Korea. Images on the right present the surrounding environment. (b) National monitoring data for salinity, Chl-*a*, TN, and TP in the bottom water of the Geum River Estuary over the last decade.

3.2.2. PTS analyses

Sediment samples were prepared to analyze PAHs and APs following an existing method, with minor modifications (Khim et al., 1999). Detailed methods of sample preparation and the instrumental conditions are provided in Table 3.1 (see Chapter 2). Method detection limits (MDLs) were determined as standard deviations 3.707 times that of standard samples. The ranges of MDLs were 0.27–0.90 ng g^{-1} for PAHs, and 0.10–0.91 ng g^{-1} for APs. Recoveries for the five surrogate standards and standard reference material 1944 were generally acceptable: 72%–121% (mean = 90%) and 80%–126% (mean = 106%) (Table 3.2).

Metals in sediments were analyzed in accordance with the Korean Standard Method for Marine Environment (MOF, 2013). In brief, for Cd, Cr, Cu, Li, Ni, Pb, and Zn, 0.2 g freeze-dried and homogenized sediment was conducted on a hot plate with nitric acid (HNO_3, Sigma Aldrich) and perchloric acid ($HClO_4$, Sigma Aldrich) as 3:1 v/v. After evaporation, 2 mL $HClO_4$ and 5 mL hydrofluoric acid (HF, Sigma Aldrich) were added and re-evaporated. The residue was dissolved with 1 mL concentrated nitric acid and diluted with 10 mL HNO_3. Finally, samples were analyzed using an Elan 6100 inductively coupled plasma mass spectrometer (ICP-MS) (Perkin-Elmer SCIEX, Norwalk, CT) and Optima 7300DV ICP-optical emission spectrometer (ICP-OES) (Perkin-Elmer SCIEX) (Figure 3.2). For As and Hg, 0.2 g freeze-dried sediment was dissolved by shaking it with 10 mL of 10% HNO_3 and 50 mL of 1 M hydrochloric acid (HCl, Sigma Aldrich), respectively. Residues were centrifuged, and the supernatant was determined using ICP-MS and a FIMS 100 mercury analysis system (Perkin-Elmer SCIEX), respectively. Recovery of the standard reference material, MESS-3 for sediment, was generally acceptable: 81%–97% (mean = 86%) (Table 3.2).

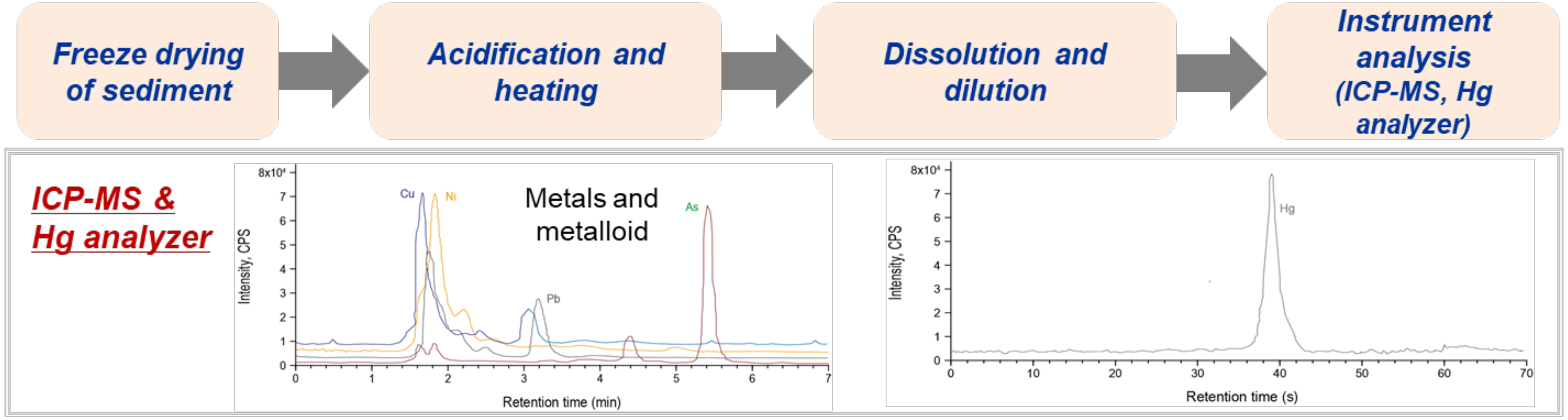

Figure 3.2.
The analysis method of metals (Cd, Cr, Cu, Hg, Li, Ni, Pb, and Zn) and metalloid (As).

Table 3.1.
Instrumental conditions of the gas chromatograph equipped with a mass selective detector for the analyses of PAHs and APs.

GC/MSD system	Agilent 7890A GC and 5975C MSD
Column	DB-5MS UI (30 m long, 0.25 mm i.d., 0.25 μm film thickness)
Gas flow	1 mL/min He
Injection mode	Splitless
Injection volume	2 μL
Injector temperature	300 °C
Ionization	EI mode (70 eV)
MS temperature	180 °C
Detector temperature	230 °C
Oven temperature (PAHs)	60 °C hold 2 min Increase 6 °C/min to 300 °C 300 °C hold 13 min
Oven temperature (APs)	60 °C hold 5 min Increase 10 °C/min to 100 °C Increase 20 °C/min to 300 °C
Targeted PAHs (16)	Acenaphthylene (Acl), Acenaphthene (Ace), Fluorene (Flu), Phenanthrene (Phe), Anthracene (Ant), Fluoranthene (Fl), Pyrene (Py), Benzo[*a*]anthracene (BaA), Chrysene (Chr), Benzo[*b*]fluoranthene (BbF), Benzo[*k*]fluoranthene (BkF), Benzo[*a*]pyrene (BaP), Perylene (Pery), Indeno[*1,2,3-c,d*]pyrene (IcdP), Dibenz[*a,h*]anthracene (DbahA), and Benzo[*g,h,i*]perylene (BghiP)
Targeted APs (6)	4-tert-Octylphenol (OP), 4-tert-Octylphenol monoethoxylate (OP1EO), 4-tert-Octylphenol diethoxylate (OP2EO), Nonylphenols (NPs, isomer mix), Nonylphenol monoethoxylates (NP1EOs, isomer mix), and Nonylphenol diethoxylates (NP2EOs, isomer mix)

Table 3.2.
Certified and measured concentrations for selected PAHs and metals in standard reference material (SRM) to check the accuracy of the method.

PAHs	Certified concentration	Measured concentration	Recovery (%)
SRM-1944[a]			
Phenanthrene	5.3 ± 0.2	4.6 ± 0.3	87 ± 5.3
Fluoranthene	8.9 ± 0.3	7.8 ± 0.1	87 ± 1.6
Pyrene	9.7 ± 0.4	7.9 ± 0.3	81 ± 2.9
Benz[*a*]anthracene	4.7 ± 0.1	4.8 ± 0.2	102 ± 5.1
Chrysene	4.9 ± 0.1	4.1 ± 0.2	85 ± 3.3
Benzo[*b*]fluoranthene	3.9 ± 0.4	4.7 ± 0.2	121 ± 6.4
Benzo[*j*]fluoranthene	2.1 ± 0.4	2.1 ± 0.1	103 ± 3.6
Benzo[*k*]fluoranthene	2.3 ± 0.2	2.9 ± 0.2	126 ± 7.7
Benzo[*a*]pyrene	4.3 ± 0.1	5.3 ± 0.2	122 ± 5.1
Benzo[*e*]pyrene	3.3 ± 0.1	4.0 ± 0.1	122 ± 4.1
Perylene	1.2 ± 0.2	0.9 ± 0.1	80 ± 4.9
Indeno[1,2,3-*c,d*]pyrene	2.8 ± 0.1	3.3 ± 0.2	119 ± 4.9
Dibenz[*a,h*]anthracene	4.2 ± 0.1	5.1 ± 0.1	121 ± 1.8
Benzo[*g,h,i*]perylene	4.8 ± 0.1	3.5 ± 0.1	122 ± 2.7
MESS-3[b]			
Cd	0.24 ± 0.01	0.20 ± 0.01	83 ± 4.2
Cr	105 ± 4.0	87.0 ± 2.0	83 ± 1.9
Cu	33.9 ± 1.6	29.3 ± 2.9	86 ± 8.6
Li	73.6 ± 5.2	65.8 ± 0.7	89 ± 1.0
Ni	46.9 ± 2.2	45.3 ± 0.7	97 ± 1.5
Pb	21.1 ± 0.7	17.4 ± 0.3	82 ± 1.4
Zn	159 ± 8.0	128 ± 2.9	81 ± 1.8

[a] ng g^{-1} dry weight
[b] mg kg^{-1} dry weight

3.2.3. Environment parameters and macrobenthic fauna analyses

COD was analyzed using non-filtered seawater with the alkaline permanganate method (MOF, 2013). Other parameters were measured after filtering using GF/F and 0.45 μm membrane filters. Particulate samples for the analyses of SS and Chl-*a* were measured using weight comparisons and a 10-AU fluorescence spectrometer (Turner Design, San Jose, CA), respectively. Concentrations of nutrients were determined by the colorimetric assay method with a spectrophotometer. The grain size of sediment was analyzed following the dry sieve (Ingram, 1971) and pipetted (McBride, 1971) methods. Organic content (OC) was analyzed by burning the sediment for 4 h at 550 °C (Heiri et al., 2001). Macrofauna samples were rinsed and placed in diluted formalin. Identification to the species level (total of 48 species) followed by counting (total of 7986 individuals) was performed using a dissection microscope.

3.2.4. Data analyses

Based on the distance from the estuary dam and salinity (<30), stations 1–3 were set as being the inner part of the estuary, and stations 4–8 were set as being the outer part of the estuary, for spatial comparison. The concentrations of Cu and Pb in sediment were normalized using Li concentrations following Song et al. (2017), for comparison with the sediment quality guideline of Korea (MOF, 2018). The positive matrix factorization receptor (PMF) model was used to allocate sources to the PAHs (Norris et al., 2014). A detailed method on the PMF model is provided in Yoon et al. (2020). As a result of performing the PMF model, the slope in the linear regression formula ranged from 0.45 to 1.00, with R^2 value ranging from 0.62 to 0.99. These results indicated that the performance of the PMF model applied in this study was satisfactory. Statistical analyses were conducted using the software SPSS 25.0 (SPSS INC., Chicago, IL), PRIMER 6 (PRIMER-E Ltd., Plymouth, UK), and R studio version 3.6.3 (R Development Core Team, 2014).

Spearman correlation was carried out to investigate significant relationships between PTSs and environmental parameters because the variables did not satisfy normality. The Kruskal-Wallis test and the Mann-Whitney test with Bonferroni correction were used to evaluate differences among the sampling month. In the original data matrix, there were fewer species with <1% total macrofaunal abundance. The abundance data of macrofauna were log(x+1) transformed. Two ecological indices were monitored to analyze the benthic communities using the Shannon-Wiener diversity index (H') and Ecological Quality Ratio (EQR) (Ryu et al., 2016). A Bray-Curtis similarity matrix was constructed, and cluster analysis (CA) and non-metric multi-dimensional scaling (nMDS) were used to group sampling stations at spatial and temporal scales. Permutational multivariate analysis of variance (PERMANOVA) was applied with the Monte Carlo test to ascertain whether the composition of the macrofaunal assemblage significantly differed across spatial and temporal scales. The zone (inner part and outer part) and sampling month were fixed factors. The homogeneity of multivariate dispersions was tested using tests of homogeneity of dispersion (PERMDISP).

A distance-based linear model (DistLM) was performed to explore the relationships between the macrofaunal community and environmental variables. The key factors determining the pattern of macrofaunal community assemblages were determined. Variables that had a high correlation (> 0.8) were excluded to avoid co-linearity. Step-wise selection and An Information Criterion were applied to determine the influence of different variables. The results of the DistLM was visualized using distance-based redundancy ordination analysis (dbRDA). To identify indicator taxa within each group based on the dbRDA results, indicator value (IndVal) analysis was used (Dufrene and Legendre, 1997). Significant representative relationships delineated by DistLM were tested using canonical analysis of principal coordinates (CAP), to place macrofaunal assemblages along the environmental gradient.

3.3. Results and Discussion

3.3.1. Spatiotemporal distributions of metals and the metalloid

All the metals and the metalloid were detected in the sediments of all stations across all months in the Geum River Estuary (Table 3.3). The concentrations of metals and the metalloid showed no consistent trend across months. Out of the sampling months, statistically significant differences ($p < 0.05$) were only found for As, Hg, and Pb, indicating a slight effect by seasonal factors (Table 3.4). The concentration of As was statistically high in April, August, and October, while concentrations of Hg and Pb were statistically high in June and October, respectively. These irregular results suggest that the effects of metals and the metalloid are independent of the season, and the result of differences in anthropogenic and/or natural inputs of individual metals and the metalloid (Cheggour et al., 2005). While seasonal variations were unclear, the distribution of metals and the metalloid was clearly distinguished spatially (Figure 3.3). Relatively high concentrations of all metals and the metalloid were detected in the inner part of the estuary, with statistically significant values ($p < 0.05$) being recorded for all metals and metalloid, except Cd (Figure 3.4a and Table 3.5). The mean concentrations of metals and the metalloid in the inner part of the estuary (stations 1 to 3) were about 1.3 to 5.9 times higher compared to those in the outer estuary (stations 4 to 8). Thus, industrial complexes, residential areas, and harbors located in the inner part of the estuary likely represent major sources of metals in the sediment (Zhao et al., 2018; Liu et al., 2019). Overall, the distribution of metals and the metalloid in the sediment of the Geum River Estuary was mainly determined by spatial factors, rather than seasonal factors.

Table 3.3.

Data statistics of the selected environmental variables and macrofauna community structure monitored in the Geum River Estuary, Korea, over one-year (2015). Minimum, maximum, mean, and standard deviation of the environmental variables are provided.

Target analytes	All (year total)			Month					
	Min	Max	Mean (± SD)	2 Mean (± SD)	4	6	8	10	12
Sediment									
As (mg kg^{-1})	0.8	4.9	2.2 (± 0.9)	2.1 (± 0.7)	2.6 (± 0.5)	1.2 (± 0.3)	2.8 (± 1.0)	2.4 (± 0.6)	2.4 (± 0.9)
Cd (mg kg^{-1})	0.01	0.16	0.06 (± 0.04)	0.08 (± 0.05)	0.08 (± 0.04)	0.09 (± 0.05)	0.04 (± 0.03)	0.06 (± 0.03)	0.04 (± 0.03)
Cr (mg kg^{-1})	4.4	73.5	33.7 (± 15.2)	23.3 (± 11.4)	27.6 (± 8.2)	38.1 (± 10.2)	32.6 (± 11.2)	41.6 (± 16.3)	38.9 (± 21.0)
Cu (mg kg^{-1})[a]	1.0	480	21.4 (± 70.3)	5.6 (± 4.0)	80.6 (± 157)	7.3 (± 5.7)	7.1 (± 5.6)	12.4 (± 10.5)	15.6 (± 26.5)
Hg (μg kg^{-1})	0.8	23.1	6.5 (± 4.7)	3.5 (± 1.9)	3.6 (± 0.9)	13.7 (± 6.1)	7.7 (± 0.9)	3.8 (± 1.5)	6.5 (± 3.4)
Ni (mg kg^{-1})	2.3	30.4	12.1 (± 6.3)	8.9 (± 4.1)	11.3 (± 3.8)	12.4 (± 4.5)	11.0 (± 4.9)	14.8 (± 7.5)	14.0 (± 9.1)
Pb (mg kg^{-1})	4.5	36.0	17.6 (± 5.1)	14.3 (± 4.2)	15.5 (± 2.6)	18.4 (± 2.8)	15.0 (± 3.5)	22.5 (± 6.2)	19.9 (± 4.45)
Zn (mg kg^{-1})[a]	5.5	1078	70.2 (± 159)	26.7 (± 14.6)	201 (± 349)	45.6 (± 18.5)	31.4 (± 14.7)	52.8 (± 34.9)	64.2 (± 84.6)
PAHs (ng g^{-1})	ND.	205	39.6 (± 49.3)	42.4 (± 46.8)	38.4 (± 37.2)	87.9 (± 73.0)	18.8 (± 29.3)	29.6 (± 26.1)	20.3 (± 29.7)
APs (ng g^{-1})	0.6	32.6	7.1 (± 6.8)	11.4 (± 9.6)	6.4 (± 4.8)	10.7 (± 8.0)	5.6 (± 3.6)	4.4 (± 4.8)	4.4 (± 3.1)
Mud content (%)	0	98.9	26.4 (± 26)	16.8 (± 18.8)	21.9 (± 23.5)	35.4 (± 24.6)	20.2 (± 19.0)	35.0 (± 25.7)	29.1 (± 34.8)
Loss on ignition (%)	0.9	6.2	2.2 (± 1.2)	1.9 (± 0.9)	2.5 (± 1.1)	2.6 (± 1.0)	1.7 (± 0.8)	2.4 (± 1.0)	2.2 (± 1.7)
Bottom water									
Temperature (˚C)	2.7	27.6	14.7 (± 7.9)	3.6 (± 0.6)	9.9 (± 0.9)	21.1 (± 1.1)	26.5 (± 0.8)	18.3 (± 0.9)	8.9 (± 0.9)
Salinity (psu)	19.8	32.8	30.3 (± 3.2)	29.7 (± 4.1)	29.5 (± 3.8)	30.1 (± 3.1)	30.4 (± 2.4)	31.2 (± 2.8)	30.8 (± 2.1)
pH	7.7	8.5	8.1 (± 0.2)	8.2 (± 0.1)	8.4 (± 0.1)	8.0 (± 0.1)	8.0 (± 0.1)	7.9 (± 0.1)	8.1 (± 0.1)
DO (mg L^{-1})	2.9	11.9	7.9 (± 2.7)	10.9 (± 0.6)	10.2 (± 1.2)	5.9 (± 1.0)	3.7 (± 0.4)	7.3 (± 0.3)	9.7 (± 0.3)
COD (mg L^{-1})	1.2	8.8	3.7 (± 1.7)	1.8 (± 0.8)	2.9 (± 0.8)	5.0 (± 2.2)	3.8 (± 1.2)	4.1 (± 1.3)	4.9 (± 1.0)
SS (mg L^{-1})	4.4	151	27.5 (± 28.3)	15.5 (± 9.5)	17.7 (± 13.5)	23.7 (± 17.2)	16.3 (± 10.0)	48.8 (± 45.3)	43.3 (± 31.4)
Chl-*a* (μg L^{-1})	0.7	13.5	4.3 (± 3.4)	7.5 (± 4.3)	6.0 (± 2.1)	3.0 (± 1.3)	5.1 (± 3.8)	3.0 (± 2.0)	1.3 (± 0.8)
DIN (μg L^{-1})	15	1460	330 (± 323)	542 (± 407)	120 (± 184)	252 (± 285)	264 (± 288)	338 (± 243)	464 (± 290)
TN (μg L^{-1})	326	2040	762 (± 370)	863 (± 538)	686 (± 300)	593 (± 221)	801 (± 282)	696 (± 183)	930 (± 448)
PO_4 (μg L^{-1})	0.5	76.6	22.2 (± 19.2)	21.2 (± 7.0)	2.4 (± 2.0)	11.8 (± 10.3)	11.0 (± 13.1)	41.3 (± 13.8)	45.4 (± 12.7)
TP (μg L^{-1})	15.2	386	73.4 (± 69.1)	41.4 (± 6.0)	44.0 (± 25.2)	41.9 (± 29.7)	57.2 (± 32.2)	159 (± 116)	96.7 (± 39.4)
SiO_2-Si (μg L^{-1})	8.3	1754	500 (± 381)	441 (± 228)	40.9 (± 44.5)	400 (± 277)	675 (± 468)	684 (± 336)	762 (± 221)

Table 3.3.

Data statistics of the selected environmental variables and macrofauna community structure monitored in the Geum River Estuary, Korea, over one-year (2015). Minimum, maximum, mean, and standard deviation of the environmental variables are provided (continued).

Target analytes	**All** (year total)			**Month**					
				2	4	6	8	10	12
	Min	Max	Mean (± SD)	Mean (± SD)					
Macrofauna community structure									
Number of taxa	1	26	14	13	14	15	16	14	12
Mean density (ind.m^{-2})	5	4125	832	830	739	1423	953	688	359
Dominant taxa*									
1st	Ann (61.0%)			Ann (50.6%)	Ann (67.9%)	Ann (54.4%)	Ann (58.9%)	Ann (68.5%)	Ann (65.5%)
2nd	Art (23.1%)			Art (31.6%)	Art (22.2%)	Art (68.8%)	Mol (16.7%)	Art (14.6%)	Art (14.9%)
3rd	Mol (9.8%)			Mol (14.9%)	Mol (7.1%)	Mol (5.4%)	Art (16.5%)	Mol (11.1%)	Mol (11.1%)
Ecological indices									
Diversity (H')	0	2.	1.8	1.7	1.9	1.6	1.9	1.8	1.8
Evenness (J)	0.3	0.9	0.7	0.6	0.8	0.7	0.7	0.7	0.8
Richness (R)	0	5.2	2.8	2.6	2.7	3.0	2.9	2.9	2.6
Dominance (D)	0.3	1.0	0.6	0.6	0.6	0.6	0.6	0.6	0.6

Table 3.4.
Statistical relationships of seasonal differences among months. The bold text highlights statistically significant relationships ($p < 0.05$).

PTSs	Kruskal-Wallis test		Month (*Post hoc* Mann-Whitney)						
	F-value	P-value	2 – 6	2 – 8	2 – 10	4 – 6	6 – 8	6 – 10	8 – 10
As	21.2	**0.001**				**0.025**	**0.002**	**0.001**	
Cd	13.0	**0.024**							
Cr	6.68	0.245							
Cu	3.49	0.626							
Hg	30.8	**<0.001**	**<0.001**	**0.019**		**0.001**		**0.002**	
Ni	4.27	0.511							
Pb	17.9	**0.003**			**0.036**				**0.015**
Zn	6.97	0.223							
PAHs	10.7	0.057							
APs	6.89	0.229							

Table 3.5.
Mann-Whitney test for comparison of monthly inner- and outer-stations. Values in bold indicate that the correlation was significant at $p < 0.05$.

	As	Cd	Cr	Cu	Hg	Ni	Pb	Zn	PAHs	APs
February	0.710	0.250	1.000	0.250	1.000	0.571	**0.036**	0.143	0.393	0.393
April	**0.036**	0.250	**0.036**	**0.036**	0.143	**0.036**	**0.036**	**0.036**	0.114	0.071
June	**0.036**	0.393	**0.036**	**0.036**	**0.036**	**0.036**	**0.036**	**0.036**	**0.036**	**0.036**
August	0.393	0.143	0.571	0.250	0.250	0.250	1.000	0.571	**0.036**	0.143
October	0.143	0.071	0.071	0.250	0.393	0.071	**0.036**	0.250	**0.036**	0.071
December	0.393	0.786	1.000	0.571	0.393	0.786	1.000	0.571	1.000	0.143

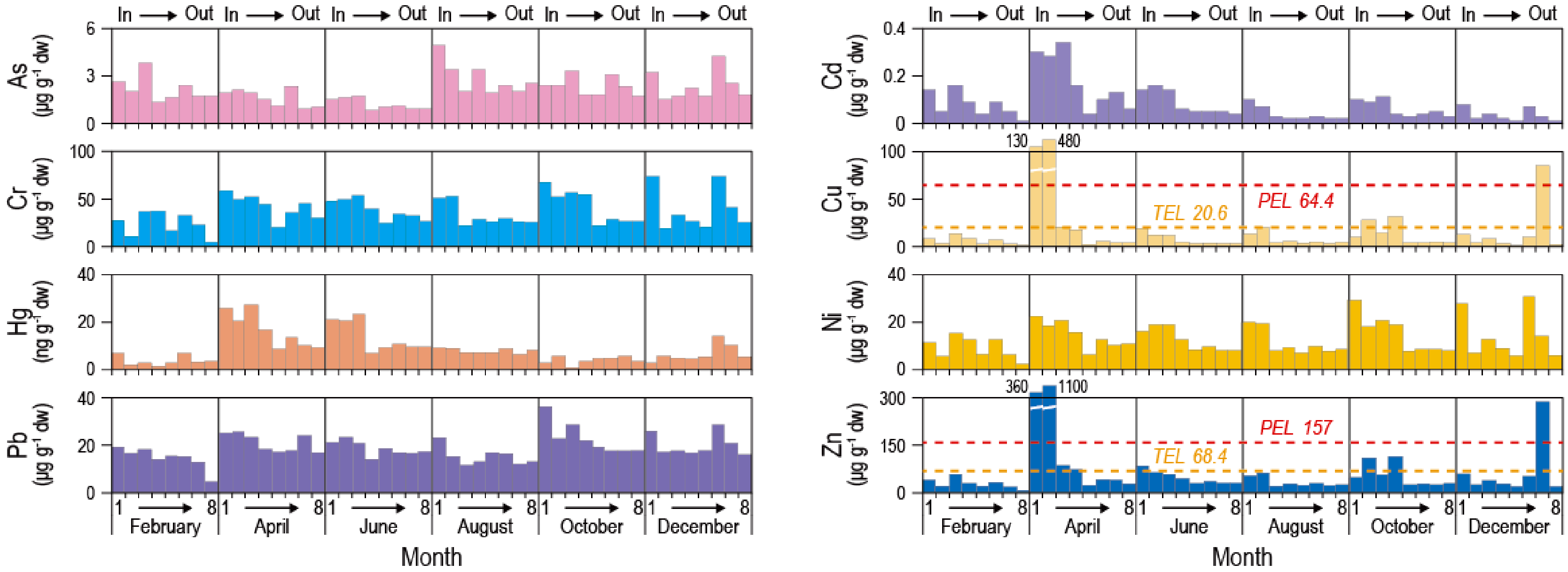

Figure 3.3.
Distribution of metals and a metalloid in sediment based on the distance from the inner part to the outsider part of the Geum River Estuary, Korea.

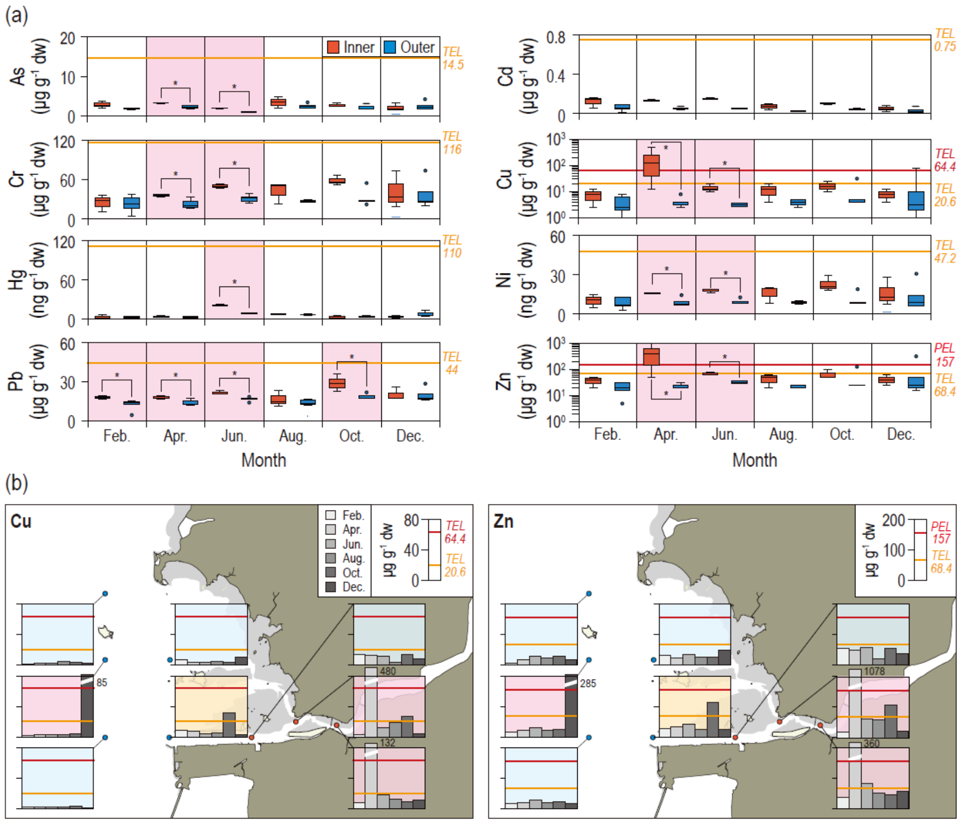

Figure 3.4.
Spatiotemporal distribution of metals and the metalloid in the sediments of the Geum River Estuary, Korea. Blue and yellow backgrounds indicate that concentrations did and did not exceed TEL, respectively; red background indicates that concentrations exceeded PEL. The graph at the top shows the concentrations in the inner and outer parts of the estuary each month. The red background on the graph indicates a case where the concentration between the inner and outer parts of the estuary was significantly different.

The concentrations of most metals and the metalloid were significantly negatively correlated ($p < 0.05$) with salinity and significantly positively correlated ($p < 0.05$) with mud and organic content (Table 3.6). Some metals showed significant positive correlations with SS (As, Cu, and Hg) and negative correlations ($p < 0.05$) with pH (Cr, Hg, Ni, and Pb). Only Hg was significantly correlated with temperature. Thus, the distribution of metals and the metalloid was mainly influenced by spatial factors and sediment properties (Lao et al., 2019; Liu et al., 2019). The results also showed that the fine-grained sediments in the Geum River Estuary are stable for contaminant retention year-round, regardless of season (Buggy et al., 2008).

Table 3.6.
Spearman correlation analysis between the persistent toxic substances and environmental parameters in bottom water and sediment. Values in bold indicate that the correlation was significant at $p < 0.05$.

	As	Cd	Cr	Cu	Hg	Ni	Pb	Zn	PAHs	APs
Temperature	-0.02	-0.08	0.24	0.14	**0.62****	0.20	0.04	0.17	0.06	-0.04
Salinity	-0.22	**-0.58****	**-0.40****	**-0.53****	0.04	**-0.52****	-0.24	**-0.52****	**-0.42****	**-0.51****
pH	0.07	-0.12	**-0.43****	-0.22	**-0.39****	**-0.38****	**-0.44****	-0.28	-0.24	-0.16
SS	**0.36***	-0.18	0.09	**0.36***	**0.38****	0.15	-0.20	0.23	0.22	**0.59****
Mud content	**0.35***	**0.69****	**0.80****	**0.71****	0.25	**0.82****	**0.63****	**0.74****	**0.75****	**0.48****
Organic content	**0.37****	**0.87****	**0.76****	**0.71****	0.13	**0.79****	**0.56****	**0.74****	**0.85****	**0.52****

* $p < 0.05$, ** $p < 0.01$.

The concentrations of metals and metalloid in sediments obtained from the present study were similar or less compared to those previously reported in the other regions of South Korea, including Jinhae Bay, the west coast of Korea, and the coastal area of the Yellow Sea (Bae et al., 2017; Kim et al., 2020; Tian et al., 2020). In addition, the concentrations of metals and the metalloid in the Geum River Estuary were generally lower compared to their background concentrations in Korean sediments (Figure 3.5) (Woo et al., 2019). The range of <MDL–22.9% (mean: 10.7%) for all metals and the metalloid exceeded the corresponding background concentrations, indicating low contamination. Thus, anthropogenic sources appeared to weakly affect the distribution of metals and the metalloid in the Geum River Estuary, suggesting that they were of mostly natural origin. The contamination status of metals and the metalloid in the sediment of the Geum River Estuary was lower compared to that previously reported (Seo and Park, 2007). Cr, Cu, Ni, Pb, and Zn concentrations decreased by 62–82% compared to the mid-2000s, implying that the benthic environment of the Geum River Estuary had improved. However, a comparison with the sediment quality guidelines of Korean marine environmental standards (MOF, 2018) showed that contamination of metals in the sediments of the Geum River Estuary was of potential ecological risk. Out of all of the metals and metalloid, only Cu and Zn concentrations exceeded the threshold effects level (TEL) and probable effects level (PEL) in both the inner and outer parts of the estuary (Figure 3.4b). Cu concentrations exceeded the guideline threshold in April, October, and December, while Zn concentrations exceeded the guideline threshold in April, June, October, and December. Thus, although the overall contamination level was low, the potential risk to aquatic organisms in the Geum River Estuary has sporadically occurred from past to present

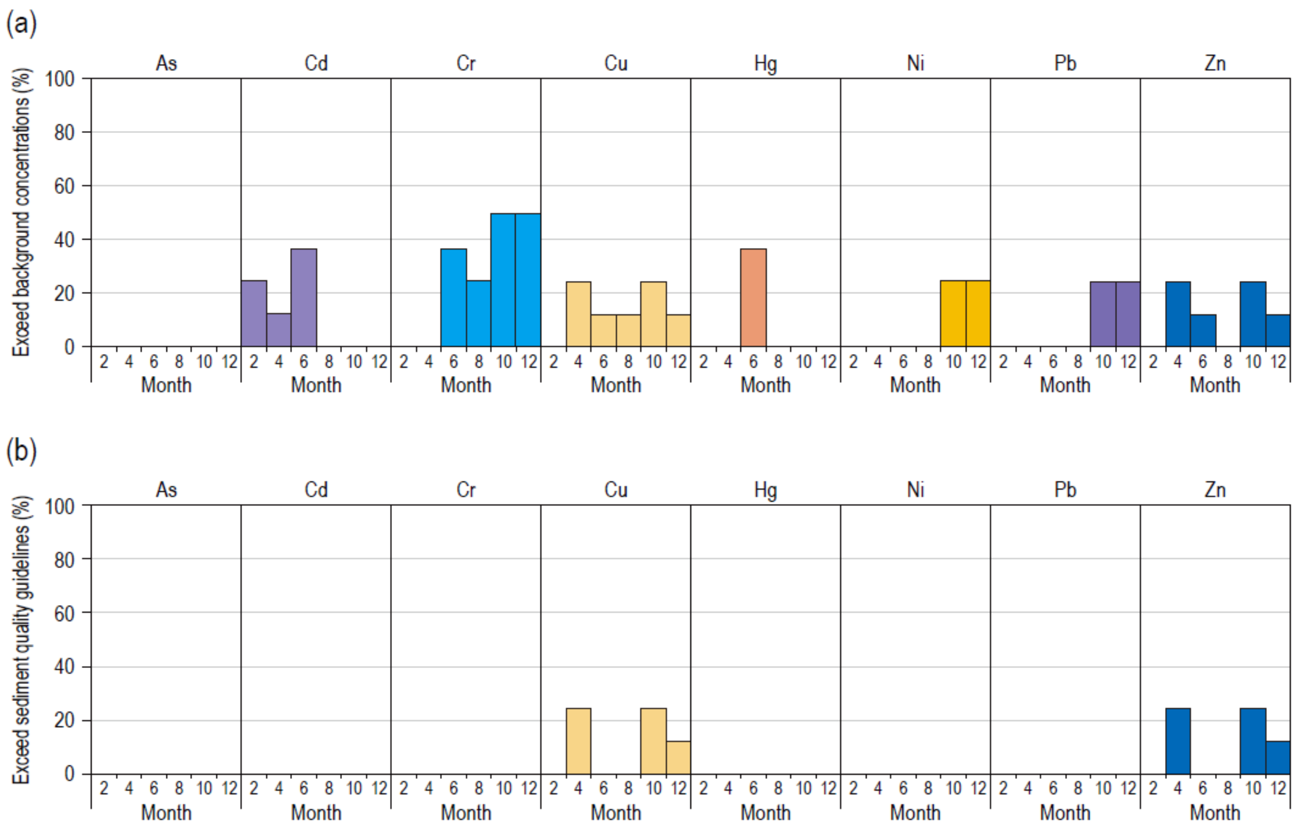

Figure 3.5.
Percentages of metals and metalloids in the sediments of the Geum River Estuary (a) exceeding background concentrations and (b) exceeding the sediment quality guidelines of Korea.

3.3.2. Spatiotemporal distributions of PAHs and APs

PAHs had a 91% detection frequency, while APs were detected in the sediments of all stations across all months (Figure 3.5a). The concentrations of PAHs and APs ranged from <MDL to 205 ng g^{-1} dw (mean: 39.6 ng g^{-1} dw) and from 0.6 to 32.6 ng g^{-1} dw (mean: 7.1 ng g^{-1} dw), respectively. The concentrations of PAHs and APs were not correlated with the season and had a similar distribution to metals. (Table 3.4). No statistically significant difference ($p > 0.05$) was found (Table 3.4) among sampling months, suggesting that the influx of similar sources continued, regardless of time. The spatial distributions of PAHs and APs were clearly divided, irrespective of time (Figure 3.6). Relatively high concentrations of PAHs and APs were detected in the inner part of the estuary with significant differences ($p < 0.05$) (Figure 3.6a and Table 3.5). The means concentrations of PAHs and APs in the inner part of the estuary were about 4.3 and 2.9 times compared to those in the outer part of the estuary, respectively. Thus, the main sources of PAHs and APs were likely industrial complexes, residential areas, and harbors around the inner part of the estuary (Ashley and Baker, 1999; Yoon et al., 2020). The concentrations of PAHs and APs were significantly correlated ($p < 0.05$) with salinity (negative), mud content (positive), and organic content (positive) (Table 3.6). Thus, the distribution of PAHs and APs in the Geum River Estuary was likely regulated by spatial factors and sediment properties (Xu et al., 2006; Liu et al., 2013). Overall, the distribution of PAHs and APs in the sediment of the Geum River Estuary was space-dependent, not seasonal.

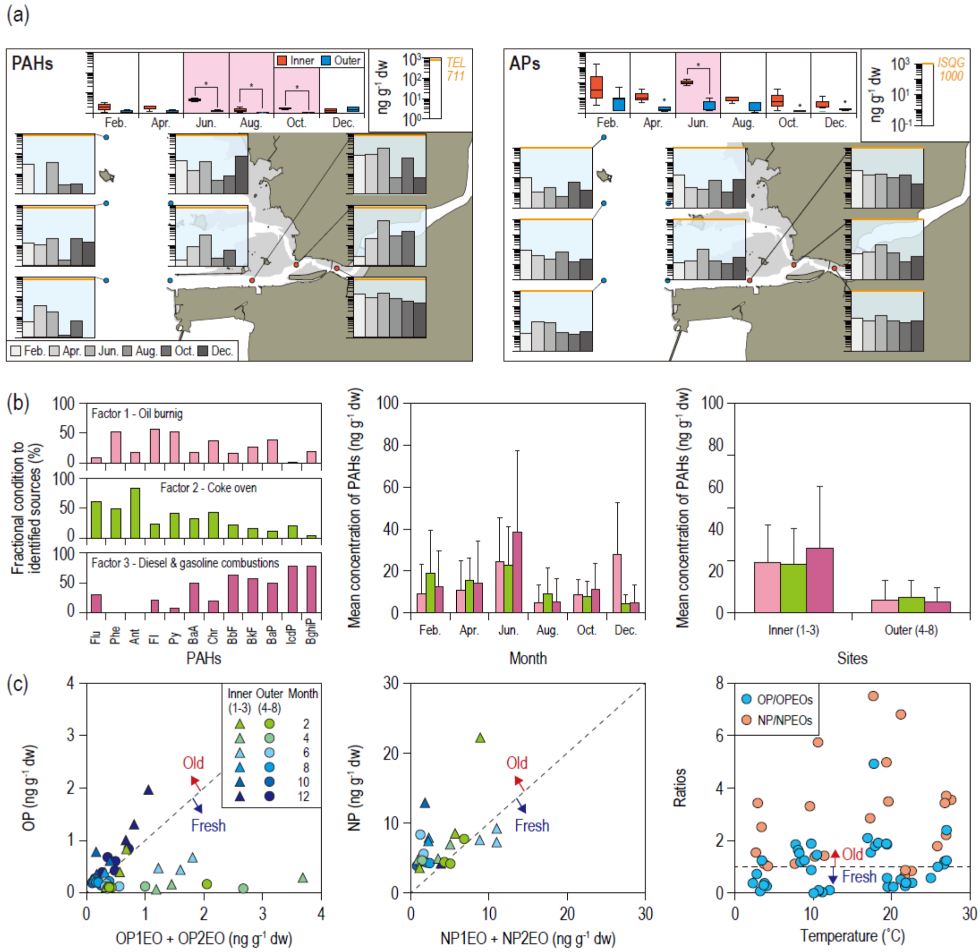

Figure 3.6.

(a) Spatiotemporal distribution of PAHs and APs in the sediments of the Geum River Estuary, Korea. The blue background indicates that the concentration did not exceed sediment quality guidelines. The graph at the top shows the concentrations in the inner and outer parts of the estuary each month. The red background on the graph indicates a case where the concentration between the inner and outer parts of the estuary was significantly different. (b) The quantitative contribution of the identified sources by positive matrix factorization receptor (PMF), and monthly and spatial distribution of each source. (c) Fresh (recent) input ratios of APs and the relationship between water temperature and fresh input ratios.

The concentrations of PAHs and APs in sediments of Geum River Estuary were similar or less compared to other regions of South Korea, including Lake Sihwa, Masan Bay, the west coast of Korea, and the coastal area of the Yellow Sea (Lee et al., 2017; 2018; Kim et al., 2020; Yoon et al., 2020). In addition, the concentrations of PAHs and APs detected in all sampling periods did not exceed the interim sediment quality guidelines (ISQG) of the Canadian Council of Ministers of the Environment (CCME, 2001, 2002). In addition, the concentrations of PAHs and APs detected in the present study were similar to those previously reported for the intertidal zone and subtidal zone of the Geum River Estuary since 2010 (Jeon et al., 2017; Yoon et al., 2017). PAHs and APs levels were in the sediment of the Geum River Estuary in the 2010s were predicted not to impact the benthic ecosystem.

The composition of PAHs was similar in time, with some spatial differences between the inner and outer parts of the estuary (Figure 3.7). Throughout the entire period, four- to six-ring PAHs were predominated (61.9–91.7%) and were dominant in the inner part of the estuary. This result was attributed to the hydrophobic nature of high molecular mass PAHs, which tend to accumulate around the source (Bixian et al., 2001; Yoon et al., 2017). The contribution of PAH sources varied with time, showing some spatial differences. The PMF model results showed that the Q_{True}/Q_{Exp} values of 2–5 factors were 2.06, 1.99, 2.27, and 2.40, respectively. The smallest Q_{True}/Q_{Exp} value was found in the result of the 3-factor, indicating the most reliable model (Crilley et al., 2017). Thus, 3-factor was selected for source identification of PAHs in Geum River Estuary. The PMF model analysis classified PAHs sources as oil burning, coke oven, and diesel & gasoline combustion (Figure 3.6b) (Khalili et al., 1995; Harrison et al., 1996; Ravindra et al., 2008). Diesel and gasoline combustion had the highest contribution, representing 36.3% of total PAHs concentration detected in the present study, followed by coke oven (32.4%) and oil burning (31.3%). Diesel and gasoline combustion were relatively high in June and October, coke oven in February, April, and August, and oil burning in December. This result indicated that various sources affected sediment seasonally. Diesel and gasoline combustion accounted for 39.6% of PAHs in the inner part of the estuary, while the most influential source in the outer part of the estuary was the coke oven (39.7%). Thus, diesel and gasoline combustion were the primary sources of PAHs in the hotspot of the Geum River Estuary, with spatially different intensities.

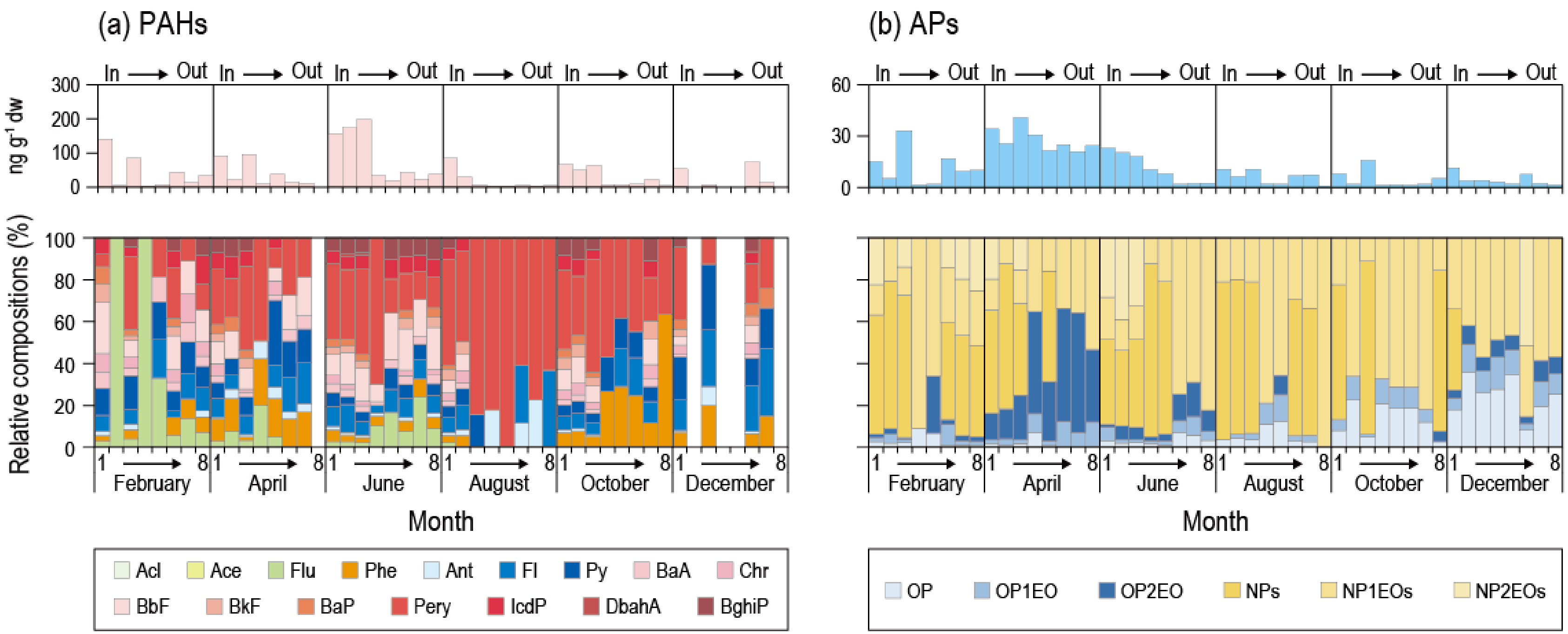

Figure 3.7.
Distribution and relative composition of (a) PAHs and (b) APs in the sediment based on the distance from the inner part to the outer part of the Geum River Estuary, Korea.

Fresh inputs of APs were evaluated based on the ratios of degraded chemicals (OPs: octylphenols and NPs: nonylphenols) and fresh chemicals (OPEOs: octylphenol ethoxylates and NPEOs: nonylphenol ethoxylates) (Figure 3.6c) (Isobe et al., 2001). Fresh inputs of OP were confirmed in February, April, and June. In comparison, fresh inputs of NP were rarely detected in any of the sampling months. For both NP and OP, the diagnostic ratio did not show any specific relationship with water temperature. Thus, fresh inputs of APs in the Geum River Estuary may be influenced by a particular time event (rather than a season), such as increased decomposition rates through microbial activity (Ying et al., 2002). The Korean government officially banned the use of NP in household products in 2007 and industrial products in 2016 (Kim et al., 2020). Thus, Fresh inputs of APs in the present study showed that government policy had a positive effect. However, this study also confirmed that chemicals that are not yet fully regulated are being continuously introduced to the environment.

3.3.3. Spatiotemporal patterns of macrofaunal assemblages

The distribution of the macrofaunal community in the Geum River Estuary reflected both spatial and seasonal differences (Table 3.3). Spatially different taxon diversity occurred in the inner part of the estuary versus in the outer part of the estuary (df = 1, Pseudo-F = 50.8, $p < 0.05$); however, there was no difference between sampling months (df = 5, Pseudo-F = 0.7, $p > 0.05$) (Table 3.7). No interaction between zone and sampling month was found. A significant dispersion difference was detected by the PERMDISP test in the zone of taxon diversity ($p < 0.05$). This phenomenon might be attributed to heterogeneous variation, rather than a real factor effect. The number of species tended to increase from the inner part of the estuary to the outer part of the estuary, indicating that the benthic communities of the inner and outer parts of the estuary were distinct (Figure 3.8a). The largest group of species was Annelida, followed by Arthropoda, Mollusca, others, and Echinodermata. Density significantly differed with respect to zone (df = 1, Pseudo-F = 14.8, $p < 0.05$) and sampling month (df = 5, Pseudo-F = 1.4, $p < 0.05$), with no interaction between zone and sampling month (Table 5.7). The PERMDISP test showed no significant difference in dispersion between zone and sampling month. Annelida dominated (mean: 442 ind. m^{-2}), but Arthropoda (mean: 222 ind. m^{-2}) and Mollusca (mean: 134 ind. m^{-2}) were predominant in the inner part of the estuary. This result could be explained by the appearance of opportunistic species, due to dynamic environmental changes in the inner part of the estuary (Dauer, 1993). The most dominant species were *Heteromastus filiformis*, accounting for 16.8% of total abundance, followed by *Potamocorbula amurensis* (14.6%), *Sinocorophium sinensis* (12.3%), *Spiochaetopterus costarum* (7.1%), and *Neanthes japonica* (5.2%). (Figure 5.8a′). These species were opportunistic, organic pollutant or enrichment indicator species, or brackish water species, which were predominantly found in the inner part of the estuary (Pearson and Rosenberg, 1978). Thus, the benthic environment in the Geum River Estuary is likely influenced by freshwater and is in a state of organic enrichment due to the inflow of terrestrial organic matter (Hermand et al., 2008). The next dominant species were *Urothoe brevicornis* (3.3%), *Gammaropsis japonicas* (2.8%), *Chaetozone setosa* (2.8%), Nemertinea (1.9%), and *Sternaspis chinesis* (1.4%), which predominantly occurred in the outer part of the estuary. The H′ and

EQR showed that the benthic environment in the inner part of the estuary was mostly "Bad" to "Moderate" and mostly "Moderate" to "Excellent" in the outer part of the estuary (Borja et al., 2004, 2008) (Figure 3.8b). Thus, the macrofaunal community in the inner and outer parts of the Geum River Estuary was spatially separated, with the outer part of the estuary being ecologically more valid and stable compared to the inner part of the estuary.

The ordination of macrofauna assemblages using CA and nMDS clearly showed that the inner and outer parts of the estuary differed (Figure 3.8c and 3.8d). However, no seasonal trend was detected among stations, even though the PERMANOVA test showed significant differences among sampling months. The cluster results were largely divided into the inner (group A) and outer parts (group B) of the estuary, except for station 3, where few macrofauna were detected. Group A was dominated by *P. amurensis*, *S. sinensis*, and *N. japonica* were predominated, and in group B, *S. costarum*, *U. brevicornis*, *G. japonicas*, and *C. setosa*. *H. filiformis* was the most dominant species and indicator of organic enrichment in both groups A and B. These results confirmed that the macrofaunal community spatially differed, with the community in the inner part of the estuary being disturbed by the dominance of opportunistic species and indicator species (organic polluted or enrichment) (Pearson and Rosenberg, 1978; Dauvin et al., 2009). In the nMDS space, each month had a relatively wide distribution range in the inner part of the estuary compared to the outer part of the estuary, with June and August (summer) differing to other months. This phenomenon could be explained by the increasing influence of freshwater from the Geum River, and the increased stress due to high water temperature and low water depth in summer (Rundle et al., 1998).

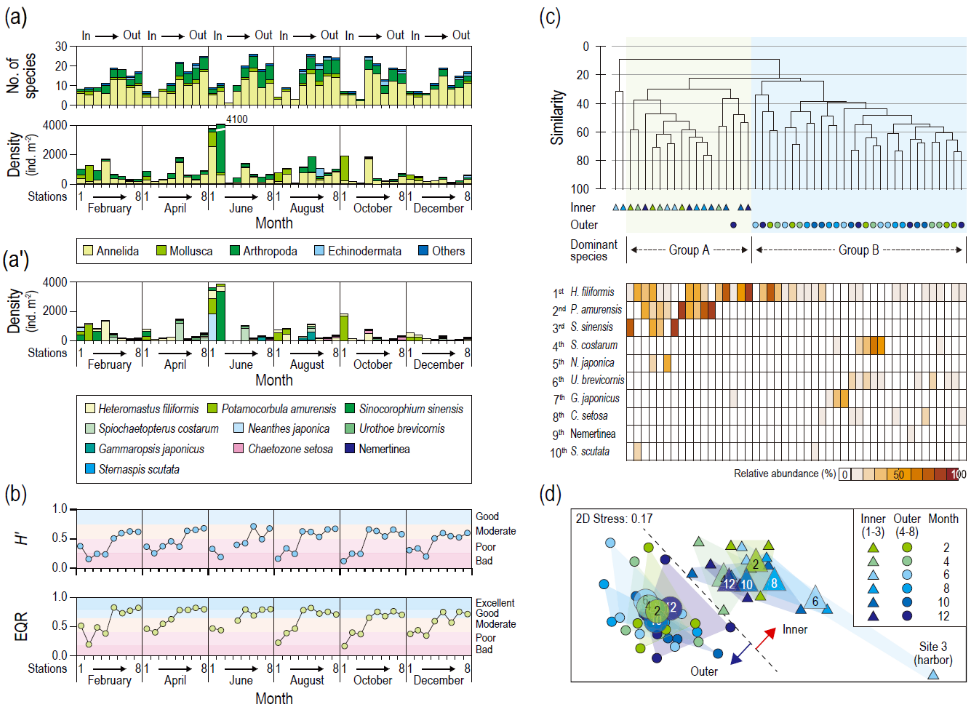

Figure 3.8.

(a) Number of species, density, and (a') density of top 10 dominant species. (b) Ecological quality status represented by Shannon-Wiener diversity index (H') and Ecological Quality Ratio (EQR). (c) Cluster analysis showing the two groups of macrofaunal assemblages, with the top 10 dominant species. (d) Non-parametric multi-dimensional scaling (nMDS) ordination plot based on relative abundance.

Table 3.7.

Results of the PERMANOVA and PERMDISP test based on the data of taxon diversity and abundance of macrofauna in the Geum River Estuary, Korea. Zo: Zone (inner part and outer part); Sm: Sampling month; df: degree of freedom; P-F: Pseudo-F; ECV: Estimate Components of Variation; Sqrt: square root of ECV; Bold values: $P < 0.05$.

Target	Term	**PERMANOVA**					**PERMDISP**	
		df	P-F	ECV	Sqrt	*P*	P-F	*P*
Taxon diversity	Zo	1	50.8	200	14.2	**0.001**	12.5	**0.003**
	Sm	5	0.7	-3.1	-1.8	0.631	1.7	0.568
	Zo x Sm	5	1.3	8.6	2.9	0.245		
	Res	36		90.4	9.5			
Density	Zo	1	14.8	1166	34.1	**0.001**	0.40	0.573
	Sm	5	1.4	106	10.3	**0.042**	0.51	0.837
	Zo x Sm	5	1.1	58.4	7.6	0.292		
	Res	36		1898	43.6			

3.3.4. Key factors influencing the spatiotemporal pattern of macrofaunal assemblages

Many factors determined the spatiotemporal distribution of the macrofaunal community in the present study. Out of the 18 input variables, DistLM showed that TN, mud content, Chl-*a*, salinity, Hg, APs, and SiO_2 accounted for significant variations in macrofauna assemblages across all sampling stations and months (Table 3.8). Collectively, these seven environmental variables explained 44% of the total variability in macrofauna assemblages. Thus, various substances from the Geum River likely have a strong influence on the distribution of benthic communities (Montagna et al., 1992). For instance, previous studies in the same area reported the origin of sediment organics as the main factor controlling benthic communities (Yoon et al. 2007). The dbRDA showed that the distribution of benthic communities differed inner (Group 1) and outer parts (Group 2) of the estuary, depending on the main environmental variables (Figure 3.8). The factors determining the benthic community structure included TN, Chl-*a*, mud content, and salinity (Figure 3.9a), but salinity and mud content seemed to be primary factors apparently explaining the spatial distribution of some opportunistic and/or indicator species between inner and outer regions. Out of the dominant species in each group, five species were selected by identifying the indicator taxa corresponding to $P < 0.01$ (Table 3.9). The indicator taxa representing the Geum River estuary were *P. amurensis* and *S. sinensis* in Group 1 (freshwater inflow, organic enrichment, fine-grained sediment), and *U. brevicornis*, *C. setosa*, and *S. costarum* in Group 2 (No freshwater inflow event, little organic matter, coarse sediment). Opportunistic species and indicator species (organic polluted or enrichment) were identified as indicator taxa, both in the inner and outer parts of the estuary, indicating that the benthic environment in the Geum River Estuary was disturbed (Pearson and Rosenberg, 1978; Dauvin et al., 2009).

Table 3.8.
Results of the DistLM analysis used to explore the relationship between macrofauna and environmental variables. *P*-values were obtained using 999 permutations of residuals under the best model (forward selection based on the AIC test). Bold numbers indicate significant values; V: Variables; AIC: Akaike information criterion; P-F: Pseudo-F; Cum: Cumulation; BS: Best Solution.

Macrofauna				
V	AIC	P-F	*P*	Cum.
TN	370.1	10.5	**0.001**	0.19
Mud content	368.7	3.38	**0.001**	0.24
Chl-*a*	367.3	3.23	**0.001**	0.29
Salinity	366.8	2.26	**0.004**	0.33
Hg	366.7	1.89	**0.032**	0.36
APs	366.5	1.90	**0.022**	0.39
PO_4	366.5	1.71	0.056	0.41
SiO_2	366.3	1.83	**0.034**	0.44
B.S	AIC	R^2	V	
	366	0.44	7	

Table 3.9.
IndVal analysis listing indicator taxa within specific environmental groups for macrofauna. Bold numbers indicate significant values. Environmental groups were defined by the results of the dbRDA routine (Figure 5.8).

Group	Indicator taxa	IndVal	*P*
1	*Potamocorbula amurensis*	0.69	**0.001**
	Sinocorophium sinensis	0.53	**0.009**
2	*Urothoe brevicornis*	0.82	**0.001**
	Chaetozone setosa	0.74	**0.008**
	Spiochaetopterus costarum	0.69	**0.003**

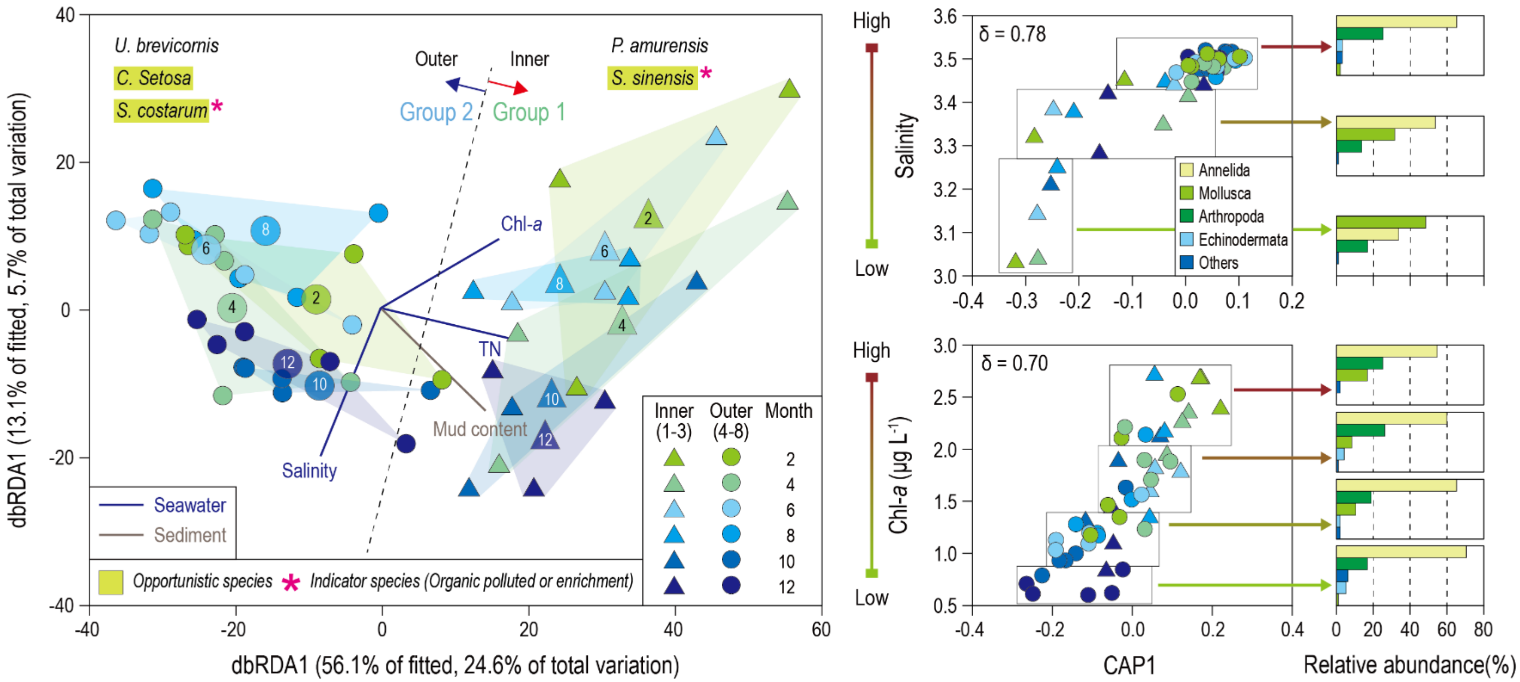

Figure 3.9.
(a) Distance-based redundancy analysis (dbRDA) ordination based on environmental parameters and the relative abundance of macrofauna. Only significant environmental variables were marked as vectors. Indicator taxa identified through IndVal analysis is displayed in each group. (b) Variation in macrofaunal assemblages along the canonical gradient in relation to salinity and Chl-*a*. The bar graph on the right side indicates the proportional abundance for five taxa at the Phylum level.

The macrofaunal assemblages were clearly distributed in relation to environmental variables (Figure 3.9b). Salinity and Chl-*a* gradients clearly changed in relation to macrofaunal assemblages, with a canonical correlation of $\delta = 0.78$ (m = 7, $r = 0.88$, $p < 0.001$) and $\delta = 0.70$ (m = 13, $r = 0.83$, $p < 0.001$), respectively. In contrast, macrofaunal assemblages were not strongly correlated with sediment properties and PTSs, with a canonical correlation of $\delta = 0.49$ (m = 6, $r = 0.70$, $p < 0.001$) and $\delta = 0.43$ (m = 5, $r = 0.66$, $p < 0.001$), respectively. At low salinity, Mollusca dominated, while under normal salinity, Annelida and Arthropoda dominated. The change to the macrofaunal community due to salinity indicates that the ability to adapt to low salinity varies across taxonomic groups. Previous studies also documented this trend (Rosenberg and Moller, 1979; Montagna and Kalke, 1992; Kennish et al., 2009). The apparent increase of Mollusca (mostly filter feeders) with increasing Chl-*a* concentration could be explained by the result of adaptation to the environment in which the amount of prey increased (Essink and Bos, 1985). The inconsistent changes to the macrofaunal community in relation to sediment properties and PTSs might be attributed to the greater influence of freshwater inflow and low levels of pollution. Even under similar PTSs contamination, the degree of exposure, due to sediment resuspension or bioturbation, would vary and consequently, the continuous release of industrial and urban wastes in the region might act differently (Cabrini et al., 2017). The type of compound is also a factor that influences the impact of benthic community change (Fusi et al., 2016). Insensitivity of macrofauna could also be explained as one reason. In the previous study, the responses of meiofauna and macrofauna to PTSs contamination showed a greater change in meiofauna community structure (Egres et al., 2019). Thus, considering these factors, it is necessary to carefully approach the understanding of benthic community response associated with PTSs contamination. Studies conducted in coastal areas with a relatively stable environment and highly polluted areas have reported that the distribution of benthic communities is controlled by the characteristics of sediments or the distribution of pollutants (Zheng et al., 2011; Wetzel et al., 2012; Fusi et al., 2016; Cabrini et al., 2017; Camargo et al., 2017). Overall, changes to the macrofaunal community in the Geum River Estuary mainly depended on phenomena caused by freshwater inflow. In comparison, the sediment properties and the contamination levels of PTSs had relatively minor effects.

The distribution of the top 10 dominant species to the gradient of salinity in the Geum River estuary was species-specific (Figure 3.10). The *H. filiformis,* which is the most dominant species, was similar in the distribution in all salinity zones, indicating euryhaline species. Nemertea and *S. scutata* also showed euryhaline but dominated mainly in salinity higher than 30. *P. amurensis* and *S. sinensis* were mainly distributed in salinity less than 28, and *N. japonica* was found only in salinity less than 22, indicating that they were adapted to the lowest salinity (Parchaso and Thomson, 2002; Lee and Ryu, 2018). *S. costarum*, *U. brevicornis*, *G. japonicas*, and *C. setosa* appeared mainly in salinity higher than 30, indicating that they are stenohaline species. The distribution of top 10 dominant species to the gradient of chlorophyll-*a* in bottom water showed a similar pattern to salinity. *P. amurensis*, which was feeding by filtration, was dominant at the highest concentration of Chl-*a.* *S. sinensis*, *S. costarum*, and *N. japonica* also dominated at the relatively high concentration of Chl-*a*. These results indicated that suspended feeder dominated by adapting to the environment where there is much food (Barnes, 1964). Species, which appeared in relatively high salinity, were primarily occurred at relatively low concentrations of Chl-*a*. Only three suspension feeders, directly ingest plankton in seawater, occurred in the Geum River Estuary, while seven deposit feeders were dominated. These results were due to the high correlation between salt and chlorophyll-*a* ($p < 0.001$), indicating that the dominant species in the Geum River estuary mainly ingest directly/indirectly non-selectively chlorophyll-*a*. Overall, the distribution of macrofauna in the Geum River estuary was primarily determined by salinity, and chlorophyll-*a*, a food source, seems to have an indirect effect on the distribution of individual species.

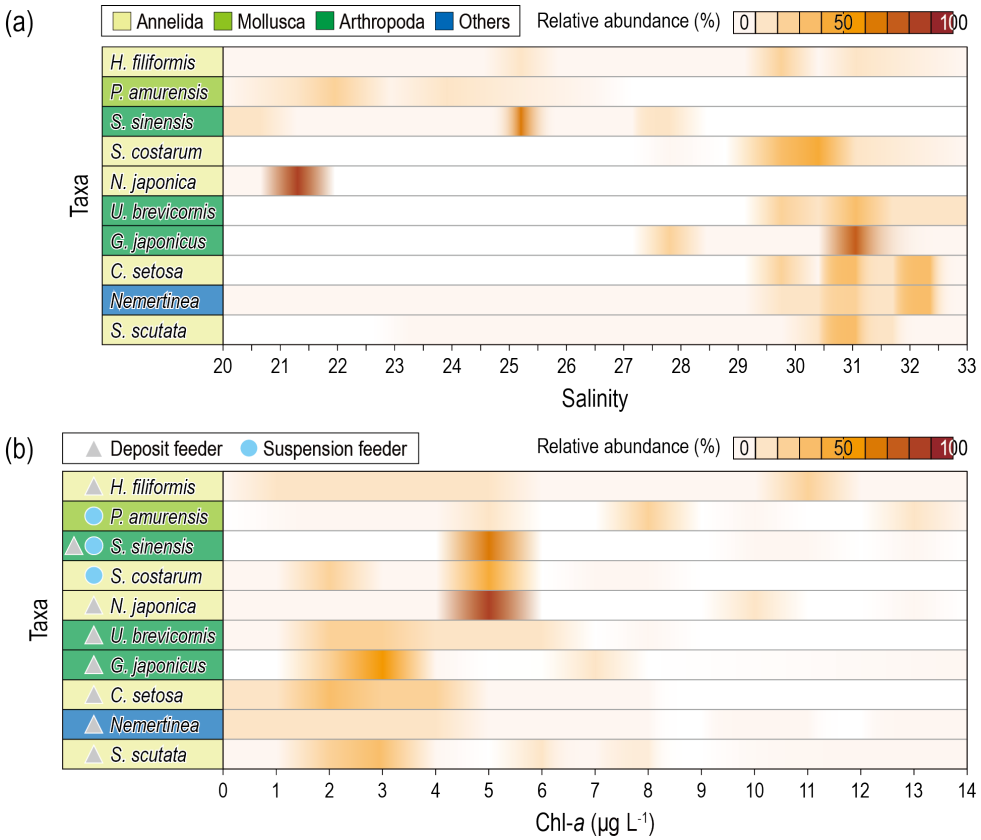

Figure 3.10.
The relative abundance of the top 10 dominant species in the gradient of (a) salinity and (b) Chl-*a* in bottom water. Taxa and feeding type of individual species are presented.

3.4. Summary

The spatiotemporal distributions of PTSs (PAHs, APs, and metals) and water quality parameters in Geum River Estuary were investigated for a year to address key factors controlling the macrofaunal community structure. Relatively high concentrations of PTSs were found in the inner part of the estuary throughout the year, and concentrations of copper and zinc posed a potential risk to the aquatic organism. During the year, the macrobenthic community in the Geum River Estuary was divided into the inner part and outer part of the estuary, regardless of the season. H. filiformis was predominant in both the inner part and outer part of the estuary, and Potamocorbula amurensis and Sinocorophium sinensis appeared as opportunistic species in the inner part of the estuary. The key factors influencing the macrofaunal community were salinity and chlorophyll-a, while the effect of PTSs was relatively low. Such changes in the closed estuary system would indicate that each taxonomic group had to adjust to lower salinities and alternative food sources. These results were similar to the result in the intertidal zone of the Yellow Sea where the concentration of PTSs was high (Chapter 2), suggesting that the macrofauna community is insensitive to contamination by PTSs. Overall, the distribution of PTSs and macrozoobenthic communities in the Geum River Estuary collectively reflected the environmental gradients caused by surrounding activities in the inner part of the estuary together with direct effects by the irregular inflow of freshwater.

CHAPTER 4.

LARGE-SCALE MONITORING AND ECOLOGICAL RISK ASSESSMENT OF PERSISTENT TOXIC SUBSTANCES IN RIVERINE, ESTUARINE, AND COASTAL SEDIMENTS OF THE YELLOW AND BOHAI SEAS

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4.1. Introduction

Persistent toxic substances (PTSs) are ubiquitous contaminants in various environmental matrices, originating from numerous sources, and are transported via a variety of mechanisms and pathways to the marine environment. The fate and impacts of classic PTSs are well known; they tend to accumulate in sediments after sinking with organic matter, where they exert adverse impacts on aquatic ecosystems (Hong et al., 2012a; Lee et al., 2018; Khim et al., 2018a). Polycyclic aromatic hydrocarbons (PAHs), alkylphenol (APs), and styrene oligomers (SOs) constitute classic and emerging PTSs. Originating from anthropogenic activities and natural sources, PTSs are widely distributed in benthic environments (Hong et al., 2016; Lee et al., 2017; Yoon et al., 2017) where they pose potentially significant ecological threats to aquatic organisms.

PTSs are hydrophobic and hydrophilic organic pollutants with fused benzene rings. PAHs with 2–6 fused benzene rings are intentionally or unintentionally released from a variety of sources, including incompletely combusted fossil fuels and biomass, spilled crude or refined oil, and smelted metals (Lin and Zhu, 2004; Moon et al., 2006; Ghosh et al., 2015). PAHs spread through atmospheric deposition, wastewater streams, and industrial effluents but their fate varies depending on the multiple potential pathways they can follow. PAHs are a major contaminant and adversely affect aquatic ecosystems at concentrations above thresholds values (Engraff et al., 2011). APs are a widely used class of nonionic surfactants, with many industrial and household applications (White et al., 1994). Nonylphenol ethoxylates (NPEOs) and octylphenol ethoxylates (OPEOs) are the most common alkylphenol ethoxylates, both of which degrade via microbial and photochemical processes to nonylphenols (NPs) and octylphenol (OP), respectively (Li et al., 2013). APs are harmful endocrine disruptors and function to adversely stimulate feminization, reduce growth rates (Chen and Yen, 2013), inhibit reproduction, and cause neurological, and immunological problems (Giesy and Snyder, 1998). SOs, recently emerging as contaminants in sediments, have been reported from inland creeks (Hong et al., 2016), from the estuary and coastal areas in a few regions (Yoon et al., 2019), and sandy beaches worldwide (Kwon et al., 2015). SOs are generated from the degradation of polystyrene at high temperatures (240–300 °C) (Kwon et al., 2014) and have been reported to harm aquatic biota by causing genetic and reproductive toxicities (Ohyama et al., 2001; Tatarazako et al., 2002). Although SOs have been recently recognized as a new class of PTSs, widespread distribution in China is unknown.

The Yellow Sea (YS) and Bohai Sea (BS) are wide but semi-enclosed seas with a complex coastline that slowly exchanges waterbody encompassing many large rivers and estuaries (Chen, 2009). These two seas together are part of the Yellow Sea Large Marine Ecosystem (YSLME), which is one of 66 large marine ecosystems (LMEs) worldwide. Among these 66 LMEs, YSLME encompasses the strongest marine industrial activity being associated with the severe PTSs pollution in the very region (Table 4.1) (Hoagland and Jin, 2006)

The YS and BS are about 470,000 km^2 in size and is bordered by three countries: South Korea, North Korea, and China. South Korea and China are undergoing massive industrial and municipal development along the coasts of the YSLME and so those human activities are likely responsible for the increase in coastal pollution by PTSs. It has been reported that many anthropogenic pollutants have accumulated in the sediments of YS and BS (Khim et al., 2018b), but the majority of the previous studies have either only reported pollution by some PTSs or in limited areas along the YSLME coasts (Meng et al., 2017). However, from these limited studies, most pollution indices for the YSLME exhibit high values and so I expect that the YSLME is severely contaminated.

Table 4.1.

Top 20 LMEs in Marine Industry Activity Index (Hoagland and Jin, 2006).

LME	LME#	Socioeconomic Index	Fishery & Aquaculture Index	Tourism Index	Ship & Oil Index	Marine Industry Activity Index
Yellow Sea	48	73.4	71.8	44.4	36.9	45.4
East China Sea	47	84.1	51.9	30.8	42.1	41.8
East Bering Sea	1	93.9	17.4	57.9	44.0	41.4
Insular Pacific-Hawaiian	10	93.9	17.4	57.9	44.0	41.4
Northeast U.S. Continental Shelf	7	94.0	15.5	52.8	37.9	36.4
Gulf of Mexico	5	89.1	13.0	46.3	36.6	33.8
Kuroshio Current	49	93.6	18.3	6.7	45.8	32.5
California Current	3	88.0	12.1	43.7	35.0	32.2
Gulf of Alaska	2	94.0	13.7	48.2	32.5	31.9
Southeast U.S. Continental Shelf	6	90.8	13.1	44.0	33.1	31.3
Chukchi Sea	54	87.4	14.7	34.9	27.5	26.4
South China Sea	36	73.8	34.5	22.3	14.9	20.3
Beaufort Sea	55	94.2	9.2	36.5	18.6	20.3
Gulf of California	4	80.2	4.9	24.9	23.1	19.8
Norwegian Shelf	21	95.6	10.7	3.7	28.0	19.7
Sea of Japan	50	83.3	13.3	3.5	24.0	17.7
Celtic-Biscay Shelf	24	92.2	2.5	38.8	14.6	17.0
North Sea	22	94.0	5.3	14.4	16.4	13.8
Oyashio Current	51	83.3	13.0	2.1	14.9	12.0
Iberian Coastal	25	91.2	2.5	47.3	3.2	11.9

Economic development intensifies land-use practices, which in turn negatively impact aquatic ecosystems. Coastal aquatic ecosystems are altered and contaminated by coastal development and discharges of land-driven pollutants from surrounding activities are a global problem (Saxena et al., 2015). The major factors responsible for sediment pollution in estuaries and coastal areas worldwide are due to changes in land-use associated with anthropogenic activities and lack of procedures to contain runoff (Karstens et al., 2016; Liu et al., 2017). Some chemical contaminants, such as metals and PTSs identified in coastal sediments can be directly linked to land-use type (Kimbrough and Dickhut, 2006). Therefore, the characterization of coastal land-use is fundamental for addressing sources of coastal pollution of PTSs.

In the present study, 125 locations were surveyed representing most coasts of the Yellow and Bohai seas to (1) measure concentrations of PTSs in sediment, specifically targeting selected chemicals of PAHs, APs, and SOs, (2) assess potential ecological risks posed by the PTSs, (3) identify sources of targeted contaminants, especially via freshwater inputs, (4) characterize spatial distribution patterns linked to land-use types, and (5) evaluate long-term changes (past 10 years) in sedimentary contamination of selected PTSs. Results of the present study would provide baseline information on PTSs contamination, such as point sources and hotspots, in a large marine ecosystem of the Yellow and Bohai seas and provide scientific data for informed decision-making and environmental management of the given coastal ecosystem

4.2. Materials and Methods

4.2.1. Study area and sampling

The present study focused on most coasts of the YSLME, encompassing both South Korea and China because both countries have a high socioeconomic dependency on the coast. Several metroplexes have grown along the coastline in South Korea (Seoul, Incheon, Asan, Gunsan, and Mokpo) and China (Beijing, Tianjin, Dalian, Huludao, Qinhuangdao, Weifang, Yantai, Qingdao, and Nantong). About 300 million people currently live near the coastline of the YS and BS, and population growth and development continue unabated (National Bureau of Statistics, 2018; KOSIS, 2018). In addition, more than 60 rivers flow to the YS and BS, including major rivers of South Korea (Han, Geum, and Youngsan) and China (Liaohe, Haihe, Yellow, Dagu, and Guanhe), all of which convey organic contaminants to coastal waters (Wang et al., 2015; Zhen et al., 2016; Jeon et al., 2017). The study's data represent inputs from all the large cities and major rivers along the coast of the YSLME.

A comprehensive field survey was employed by collecting freshwater and saltwater sediments in the major rivers, estuaries, and some intertidal areas along the entire coasts of the YSLME. Four teams simultaneously conducted extensive field sampling for about three weeks in June-July 2018 in China and South Korea, in order to collect all the samples within a short period. 125 locations were surveyed in four provinces in South Korea (Gyeonggi, Chungnam, Jeonbuk, and Jeonnam) and four provinces in China (Liaoning, Hebei, Shandong, Jiangsu), and one city in China (Tianjin) (Figure 4.1). Detailed information on sampled locations, including geographic location and basic water quality parameters, are measured. In brief, the land-use types adjacent to the 125 sampled locations varied widely. There were 21 industrial locations, 20 municipal locations, 38 agriculture locations, 9 beaches, 6 aquaculture locations, 5 salterns, and 26 barren lands (unused area). I assigned land-use types based on dominant surrounding activity at the time of sampling and supplemented our records by referring to the previous studies that provided data on land-use type at the same locations (Jiao et al., 2012; Hong et al., 2012b). I collected surface sediment samples using stainless steel devices (from top 2 cm), consisting of three replicates at each site and then stored the samples in pre-cleaned glass bottles.

I stored all collected sediment samples in a cooler at -20 ℃ for transportation to a laboratory. Macrobenthic fauna samples were collected triplicate using square core ($200 \times 120 \times 100$ mm) and fixed with 5% buffered formalin.

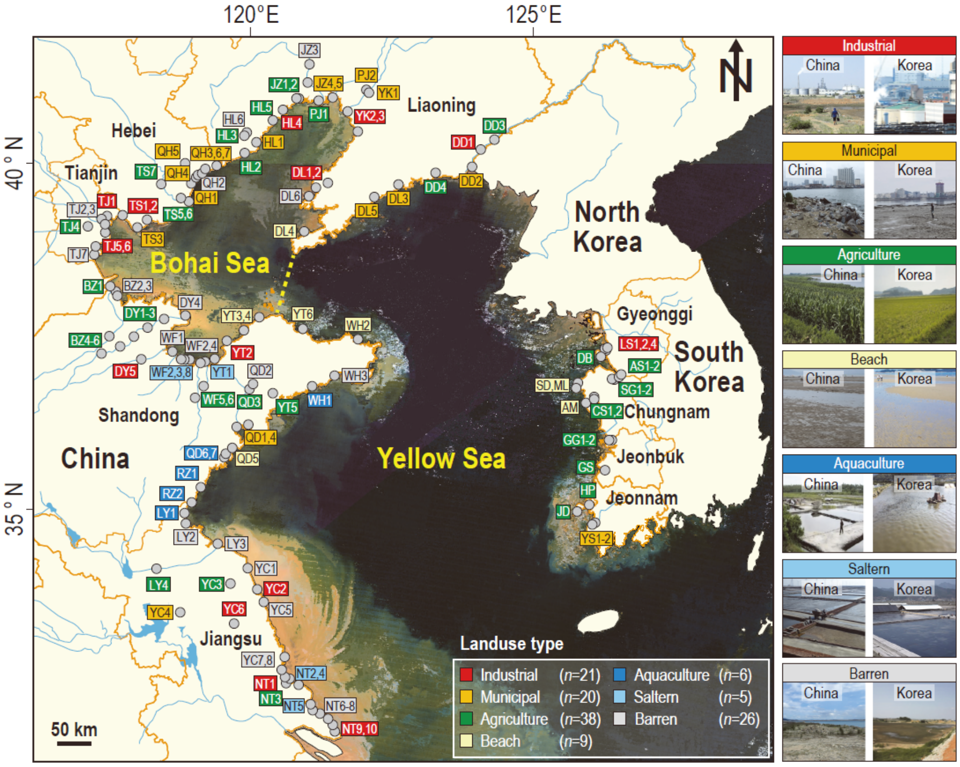

Figure 4.1.
Map showing the sampled locations in the Yellow and Bohai seas. The images on the right depict typical land-use types in South Korea and China (land-use classifications are based on dominant surrounding activity).

4.2.2. Chemicals and reagents

Standards were obtained for target PTSs from ChemService (West Chester, PA), which included 16 PAHs, including naphthalene (Na), 2-metylnaphthalene (2-Na), acenaphthylene (Acl), acenaphthene (Ace), fluorene (Flu), dibenzothiophene (Dbthio), phenanthrene (Phe), anthracene (Ant), fluoranthene (Fl), pyrene (Py), benzo[*a*]anthracene (BaA), chrysene (Chr), benzo[*b*]fluoranthene (BbF), benzo[*k*]fluoranthene (BkF), BaP, indeno[*1,2,3-c,d*]pyrene (IcdP), dibenz[*a,h*]anthracene (DahA), benzo[*g,h,i*]perylene (BghiP), and another 23 alkyl-PAHs. Authentic standards for 6 APs and 10 SOs were obtained from Sigma-Aldrich, Wako Pure Chemical Ind. (Osaka, Japan) and Hayashi Pure Chemical Ind. (Osaka, Japan), which included 4-*tert*-octylphenol (OP), 4-*tert*-octylphenol monoethoxylate (OP1EO), 4-*tert*-octylphenol diethoxylate (OP2EO), nonylphenols (NPs), nonylphenol-monoethoxylates (NP1EOs), and nonylphenol diethoxylates (NP2EOs), 1,3-diphenylproane (SD1), *cis*-1,2-diphenylcyclobutane (SD2), 2,4-diphenyl-1-butene (SD3), *trans*-1,2-diphenylcyclobutane (SD4), 2,4,6-triphenyl-1-hexene (ST1), 1e-phenyl-4e-(1-phenylethyl)-tetralin (ST2), 1a-phenyl-4e-(1-phenylethyl)-tetralin (ST3), 1a-phenyl-4a-(1-phenylethyl)-tetralin (ST4), 1e-phenyl-4a-(1-phenylethyl)-tetralin (ST5), and 1,3,5-triphenylcyclohexane (isomer mix) (ST6). Detailed information and abbreviations for the target compounds are provided in Table 4.2.

Table 4.2.
Instrumental conditions of gas chromatograph equipped with a mass selective detector for analyses of persistent toxic substances.

GC/MSD system	Agilent 7890A GC and 5975C MSD
Column	DB-5MS UI (30 m long, 0.25 mm i.d., 0.25 μm film thickness)
Gas flow	1 mL/min He
Injection mode	Splitless
Injection volume	2 μL
Injector temperature	300 °C
Ionization	EI mode (70 eV)
MS temperature	180 °C
Detector temperature	230 °C
Oven temperature (PAHs and SOs)	60 °C hold 2 min Increase 6 °C/min to 300 °C 300 °C hold 13 min
Oven temperature (APs)	60 °C hold 5 min Increase 10 °C/min to 100 °C Increase 20 °C/min to 300 °C
Targeted PAHs (39)	Naphthalene (Na), 1-Methylnaphthalene (1-Na), 2-Methylnaphthalene (2-Na), 1,3-Dimethylnaphthalene (1,3-Na), 1,4,5-Trimethylnaphthalene (1,4,5-Na), 1,2,5,6-Tetramethylnaphthalene (1,2,5,6-Na), Acenaphthylene (Acl), Acenaphthene (Ace), Fluorene (Flu), 9-Methylfluorene (9-Flu), 1-Methylfluorene (1-Flu), 1,7-Methylfluorene (1,7-Flu), 9-n-Propylfluorene (9-n-Propyl-Flu), Dibenzothiophene (Dbthio), 2-Methyldibenzothiophene (2-Dbthio), 2,4-Dimethyldibenzothiophene (2,4-Dbthio), 2,4,7-Trimethyldibenzothiophene (2,4,7-Dbthio), Phenanthrene (Phe), 3-Methylphenanthrene (3-Phe), 2-Methylphenanthrene (2-Phe), 1,6-Dimethylphenanthrene (1,6-Phe), 1,2-Dimethylphenanthrene (1,2-Phe), 1,2,9-Trimethylphenanthrene (1,2,9-Phe), 1,2,6,9-Tetramethylphenanthrene (1,2,6,9-Phe), Anthracene (Ant), Fluoranthene (Fl), Pyrene (Py), Benzo[*a*]anthracene (BaA), Chrysene (Chr), 3-Methylchrysene (3-Chr), 6-Ethylchrysene (6-Ethyl-Chr), 1,3,6-Trimethylchrysene (1,3,6-Chr), Benzo[*b*]fluoranthene (BbF), Benzo[*k*]fluoranthene (BkF), Benzo[*a*]pyrene (BaP), Perylene (Pery), Indeno[*1,2,3-c,d*]pyrene (IcdP), Dibenz[*a,h*]anthracene (DbahA), and Benzo[*g,h,i*]perylene (BghiP)
Targeted SOs (10)	1,3-Diphenylpropane (SD1), *cis*-1,2Diphenylcyclobutane (SD2), 2,4-Diphenyl-1-butene (SD3), 2,4,6-Triphenyl-1-hexene (SD4), 2,4,6-Triphenyl-1-hexene (ST1), 1e-Phenyl-4e-(1-phenylethyl)-tetralin (ST2), 1a-Phenyl-4e-(1-phenylethyl)-tetralin (ST3), 1a-Phenyl-4a-(1-phenylethyl)-tetralin (ST4), 1e-Phenyl-4a-(1-phenylethyl)-tetralin (ST5), and 1,3,5-Triphenylcyclohexane (isomer mix) (ST6)
Targeted APs (6)	4-tert-Octylphenol (OP), 4-tert-Octylphenol monoethoxylate (OP1EO), 4-tert-Octylphenol diethoxylate (OP2EO), Nonylphenols (NPs, isomer mix), Nonylphenol monoethoxylates (NP1EOs, isomer mix), and Nonylphenol diethoxylates (NP2EOs, isomer mix)

4.2.3. PTSs analyses

Sediment samples were prepared for analyses of PTSs following previous methods of Khim et al. (1999) and Hong et al. (2016), with minor modifications (Figure 4.2). With a Soxhlet extractor, I extracted freeze-dried and homogenized 10 g of sediment over a 16 h period with five surrogated standards (acenaphthene-d_{10}, phenanthrene-d_{10}, chrysene-d_{12}, perylene-d_{12}, and bisphenol A-d_{16}) and 300 mL dichloromethane (DCM) (Burdick & Jackson, Muskegon, MI). Activated copper powder (Sigma Aldrich, Saint Louis, MO) was added to remove elemental sulfur. Organic extracts were then concentrated using rotary evaporators and fractionated with activated silica gel column (70−230 mesh, Sigma-Aldrich). The first fraction (F1) was eluted for PAHs and SOs with 60 mL of 20% DCM in hexane (v/v) (Burdick & Jackson). The second fraction (F2) was collected for APs with 50 mL of 60% DCM in acetone (J.T. Baker, Center valley, PA). Then, extracts were concentrated using N_2 gas flow and added 2-fluorobiphenyl as an internal standard.

Target PTSs were quantified using an Agilent 7890A gas chromatograph equipped with a mass selective detector (GC-MSD) (Agilent Technologies, Santa Clara, CA). I injected each sample onto a DB-5MS Ultra Inert fused silica capillary column (30 m × 0.25 mm i.d. × 0.25 μm film, Agilent) for chromatographic separation. Details on the instrumental conditions for PTS analyses are provided in Table 4.3.

Method detection limits (MDLs) were defined as standard deviations 3.707-fold of standard materials quantified seven times. Concentration ranges for MDLs were 0.27–0.90 ng g^{-1} dry weight (dw) for PAHs, 0.10–0.91 ng g^{-1} dw for APs, and 0.24–0.91 ng g^{-1} dw for SOs. The concentrations of PAHs in the procedural blank samples were all lower than those of MDLs. Recoveries for the five surrogate standards were 68%–96% (mean = 80%) for acenaphthene-d_{10}, 90%–121% (mean = 110%) for phenanthrene-d_{10}, 75%–105% (mean = 93%) for chrysene-d_{12}, 69%–98% (mean = 88%) for perylene-d_{12}, and 62%–90% (mean = 78%) for bisphenol A-d_{16}. Recovery rates of the standard reference material 1944 were generally acceptable, ranging from 80% to 126% (mean = 106%) (Table 2.3).

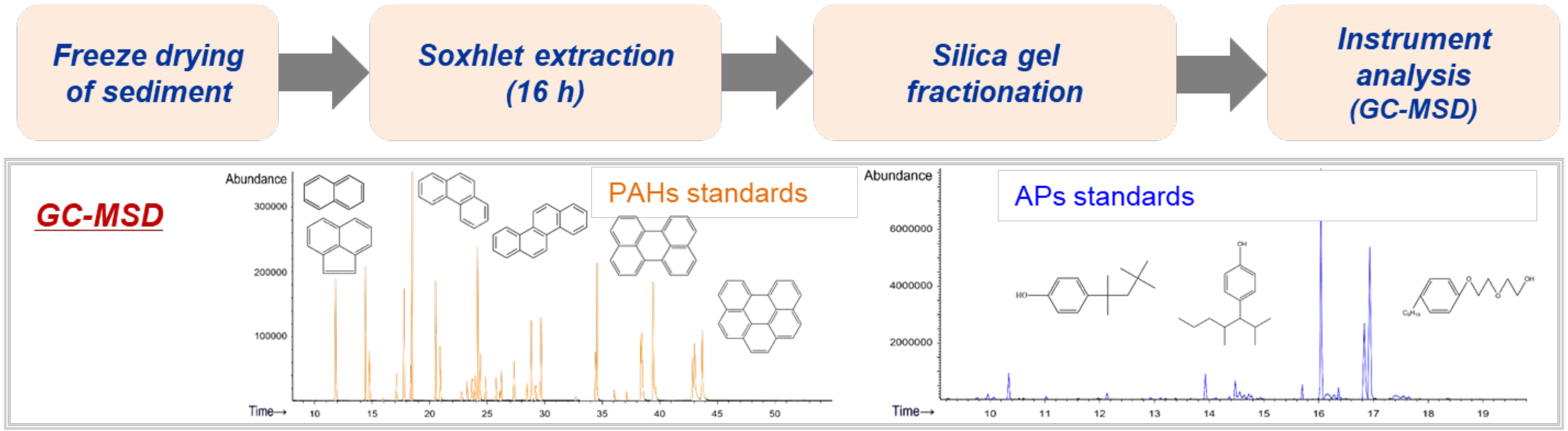

Figure 4.2.
The analysis method of persistent toxic substances including PAHs, APs, SOs, PCBs, E-PAHs, and Hl-PAHs.

Table 4.3.
Certified and measured concentrations for selected PAHs in standard reference material (SRM) 1944 to check the accuracy of the method.

PAHs	Certified concentration ($\mu g\ g^{-1}$ dry weight)	Measured concentration ($\mu g\ g^{-1}$ dry weight, n=3)	Recovery (%)
Phenanthrene	5.3 ± 0.2	4.6 ± 0.3	87 ± 5.3
Fluoranthene	8.9 ± 0.3	7.8 ± 0.1	87 ± 1.6
Pyrene	9.7 ± 0.4	7.9 ± 0.3	81 ± 2.9
Benz[*a*]anthracene	4.7 ± 0.1	4.8 ± 0.2	102 ± 5.1
Chrysene	4.9 ± 0.1	4.1 ± 0.2	85 ± 3.3
Benzo[*b*]fluoranthene	3.9 ± 0.4	4.7 ± 0.2	121 ± 6.4
Benzo[*j*]fluoranthene	2.1 ± 0.4	2.1 ± 0.1	103 ± 3.6
Benzo[*k*]fluoranthene	2.3 ± 0.2	2.9 ± 0.2	126 ± 7.7
Benzo[*a*]pyrene	4.3 ± 0.1	5.3 ± 0.2	122 ± 5.1
Benzo[*e*]pyrene	3.3 ± 0.1	4.0 ± 0.1	122 ± 4.1
Perylene	1.2 ± 0.2	0.9 ± 0.1	80 ± 4.9
Indeno[1,2,3-*c,d*]pyrene	2.8 ± 0.1	3.3 ± 0.2	119 ± 4.9
Dibenz[*a,h*]anthracene	4.2 ± 0.1	5.1 ± 0.1	121 ± 1.8
Benzo[*g,h,i*]perylene	4.8 ± 0.1	3.5 ± 0.1	122 ± 2.7

4.2.4. TOC, TN, and stable isotopes analyses

To determine the grain sizes of sediments, about 20 g of sediment was treated with hydrogen peroxide before being analyzed with a Mastersizer 3000 (Malvern Panalytical, Malvern, West Midlands). Sediments were freeze-dried and homogenized for analyzing total organic carbon (TOC), total nitrogen (TN), and stable isotope ratios of carbon ($\delta^{13}C$). To decalcify sediments for TOC and $\delta^{13}C$ analyses, acidified samples were acidified with 1 M HCl. Then samples were washed three times with deionized water and freeze-dried again. TOC, TN, $\delta^{13}C$, and $\delta^{15}N$ were then measured with an Elemental Analyzer-Isotope Ratio Mass Spectrometer (EA-IRMS) (Elementar, Gmbh, and Hanau). All isotopic compositions were expressed as δ notation (‰) (Eq. 1):

$$\delta^{13}C\ (‰) = [R_{sample}/R_{reference} - 1] \times 1000 \quad (1)$$

Wherein R is the composition ($^{13}C/^{12}C$) of the sample and reference. Vienna Peedee Belemnite (VPDB) was used as carbon reference material and IAEA-CH-3 [International Atomic Energy Agency (IAEA), Vienna, Austria] as a standard material. The analytical errors were 0.04‰ for C estimated by IAEA working standards [CH-6 for carbon, International Atomic Energy Agency (IAEA), Vienna, Austria].

4.2.5. Positive matrix factorization receptor model

The U.S. Environmental Protection Agency positive matrix factorization (PMF) receptor model (Ver. 5.0) was employed to source apportion PAHs, which is a generic factorization method for quantifying the contribution of source compositions (Larsen and Baker, 2003; Norris et al., 2014). Each factor contribution and profile is drawn from minimizing the objective function Q, defined as

$$Q = \sum_{i=1}^{n} \sum_{j=1}^{m} \left[\frac{x_{ij} - \sum_{k=1}^{p} g_{ik} f_{kj}}{u_{ij}} \right]^2 \quad (2)$$

wherein u_{ij} is the uncertainty in the x_{ij} measurement, x_{ij} is the concentration of species j in sample i, p is the number of factors, g_{ik} is a relative contribution of each factor k, and f_{kj} is the species profile of each source. Uncertainties (*Unc*) for each PAH relative to each MDL were calculated using either Eq. 3 or Eq. 4 (below), following PMF user guidelines. Equation 3 was used when the concentration was less than the MDL; Eq. 4 was used when the concentration was higher than the MDL.

$$Unc = 5/6 \times MDL \quad (3)$$

$$Unc = \sqrt{(Error\ Fraction \times concentration)^2 + (0.5 \times MDL)^2} \quad (4)$$

wherein the *ErrorFraction* was calculated as the standard deviation of the concentration of j. When the detection frequency was <40%, Acl, Ace, Dbthio, and alkyl-PAHs were excluded. Additionally, Na was not included in the model due to possible losses of it during analysis.

4.2.6. Macrobenthic fauna analysis

After transferring the macrofauna to the laboratory, the samples were re-sieved using a 1 mm screen to rinse away formalin before analysis. The macrofaunal samples were sorted, identified to the species level, and counted using a dissection microscope.

4.2.7. Data analyses

Concentrations of PTSs were categorized following methods outlined by NOAA (1991) and Daskalakis and O'Connor (1995). 'High' concentrations of PTSs were defined as the 85th percentile. The High and five-times-High (5-x-High) concentrations in sediments of YS and BS are suggested for providing regional criteria of PTSs in sediments. All locations were categorized as being High, 5-x-High, or Low (neither High nor 5-x-High). SPSS 25.0 (SPSS INC., Chicago, IL) was used to conduct statistical analyses and used non-parametric statistical analysis for data that were not normally distributed. Differences in concentrations of PTSs by land-use type and region were evaluated with the Kruskal-Wallis test and the Mann-Whitney test with Bonferroni correction. Principal Component Analysis (PCA) was performed using fourth-root transformed values of PTS concentrations and physicochemical parameters and linear regression analysis was used to understand the relationship between concentrations of PTSs and physicochemical parameters. To compare our data to guidelines of the Canadian Council of Ministers of the Environment (CCME, 2002), the concentration of APs was converted with toxic equivalency factors (TEFs) and normalized them to 1% TOC, as outlined in Section 3.2 of CCME guidelines. For the 16 PAHs provided for South Korea and China in 2008, data of a previous study used reported by Hong et al. (2012b). A distance-based linear model (DistLM) was performed using the software PRIMER 6 (PRIMER-E Ltd., Plymouth, UK) to explore the relationships between the macrofaunal community and environmental variables. Variables that had a high correlation (> 0.8) were excluded to avoid co-linearity. Step-wise selection and An Information Criterion were applied. The results of the DistLM was visualized using distance-based redundancy ordination analysis (dbRDA).

4.3. Results and Discussion

4.3.1. Distributions of PTSs in sediments of Yellow and Bohai Seas

PAHs, APs, and SOs were detected in all sediments of the YS and BS (Figure 4.3). Concentrations of PAHs in the YS and BS ranged from 6.2 to 65,000 ng g^{-1} dw in sediment from freshwater locations and 2.1 to18,000 ng g^{-1} dw in sediment from seawater locations. The high concentrations exceeding 5-x-High concentration (3,200 ng g^{-1} dw) were detected in both industrial (NT10, HL4, and NT9) and municipal locations (QH5 and QH6). In previous studies, relatively lower concentrations of PAHs had been detected (20-5700 ng g^{-1} dw) from some areas sampled in the present study (Ma et al., 2001; Jiao et al., 2012; Zhang et al., 2014), despite them not having changed in their land-use designations, which suggested that these areas have been affected by increasing contamination sources.

The High and 5-x-High concentration categories of our study were compared to other defined criteria, including effect-range low (ERL) and effect-range median (ERM) concentrations defined by Long et al. (1995), threshold-effect concentrations (TEC) and probable-effect concentrations (PEC) defined by Solberg et al. (2003), and interim sediments quality guidelines (ISQG) and probable effect levels (PEL) defined by CCME (2001) (Figure 4.3 and Table 4.4). Our High and 5-x-High concentrations were similar to the threshold effect concentration guidelines (TEC), such as ERL, TEC, and ISQG. However, both High and 5-x-High concentrations were lower than the probable effect concentration guidelines (PECs), such as ERM, PEC, and PEL. In addition, our High and 5-x-High concentrations for individual compounds were generally lower than TECs and PECs, with the exception of DbahA, which was higher than TECs and PECs, indicating input from sources specific to the Yellow and Bohai seas. Overall, regional criteria of PAHs for YS and BS were similar or lower than existing sediment quality guidelines, indicating that YS and BS were moderately contaminated by PAHs.

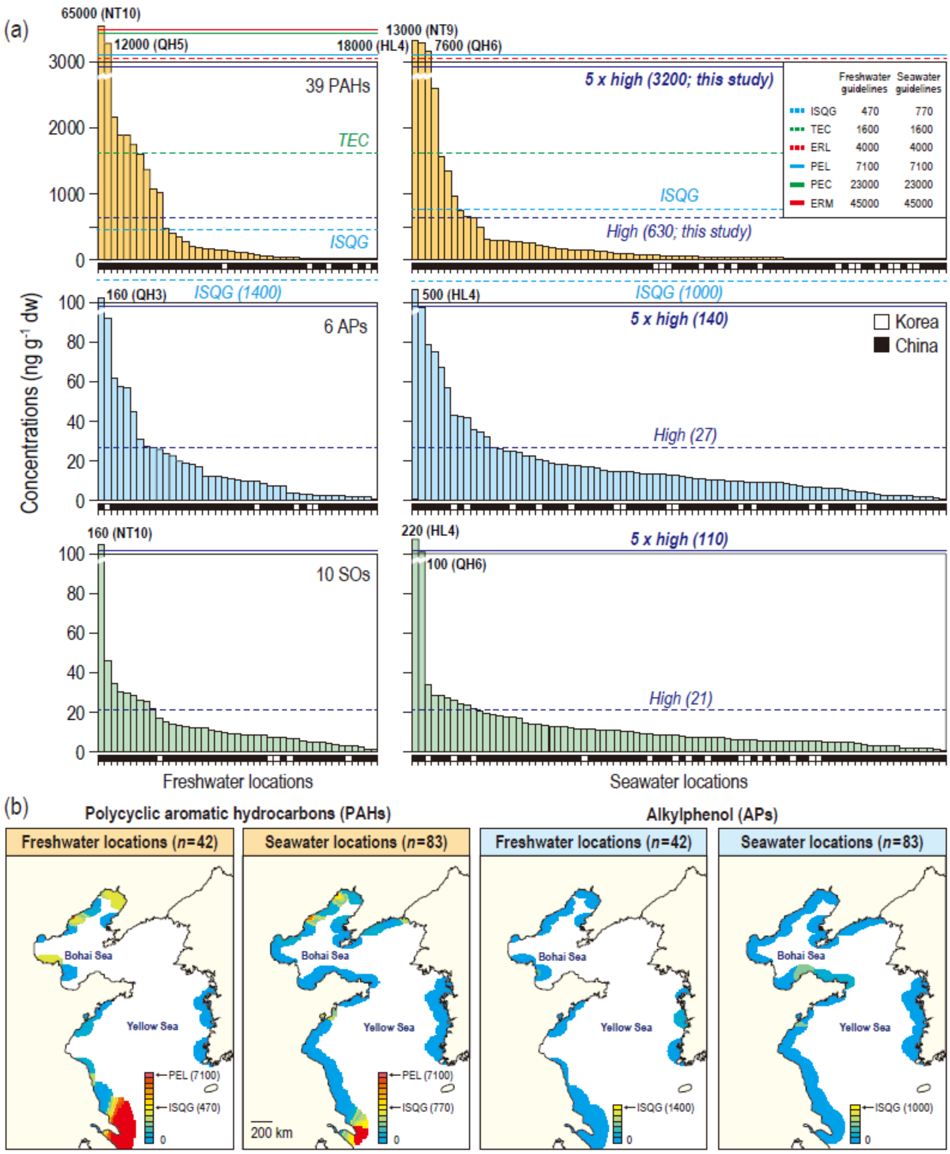

Figure 4.3.
Distributions of PTSs in sediments of the Yellow and Bohai seas. Panels: (a) PAHs (n = 39), APs (n = 6), and SOs (n = 10) and (b) potential ecological risk from low (blue) to high (red) levels of contamination. High concentrations are defined as the 85th percentile of samples in this study, whereas 5-x-high concentrations are five times higher than the High concentration. Dotted and solid lines indicate existing sediment quality guidelines [(ISQG: interim sediment quality guidelines, PEL: probable effect levels (CCME, 2001; CCME, 2002); TEC and PEC: threshold and probable effect concentrations (Solberg et al., 2003); ERL and ERM: effect range low and median values (Long et al., 1995)].

Table 4.4.
Sediment quality guidelines (SQGs) for threshold effect concentrations (TECs: ISQG, TEC, and ERL) and probable-effect concentrations (PECs: PEL, PEC, and ERM) of contaminants. Concentrations are provided relative to 15th, 50th, and 85th percentiles for 125 sites. High concentrations were defined as the 85th percentile value of total concentration.

Compound	SQGs						This study				
	TECs			PECs			Concentration (%)			Criteria	
	ISQG	TEC	ERL	PEL	PEC	ERM	15th	50th	85th	High	5*High
Naphthalene	35	180	160	390	560	2100	7.1	11	20	20	100
2-methyl naphthalene	20	20	70	200	200	670	1.8	2.7	7.6	7.6	38
Acenaphthylene	5.9	5.9	44	130	130	640	1.8	2.9	8.6	8.6	43
Acenaphthene	6.7	6.7	16	89	89	500	2.4	6.0	23	23	120
Fluorene	21	77	19	140	540	540	1.9	3.1	13	13	65
Phenanthrene	87	200	240	540	1200	1500	1.7	4.8	20	20	100
Anthracene	47	57	85	250	850	1100	0.6	1.6	9.3	9.3	47
Fluoranthene	110	420	600	1500	2200	5100	1.8	7.5	51	51	250
Pyrene	150	200	670	1400	1500	2600	1.7	6.8	46	46	230
Benz*(a)*anthracene	75	110	260	690	1100	1600	1.1	4.8	44	44	220
Chrysene	110	170	380	850	1300	2800	1.8	9.4	82	82	410
Benzo*(a)*pyrene	89	150	430	760	1500	1600	1.9	8.9	110	110	550
Dibenzo*(a,h)*anthracene	6.2	33	63	140	140	260	2.9	12	93	93	460
Total PAHs	770	1600	4000	7100	23000	45000	14	62	630	630	3200
Alkylphenols	1000						2.8	11	27	27	140

Concentrations of PAHs exceeding guidelines were found mainly in the Yellow Sea of China (YSC) and the BS. In the Yellow Sea of South Korea (YSK), High and 5-x-High concentrations were not detected, whereas concentrations at two locations (NT10 and NT9) in the YSC and three sites (HL4, QH5, and QH6) in the BS exceeded the 5-x-High concentrations. Thirty-three locations [YSC (n = 10) and BS (n = 23)] exceeded ISQG guidelines, whereas five locations [YSC (n = 2) and BS (n = 3)] exceeded PEL guidelines. Concentrations exceeding TEC were detected at one location in YSC and 12 locations in BS, whereas PEC criteria were exceeded at two locations in YSC and one site in BS. Six locations exceeded ERL and two locations exceeded ERM in YSC and BS. PAHs in the sediment of the YS and BS mostly exceeded the criteria of CCME but did not exceed all of the criteria for locations along the YSK. Most of the sampled locations that exceeded threshold criteria were situated near industrial and municipal areas, suggesting that PAH pollution is closely associated with land-use intensity.

Concentrations of APs in the sediments of freshwater rivers feeding the YS and BS ranged from 0.5–160 ng g^{-1} dw (mean = 20 ng g^{-1} dw), whereas APs in seawater sediments ranged from 0.6–500 ng g^{-1} dw (mean = 23 ng g^{-1} dw). High concentrations of APs exceeded 5-x-High concentrations at location HL4 (500 ng g^{-1} dw) and location QH3 (160 ng g^{-1} dw), followed by locations QD1, GG1, QH4, and WH1. These locations comprised a variety of land-use, such as industrial, municipal, agriculture, and aquaculture land-uses, indicating that contamination by APs was site-specific and not associated with any one type of land-use. In addition, concentrations of APs in those locations were similar to concentrations measured by Jeon et al. (2017) at Geum River (32–180 ng g^{-1} dw) and Wang et al. (2011) at Panjin and Yingkou (28–380 ng g^{-1} dw), indicating the continued use of APs. High and 5-x-High concentrations were lower than ISQGs of CCME, and the number of locations measured with High concentrations of APs was similar in YS and BS. The three locations (15%) occurring in sediments of the YSK, eight locations (19%) in YSC, and eight locations (11%) occurring in the BS, indicating that contamination of sediments by APs is similar in the YS and BS seas.

The mean concentrations of SOs in the YS and BS were 16 ng g^{-1} dw (range 0.9–160 ng g^{-1} dw) at freshwater locations and 14 ng g^{-1} dw (range 0.7–220 ng g^{-1} dw) at seawater locations. Relatively high concentrations of SOs were measured near industrial and municipal areas (locations HL4, NT10, QH6, DY5, and YC6) and only site HL4 (BS) and site NT10 (YSC) exceeded the 5-x-High concentrations (110 ng g^{-1} dw). This study is the first to report SOs concentrations in YSC and BS. The concentrations were less than reported in the creeks feeding Lake Sihwa (mean = 400 ng g^{-1} dw) and Masan Bay (mean = 130 ng g^{-1} dw) in Korea and were similar to coastal areas of Gyeonggi Bay (mean = 25 ng g^{-1} dw) and the Geum River Estuary (mean = 14 ng g^{-1} dw) in Korea (Hong et al., 2016; Yoon et al., 2017; Lee et al., 2018). In general, SOs contamination in YS and BS was lower than determined by previous studies, although high concentrations at some locations were detected, suggesting the need for further research in high concentration regions.

Sources of organic matter in sediments varied (Figure 4.4). In general, the $\delta^{13}C$ values for organic matter from the terrestrial origin are about -27‰ to -25‰ (Schubert and Calvert, 2001; Lehmann et al., 2002), whereas $\delta^{13}C$ values from marine origins are about -22‰ to -20‰ (Peters et al., 1978; Meyers, 1994). The mean values of $\delta^{13}C$ in our study area were -24.0‰ at freshwater locations and -22.0‰ at marine (seawater) locations, indicating a mixture of terrestrial and marine origins. These values are similar to the previous studies reported for the Yellow Sea and Korean coastal areas; Geum River (-32.6 to -19.4‰; Kang et al., 2019), Seomjin River (-29.1 to -24.6‰; Kang et al., 2019), Lake Sihwa and surrounding inland creeks (-32.2 to -20.4‰; Lee et al., 2017), and eastern Yellow Sea (-23.5 to -20.9‰; Yoon et al., 2016). Among locations of the study area, relatively low $\delta^{13}C$ values were found in the sand beach and estuarine sediments (locations DD2, QH4, QH7, BZ3, NT1, and NT5). These low $\delta^{13}C$ values may be due to biogeochemical process (e.g., microbial activity) and/or hydrodynamic conditions such as freshwater and seawater mixing (Chen et al., 2005; Gao et al., 2012). In addition, relatively high $\delta^{13}C$ values were found in the riverine system (locations JZ3, JZ4, DY2, DY3, WF5, QD2, LY4, and GG1), probably due to algal blooms and/or agricultural runoff of organic material from C4 plants (Shi et al., 2017; Kang et al., 2019).

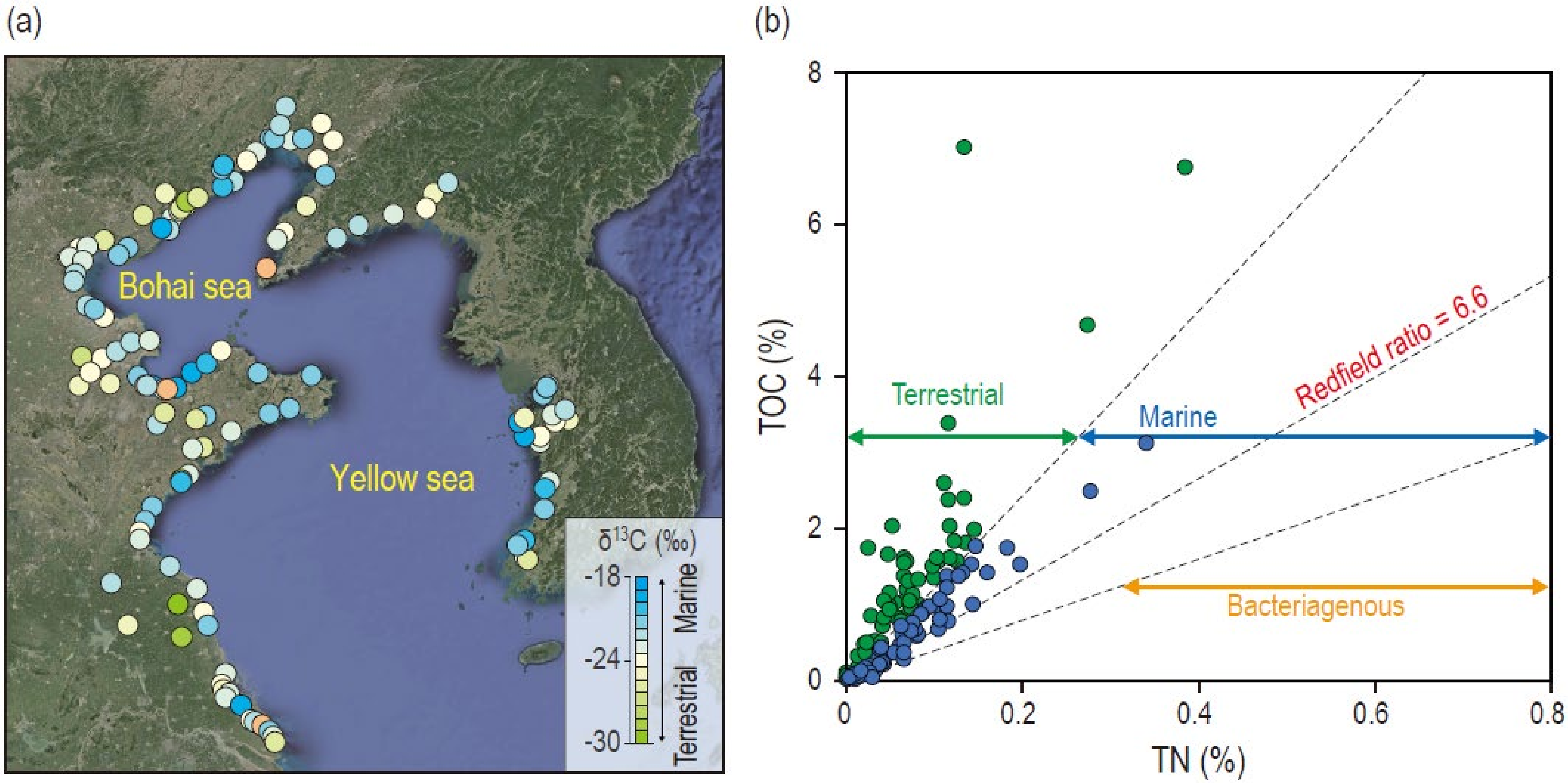

Figure 4.4.
(a) Spatial distribution of δ^{13}C values and (b) C/N ratios in the sediment of Yellow and Bohai seas.

Sources of organic matter measured by carbon/nitrogen (C/N) ratios showed a pattern similar to $\delta^{13}C$ values. The C/N ratios of marine origin were between 4 and 12, whereas C/N ratios of terrestrial origin were above 12 (Wu et al., 2007; Szczepańska et al., 2012). C/N ratios in the present study ranged from 0.76 to 52 in freshwater locations and from 2.66 to 66 in seawater locations, indicating mixed sources of organic matter. Relatively low or high C/N ratios were found in riverine and estuarine sediments and from beach sand, which may be due to bacterial decomposition in response to superimposed effects of carbon and nitrogen influx or efflux into/from organic matter (Rice and Tenore, 1981; Thornton and McManus, 1994). Overall, the sediment stable isotopic signatures identified in the Yellow and Bohai seas would indicate a mixture of terrestrial and marine sources for the organic matters, with some regionally specific values

Concentrations of PTSs were correlated with particular physicochemical parameters of sediments (Figure 4.5). PCA analysis showed that the PC2 axis explained the positive relationship between PTSs and TOC and the negative relationship between PTS and $\delta^{13}C$, whereas the axis weakly correlated with grain size and C/N ratio. Results of regression analysis showed significant correlation between PTSs and TOC (positive: r = 0.29–0.65, $p < 0.01$), whereas PAHs and SOs were significantly correlated with $\delta^{13}C$ (negative: r = 0.18–0.26, $p < 0.05$). The correlative relationships with TOC were similar to those found in previous studies by Liu et al. (2013) and Yoon et al. (2017). Correlation of TOC with $\delta^{13}C$ indicates that PAHs and SOs are derived from terrestrial organic sources, as opposed to previously reported results identifying sources as originating in the estuary (Yoon et al., 2017). However, both seawater and freshwater locations had high concentrations of PTSs, suggesting that the concentrations of PTS are related to the TOC and source of organic carbon, regardless of whether they are derived from coastal or more landward location.

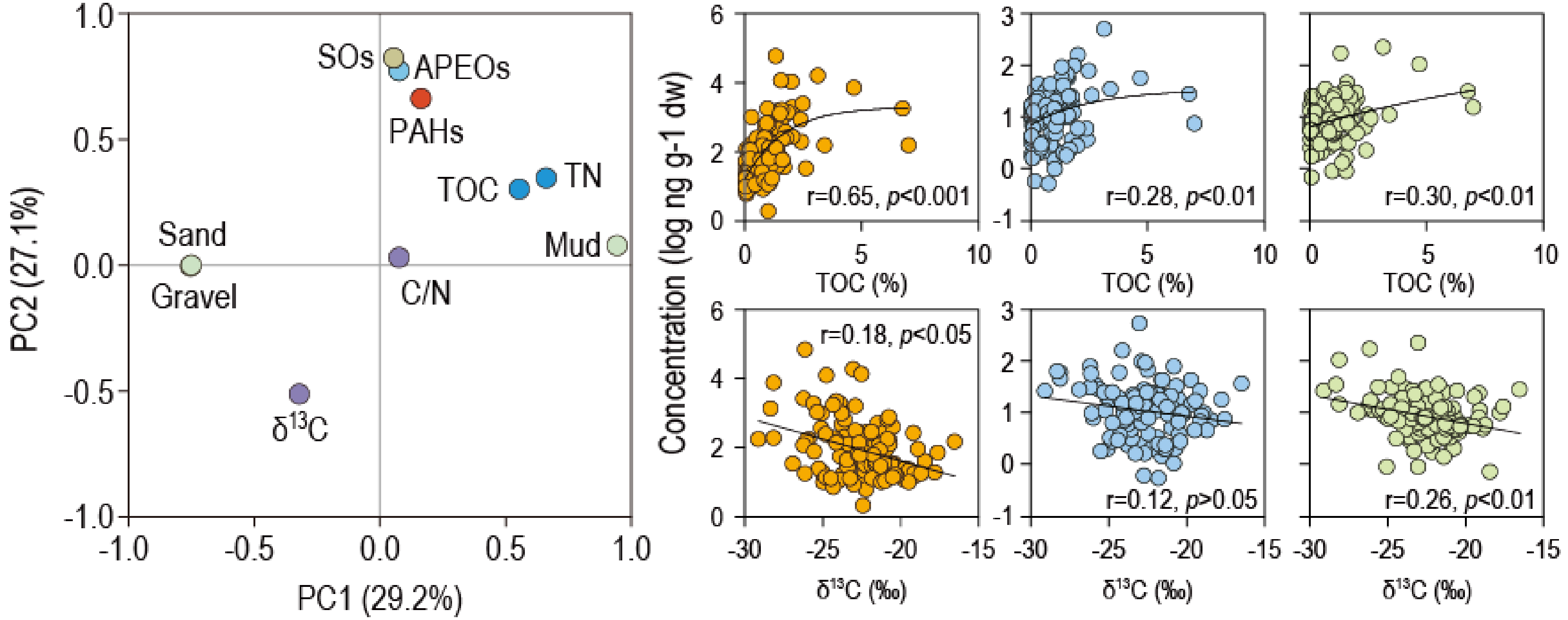

Figure 4.5.

Relationships among PTSs. Panels: (left) Principal Component Analysis (PCA) ordination of PTSs and physicochemical parameters and (right) the relationship between PTSs and TOC or δ^{13}C.

4.3.2. Assessment of potential ecological risks

The potential ecological risk posed by the detected PTSs was assessed using ISQG and PEL suggested by CCME (CCME, 2001, 2002). Of the 125 locations, concentrations of PAHs exceeded ISQG and PEL at 43 locations (Figure 4.3). Concentrations of PAHs in sediments exceeded thresholds at 22% of seawater locations (18 of 83 locations) and 48% of freshwater locations (20 of 42 locations). Six PAHs (Na, 2-Na, BaA, Chr, BaP, and DbahA) exceeded ISQG at seawater sites DD, DL, and QD in the YSC and sites YK, JZ, HL, QH, and TS in the BS. In freshwater locations, 10 PAHs (Na, 2-Na, Ace, Phe, Fl, Py, BaA, Chr, BaP, and DbahA) exceeded ISQG at sites DD and YC in the YSC and at sites DL, YK, PJ, JZ, HL, QH, TS, and DY in the BS. Some PAHs (including Ace, Flu, Phe, Ant, Fl, Py, BaA, Chr, BaP, and DbahA) exceeded PEL thresholds at locations NT10, NT9, HL4, QH5, and QH6. Locations in the YSK did not exceed ISQG and PEL, indicating a higher potential risk to aquatic organisms in the sediment of China than Korea. Most locations exceeding sediment quality guidelines were from industrial or municipal areas, indicating that land-use type affects the distributions of PAHs at concentrations that may detrimentally impact aquatic ecosystems.

Concentrations of APs-TEQ were generally lower than ISQG in both seawater and freshwater locations. I found relatively high concentrations of APs-TEQ in seawater locations in the YSC (sites YT and QD) and the freshwater area of the YSK (location GG1) and the BS (sites DY). However, in all regions, concentrations did not exceed ISQG, indicating a lower potential ecological risk of APs in the YS and BS. Overall, high potential risks to aquatic organisms were found from PAHs from sediments from YS and BS, suggesting that continuous monitoring and management would be needed.

4.3.3. Compositions and sources of PTSs

The gradient in the compositions of PTSs was confirmed by concentration (Figure 4.6). The composition of high molecular weight (HMW: 4–6 rings) PAHs dominated the top 20% of PAHs concentration, whereas the composition of low molecular weight (LMW: 2–3 rings) PAHs increased as concentrations of PAHs declined. LMW PAHs were dominant in sediments of the YSK, but HMW PAHs dominated sediments of the YSC and BS, indicating that PAHs in those areas are derived from different sources. Among APs, the compositions of NPs and NPEOs were higher than OP and OPEOs in the top 20% of the concentration of APs, with NPs being the most prevalent. At less contaminated locations, compositions of OPEOs were higher when concentrations of NPs and NPEOs were lower, which suggests that the use of NPEOs has continued in highly contaminated locations. Compositions of NPEOs were highest in BS, followed by YSC and YSK, indicating that sediments in China are more contaminated by APs than Korea. Styrene trimers (STs) dominated the top 20% concentrations of SOs and the compositions of styrene dimers (SDs) increased as the concentration of SOs declined. However, the compositions of SOs in the YSK, YSC, and BS were similar, indicating that concentrations and sources of SOs are not related to specific regions, but are site-specific.

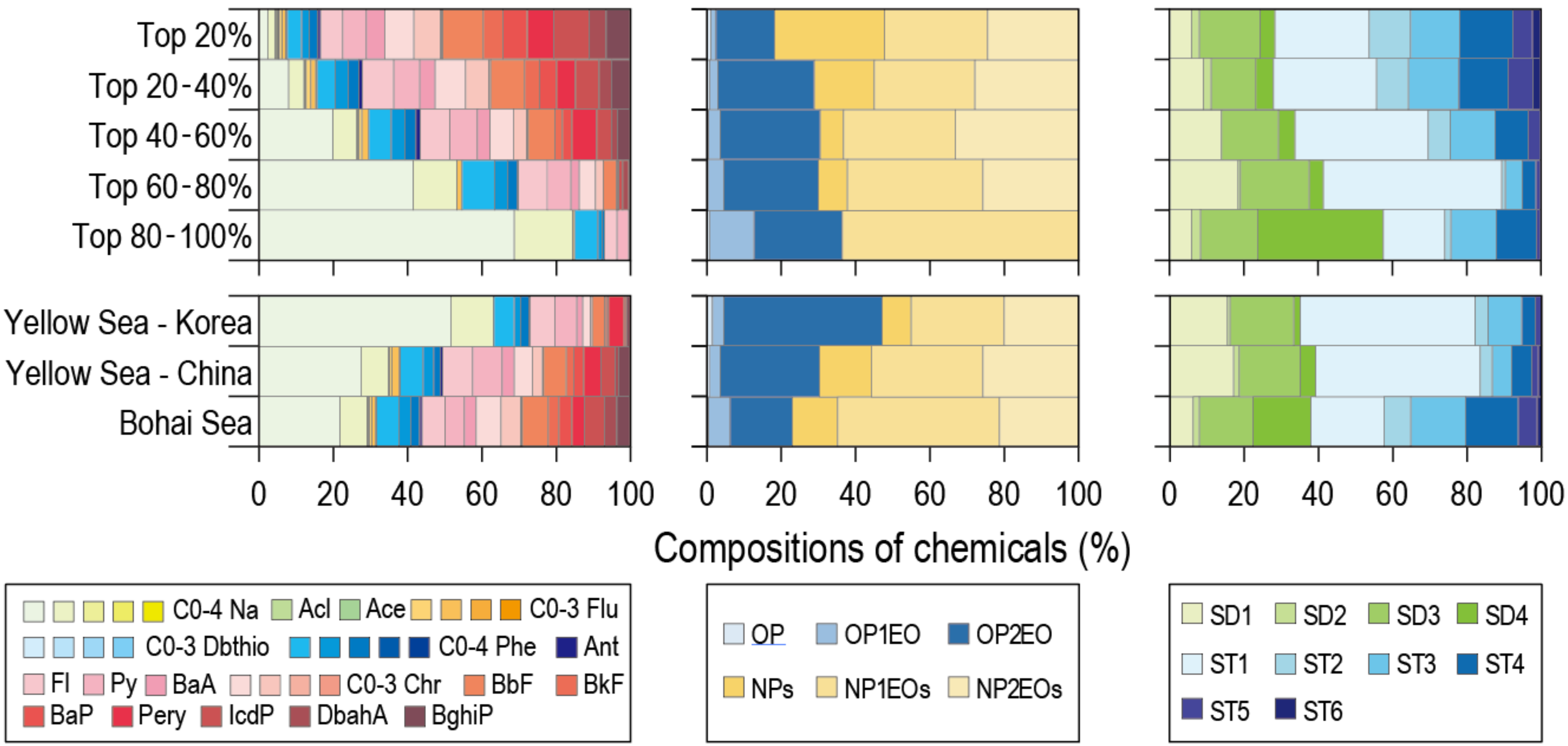

Figure 4.6.
Composition of PTSs among concentration groups, by concentration (20% interval of concentrations) and region.

The four leading potential sources of PAHs were identified by the PMF model (Figure 4.7). PAHs have a similar composition from the origin to coastal sediments despite difference of great concentrations, making it possible to estimate the source of PAHs in coastal sediments (Hong et al., 2016). The primary PAHs source was characterized by BbF (68%), BaP (66%), IcdP (66%), BkF (65%), BghiP (65%), Chr (60%), BaA (59%), and DbahA (55%) (Table 4.5). These contributors indicate that the primary source of PAHs was strongly linked to diesel and gasoline combustion (Harrison et al., 1996; Simcik et al., 1999; Ravindra et al., 2008). Diesel and gasoline sources contributed to 0.7% (YSK), 45% (YSC), and 39% (BS), for concentrations of PAHs, by region, and 42% (62,000 ng g^{-1}) of the total concentration of PAHs in YS and BS. However, among all locations sampled, only nine locations were dominated by PAH from diesel and gasoline combustion. In the YSK, this source of combustion was not dominant in sediments overall, but they did dominate in three locations (NT9, NT10, and QD1) in the YSC and six locations (HL4, QH3, QH5, QH6, TS2, and TS3) in the BS. These results indicate that sources of PAHs in diesel and gasoline combustion mainly affected high concentration areas.

The secondary source of PAHs was characterized by Fl, Py, Phe, Flu, BaA, and Ant (Table 4.5), particularly high proportions of Fl (46%), Py (46%), and Phe (41%), which suggests that biomass combustion in the main secondary source of PAHs (McGrath et al., 2001; Guzzella et al., 2016). This secondary source of PAH contributed 35,000 ng g^{-1} (24% of total PAHs) in YS and BS and 37% regionally (mainly at sites LS and GG) in the YSK, 26% (mainly at sites YC and NT) in the YSC, and 22% (mainly at sites TJ) in the BS. These results indicate that by-products of biomass combustion are more concentrated in sediments of the YSK than the YSC and BS.

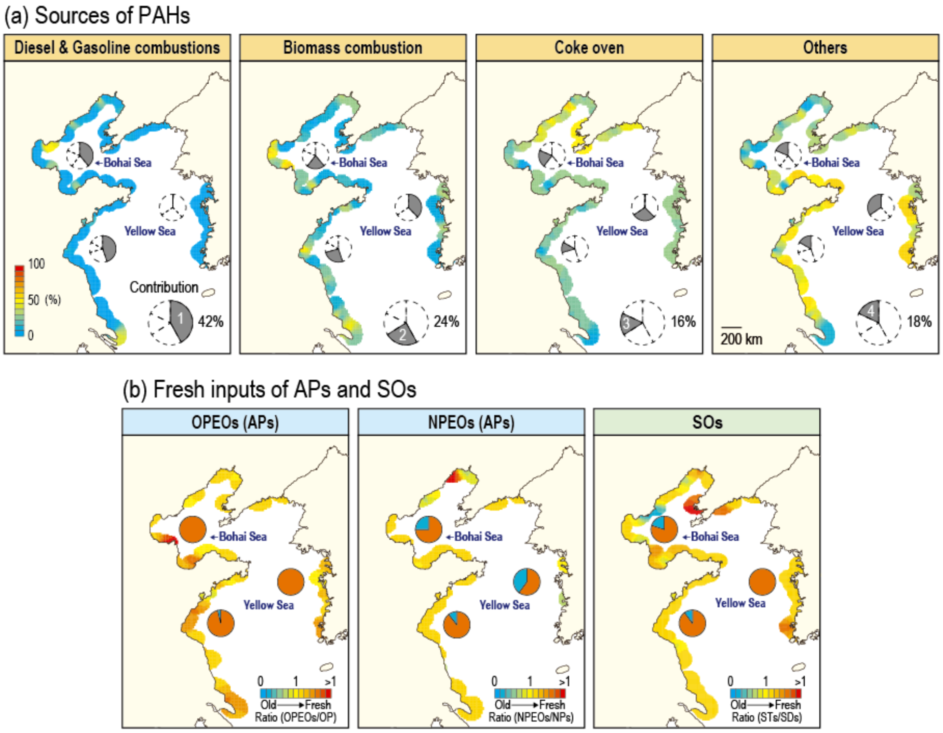

Figure 4.7.
Spatial-distribution of PTSs in sediments of the study area. Panels: (a) sources of PAHs derived with a PMF receptor model and (b) fresh (recent) input ratios of OPEOs, NPEOs, and SOs. The contributions represent the proportions of PTS from each source to total PTSs and regional concentrations of PAHs (Yellow Sea of Korea, Yellow Sea of China, and the Bohai Sea).

Table 4.5.
Fractional condition to identified sources (%) from base run using positive matrix factorization receptor model.

	Flu	Phe	Ant	Fl	Py	BaA	Chr	BbF	BkF	BaP	IcdP	DbahA	BghiP
Factor 1 – diesel & gasoline combustion	7	32	46	40	40	59	60	68	65	66	66	55	65
Factor 2 – biomass combustion	34	41	23	46	46	25	21	16	17	16	2	0	17
Factor 3 – coke oven	43	27	16	6	7	5	9	0	3	2	9	45	2
Factor 4 – others	16	0	16	7	7	11	10	16	16	16	12	0	16

The tertiary source of PAHs was dominated by Flu, DbahA, Phe, and Ant (Table 2.5). The major constituent, Flu (43%), is a by-product of producing coke (Kwon and Choi, 2014). In addition, major mass fractions of Phe and Ant are considered particular indicators of Coke oven combustion (Khalili et al., 1995). The signature of coke ovens mainly dominated sediments of the BS, but the regional contribution was 21%. The regional contributions of YSK and YSC were 28% and 13%, but the coke oven sources had the lowest total contribution (16%) of the total concentration of PAHs (23,000 ng g^{-1}). This result indicates that coke oven by-products have the least impact in sediments of the YS and BS.

Finally, the fourth source contributor to PAH pollution in sediments was comprised of Flu, Ant, BbF, BkF, BaP, and BghiP, but the factor profile was too low (< 20%) and was composed of a variety of chemical species. This source of PAHs occupied the highest proportion for all regions. The contribution of PAHs to sediments was 34% (YSK), 17% (YSC), 19% (BS), and 18% (26,000 ng g^{-1}: contribution to total). These contributions indicated that the relatively less polluted locations are mainly dominated by the chemical species listed above (especially in the sediments of the YSK). The diagnostic ratios of PAHs also showed similar sources as those determined by the PMF model (Figure 4.8). The results indicated that PAHs in the sediment of Yellow and Bohai seas were mainly derived from petroleum combustion and biomass & coal combustion. Although the ratios did not quantitatively determine the impact of each source, the same trends were observed in the Bohai Sea, where coal and biomass combustion sources were identified as dominant inputs.

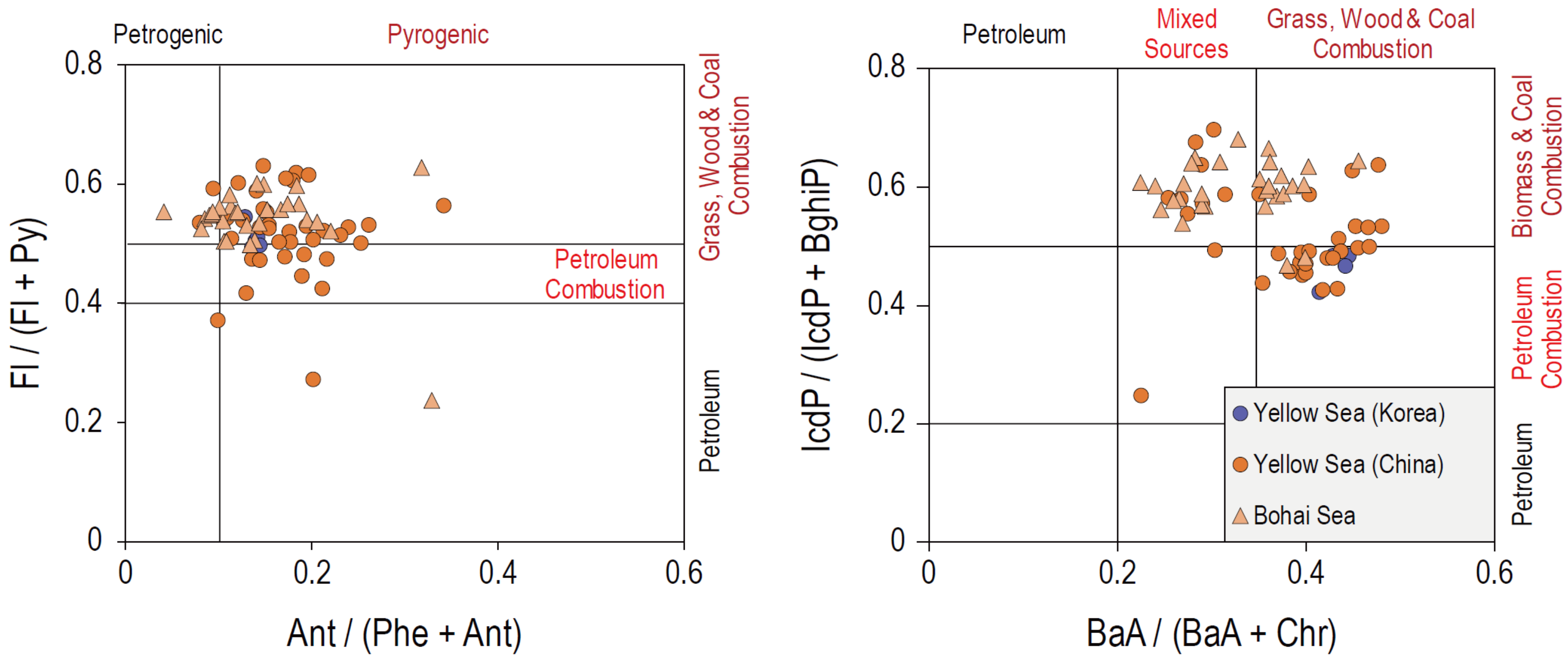

Figure 4.8.
Diagnostic ratios for prediction of PAHs sources between Ant/(Ant+Phe) and Fl/(Fl+Py), and BaA/(BaA+Chr) and IcdP/(IcdP+BghiP).

Fresh inputs of OPEOs, NPEOs, and SOs were determined by calculating the proportion of degraded chemicals to fresh chemicals (Hong et al., 2016; Yoon et al., 2017). In all studied regions, fresh inputs to sediments were dominant in the YS and BS. In OPEOs, all input ratios, except at QD3, suggested fresh inputs of OPEOs (Figure 4.7). The highest input ratio was found at location DY5, upstream of the Yellow River, indicating intensive use of OPEOs around the industrial area of location DY5. Subsequently, the ratios for sites LS, QD, AS, NT, WF, and YT were also high, indicating that OPEOs are used in all regions near the YS and BS. The fresh input of NPEOs varied by region and location. For example, fresh inputs were high in sediments at location HL4 (adjacent to an industrial area), indicating intensive use of NPEOs by the industry located there. In addition, fresh inputs were evident at sites DD, QH4, QD7, TJ, DY, and WF in BS, at sites YT, WH, QD, RZ, LY, YC, and NT in YSC, and at sites LS and AS in YSK. In contrast, at sites, YK, PJ, QH3, and QD6 in the BS and at sites GG in YSK showed ratios exhibiting a predominance of degraded (old) NPEOs. These results indicate that recent inputs dominate most regions, but the degree of intensity is site-specific (Yoon et al., 2017).

Fresh inputs of SOs also dominated sediments in the YS and BS (Figure 4.7). At sites DL in the BS, the highest fresh inputs were found in regions, indicating the copious use of precursors of SOs in manufacturing, such as in polystyrene production. In the YS, at sites, JD and YS in YSK showed the highest fresh inputs of SOs, followed by all the other locations sampled in YSK, indicating continuous, reoccurring inputs of SOs throughout YSK. A predominance of degraded SOs was found at a few sites (HL, TS, DY, YT, and YC), with TS exhibiting the highest degradation ratio in sediments, indicating less use of plastic materials in TS than in other regions. Our results indicated that fresh inputs of SOs are derived from localized industrial and municipal activities and that they show the same trend as a previous study by Hong et al. (2016). Overall, fresh inputs of PTSs dominated the YS and BS, but distributions were regional- and site-specific.

4.3.4. PTSs distributions by land-use types

The distributions of PTSs by land-uses varied by chemical constituent (Figure 4.9). The highest concentrations of PAHs were associated with industrial land-use, followed (in order) by municipal, agriculture, aquaculture, saltern, barren lands, and beach land-uses. The concentrations of PAHs in industrial and municipal areas differed significantly from concentrations in other land-use types ($p < 0.05$) (Table 4.6). At the regional scale, concentrations of PAHs in sediments of the YSK were less than in other areas, regardless of land-use type (< 200 ng g^{-1} dw), and there were no significant differences among land-use types. In contrast, significant differences in sediment concentrations were found in the YSC and BS between industrial, municipal, and other land-use types ($p < 0.05$). Our results indicate that concentrations of PAHs are associated with land-use type, but differ among regions. In addition, differences in the concentration of PAHs were statistically significant ($p < 0.05$) among regions relative to industrial land-use (Table 4.7). These differences were attributed to variations in land-use intensity in industrial areas of South Korea and China and in how the various regions pre-treat discharged wastewater (Li et al., 2010; Luo et al., 2014). The same land-use designation showed a wide range of concentrations of PAHs across regions, which in some regions correlated significantly with sediment mud content, TOC, or TN (Table 4.8). However, such correlations could not explain the distributions of PAH concentrations in YS and BS, which might be explained by differences in the types of other contaminants delivered from the same land-use types in different areas or the various impacts of nonpoint pollutants in sediments (Stout and Graan, 2010).

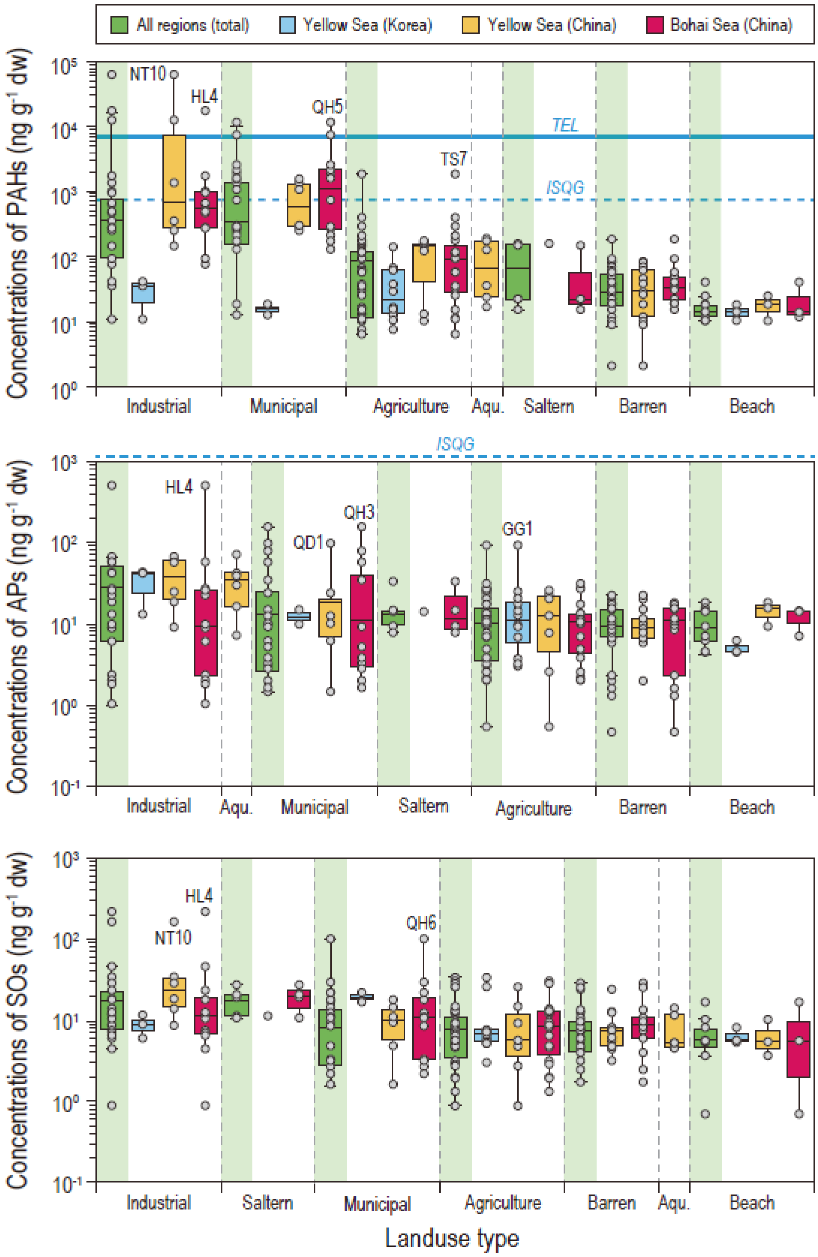

Figure 4.9.

Box plot of PAHs, APs, and SOs relative to seven land-use types [industrial, municipal, agriculture, beach, saltern, barren, and aquaculture (Aqu.)]. Each dot represents raw data of PTS measurements. Dotted and solid lines indicate existing sediment quality guidelines [(ISQG: interim sediment quality guidelines, PEL: probable effect levels (CCME, 2001, 2002)].

Table 4.6.
Statistical relationships of landuse type on persistent toxic substances (PTSs), for all PTS categories and by region. The bold text highlights statistically significant relationships.

Sea	Country	PTSs	Kruskal-Wallis test		*Post hoc* Mann-Whitney (*P* values)[a]						
			F-value	P-value	I-A	I-B	I-Ba	M-A	M-B	M-S	M-Ba
All	All	PAHs	54.3	**<0.001**	**0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**	0.616	**<0.001**
		APs	10.9	0.146							
		SOs	16.2	**0.015**	0.196	0.251	0.554	1.000	1.000	1.000	1.000
Yellow Sea	Korea	PAHs	1.44	0.676							
		APs	5.80	0.128							
		SOs	4.27	0.227							
	China	PAHs	26.9	**<0.001**	0.324	**0.023**	**0.002**	0.346	**0.025**	-[b]	**0.002**
		APs	10.5	0.061							
		SOs	11.0	0.052							
Bohai Sea	China	PAHs	36.4	**<0.001**	**0.030**	**0.010**	**0.001**	**0.005**	**0.025**	**0.023**	**<0.001**
		APs	1.22	0.934							
		SOs	5.82	0.571							

[a] I-Industrial; M-Municipal; A-Agricultural; B-Beach; Ba-Barren; S-Saltern
[b] Post-hoc test not conducted

Table 4.7.
Statistical relationships of regional differences, by land-use type. The bold text highlights statistically significant relationships.

Landuse type	PTSs	Kruskal-Wallis test		*Post hoc* Mann-Whitney (*P* values)		
		F-value	P-value	Y-K[a] *vs* Y-C[b]	Y-K *vs* B-C[c]	Y-S *vs* B-C
Industrial	PAHs	7.52	**0.023**	**0.029**	**0.035**	1.000
	APs	3.46	0.178			
	SOs	4.06	0.132			
Municipal	PAHs	5.40	0.067			
	APs	0.67	0.714			
	SOs	2.03	0.363			
Agricultural	PAHs	4.70	0.095			
	APs	0.34	0.842			
	SOs	0.13	0.937			
Beach	PAHs	0.43	0.805			
	APs	6.06	**0.048**	**0.048**	0.295	1.000
	SOs	0.16	0.924			
Barren[d]	PAHs					0.545
	APs					0.880
	SOs					0.390

[a] Y-K: Yellow Sea-Korea
[b] Y-C: Yellow Sea-China
[c] B-C: Bohai Sea-China
[d] n = 2 (Yellow Sea-China and Bohai Sea-China)

Table 4.8.

Statistical relationships (Spearman rank) of regional differences between PTSs and physicochemical parameters in sediments, by land-use type and region for the Yellow and Bohai seas. The bold text highlights statistically significant relationships.

PTSs	Physicochemical parameters	Yellow Sea-Korea			Yellow Sea-China						Bohai Sea-China					
		Industrial	Agricultural	Beach	Industrial	Municipal	Agricultural	Beach	Aqua[a]	Barren	Industrial	Municipal	Agricultural	Beach	Saltern	Barren
PAHs	Mud content	0.50	**0.69***	0.00	-0.20	0.31	0.21	**1.00****	0.54	0.18	0.25	0.09	0.39	0.87	-0.32	-0.14
	TN	**1.00****	**0.69***	0.00	-0.15	0.17	**0.90****	0.87	0.60	0.20	-0.58	0.64*	**0.82****	0.87	0.95	0.13
	TOC	**1.00****	**0.87****	-0.50	-0.03	0.37	**0.79***	**1.00****	0.43	0.33	0.48	0.42	**0.68****	-0.50	0.95	0.22
	C/N	**1.00****	-0.16	0.00	0.54	0.37	0.43	-0.50	-0.14	0.37	-0.29	-0.20	0.30	-0.50	0.32	0.32
	$\delta^{13}C$	0.50	-0.18	-0.50	0.31	0.60	0.75	-0.50	-0.43	0.12	0.21	0.54	-0.07	-0.50	0.32	0.22
APs	Mud content	**1.00****	**0.59***	**1.00****	0.14	0.31	-0.18	0.50	0.43	0.44	-0.12	-0.03	-0.01	**-1.00****	-0.40	**0.56***
	TN	0.50	**0.80****	**1.00****	0.03	0.23	-0.02	1.00	0.49	0.42	0.20	0.60*	0.20	**-1.00****	**1.00****	0.53
	TOC	0.50	**0.76****	0.87	0.09	0.03	-0.29	0.67	0.66	0.15	0.16	0.65*	0.19	0.01	**1.00****	**0.61***
	C/N	0.50	-0.01	**1.00****	0.43	0.03	-0.57	0.67	0.26	0.22	-0.49	0.04	0.08	0.01	0.20	0.10
	$\delta^{13}C$	**1.00****	-0.28	0.87	0.09	0.54	0.46	0.67	-0.14	0.29	-0.15	0.40	0.01	0.87	0.40	-0.16
SOs	Mud content	0.50	0.53	0.87	-0.03	0.26	0.14	**1.00****	0.78	-0.09	-0.14	-0.38	0.13	-0.87	-0.20	**0.56***
	TN	**1.00****	0.27	0.87	-0.27	0.15	0.40	0.87	0.78	-0.15	0.01	0.22	0.14	-0.87	0.80	0.27
	TOC	**1.00****	0.12	0.50	-0.66	0.09	0.21	**1.00****	0.78	-0.31	0.25	0.19	0.16	-0.50	0.80	0.14
	C/N	**1.00****	-0.01	-0.87	0.14	0.09	-0.14	-0.50	0.27	-0.05	-0.21	-0.22	0.06	-0.50	0.40	-0.08
	$\delta^{13}C$	0.50	0.09	0.50	0.37	0.37	0.68	-0.50	-0.68	-0.41	-0.13	0.53	**0.59****	**1.00****	0.20	0.26

[a] Aqua: Aquaculture

[*] Significantly correlated at $p < 0.05$ level (2-tailed).

[**] Significantly correlated at $p < 0.01$ level (2-tailed).

Concentrations of APs were highest in industrial areas, followed (in order) by aquaculture, municipal, saltern, agriculture, barren lands, and beach land-uses, but differences were not statistically significant ($p > 0.05$) (Table 4.6). At the regional scale, concentrations of APs by land-use types showed a similar trend among regions. Although the ordering of concentration of APs by land-use type varied slightly among sediments in the YSK, YSC, and BS, they were not significantly different in the ranking ($p > 0.05$) (Table 4.7). In addition, for a given land-use type, a significant difference was found in concentrations of APs only for the beach land-use type between the YSK (mean = 5.0 ng g^{-1} dw) and YSC (mean = 11 ng g^{-1} dw) ($p < 0.05$) (Table 4.8), but the overall concentration was less than in other land-use types. These results indicate that for all land-use types, similar concentrations of APs accumulated in sediments of the YS and BS. Concentrations of APs by land-use types in each region could be explained by differences in environmental conditions for some regions, no obvious trend was found in YS and BS. These results suggested that the distribution of APs is more dependent on specific pollutant sources than on land-use type or other environmental factors throughout the YS and BS, as has been found in other studies of coastal contaminants (EPA, 2010).

Concentrations of SOs in sediments associated with each land-use type differed significantly ($p < 0.05$) among types, but the post-hoc test did not identify any differences between each land-use type (Table 4.6). Concentrations of SOs in each region were similar regardless of land-use type with no significant difference in mean concentrations of SOs relative to land-use types ($p > 0.05$). Moreover, concentrations from the YSK, YSC, and BS relative to any given land-use type were also not statistically significant ($p > 0.05$) (Table 4.7). Correlations of land-use type with environmental variables were region-specific (Table 4.8), indicating that land-use type is not significantly related to concentrations of SOs. However, relatively high concentrations of SOs in sediments at locations HL4, NT10, and QH6 were related to specific ambient sources from industrial and municipal land-uses. Hong et al. (2016, 2019) suggested that the distribution of SOs released from industrial and municipal sources are similar, but that the magnitude of release is site-specific.

4.3.5. Comparison of PTSs contaminations between 2008 and 2018

Change over time in the distributions of PAHs between 2008 and 2018 in Korea (YSK) and China (BS and YSC) differed (Figure 4.10a). Concentrations of PAHs in YSK declined at all freshwater and seawater locations, and all locations not already exceeding sediment quality guidelines (ISQG and PEL). There was a significant difference in PAH concentrations overtime at freshwater ($p < 0.05$) and at seawater locations ($p < 0.01$) (Figure 4.10b). The change might be explained as a response to regulations by the Ministry of Environment (MOE, 2009) to control the release of PTSs into the environments.

In contrast, concentrations of PAHs in sediments in BS and YSC were site-specific relative to freshwater and seawater locations. Concentrations of PAHs generally declined in 2018 relative to 2008. For example, concentrations had exceeded ISQG in 2008 (1700 ng g^{-1} dw) at location DL1 but had declined 350 ng g^{-1} dw below ISQG by 2018. However, some concentrations were many times higher in 2018 than in 2008, particularly at locations TS7 (6.9 times higher), QH3 (6.2 times higher), HL4 (24 times higher), and QH5 (150 times higher), all of which exceeded ISQG and PEL guidelines. In contrast, mean concentrations of PAHs slightly declined from 2008 to 2018, but not in a statistically significant degree ($p > 0.05$). Our results indicate that environmental regulations on persistent organic pollutants have not been enforced in BS and YSC, because concentrations of PAHs have increased over the past 10 years at some locations. In addition, changes in specific sources of PAHs could explain changes in distributions of PAHs in YSK, BS, and YSC over time (2008 to 2018).

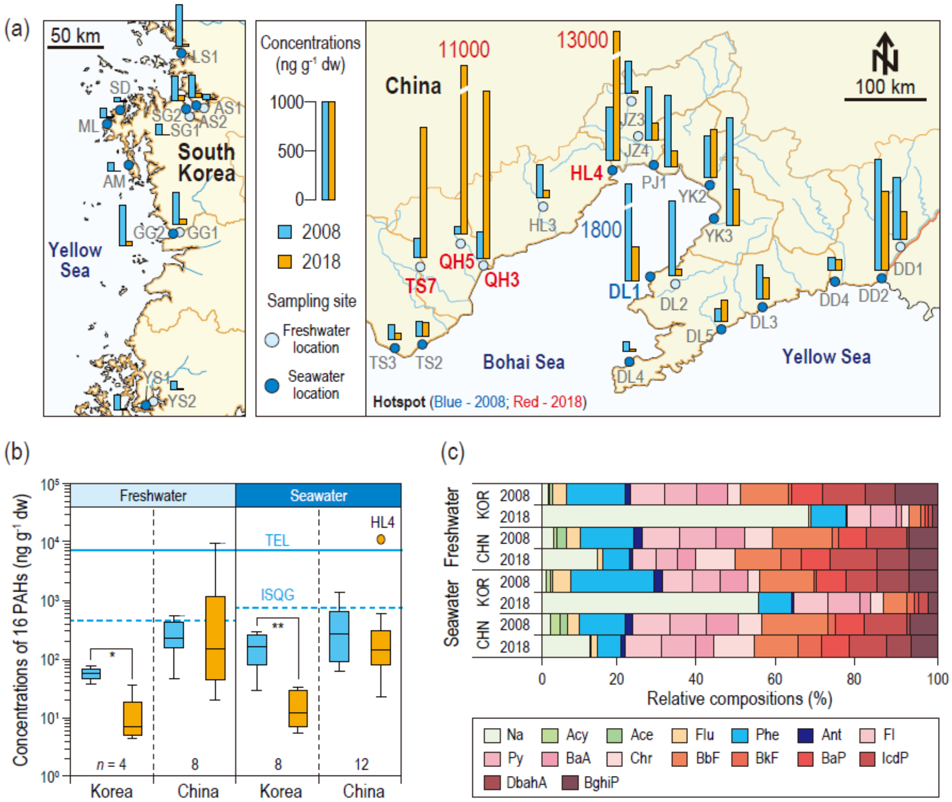

Figure 4.10.

The change observed over time (2008–2018) for 16 polycyclic aromatic hydrocarbons (PAHs) in sediments in South Korea and China relative to freshwater and saltwater environments. Panels: (a) spatial distribution of PAHs, (b) box plots for PAHs in freshwater and seawater locations, and (c) change in relative compositions of PAHs, by chemical species, over time. The ISQG and PEL are depicted with horizontal lines in Panel b (CCME, 2001).

The compositions of PAHs in Korea (YSK) and China (BS and YSC) between 2008 and 2018 appear to have changed (Figure 4.10c). In 2008, The HMW PAHs dominated in both freshwater (78%) and saltwater locations (70%) in YSK, whereas LMW PAHs were detected in high proportions in 2018 at both freshwater locations (77%) and seawater locations (64%). This change in predominant types of PAHs indicates that the sources in 2008 were mainly pyrogenic in origin (Gschwend and Hites, 1981; Budzinski et al., 1997). However, because LMW compounds have relatively high volatility, sources of PAHs in 2018 were likely derived from air-water exchanges and atmospheric deposition (Tobiszewski and Namiesnik, 2012). Compositions of PAHs in BS and YSC did not change much between 2008 and 2018 at either freshwater or saltwater locations.

HMW PAHs dominated (upper 75%), regardless of year and salinity of sampling locations, but in some sites in BS, HMW PAHs concentrations increased by > 90% by 2018, such as at locations TS7, QH3, QH5, and HL4. PAHs with 5–6 rings, including BbF, BaP, IcdP, BghiP, dramatically increased, indicating an input of diesel and gasoline combustion (Figure 4.11) (Simcik et al., 1999; Ravindra et al., 2008) over the intervening 10-y period. Overall, in South Korea, concentrations of PAHs in sediments are now lower than they were 10 years prior due to efforts by the federal government to reduce PTSs. Meanwhile, higher concentrations were detected in 2018 in China, due to the lack of regulations to combat PAHs pollution. Because concentrations of PTSs were high enough to detrimentally impact aquatic ecosystems, further studies are necessary to better understand the sources, fates, and potential risks to the aquatic ecosystem.

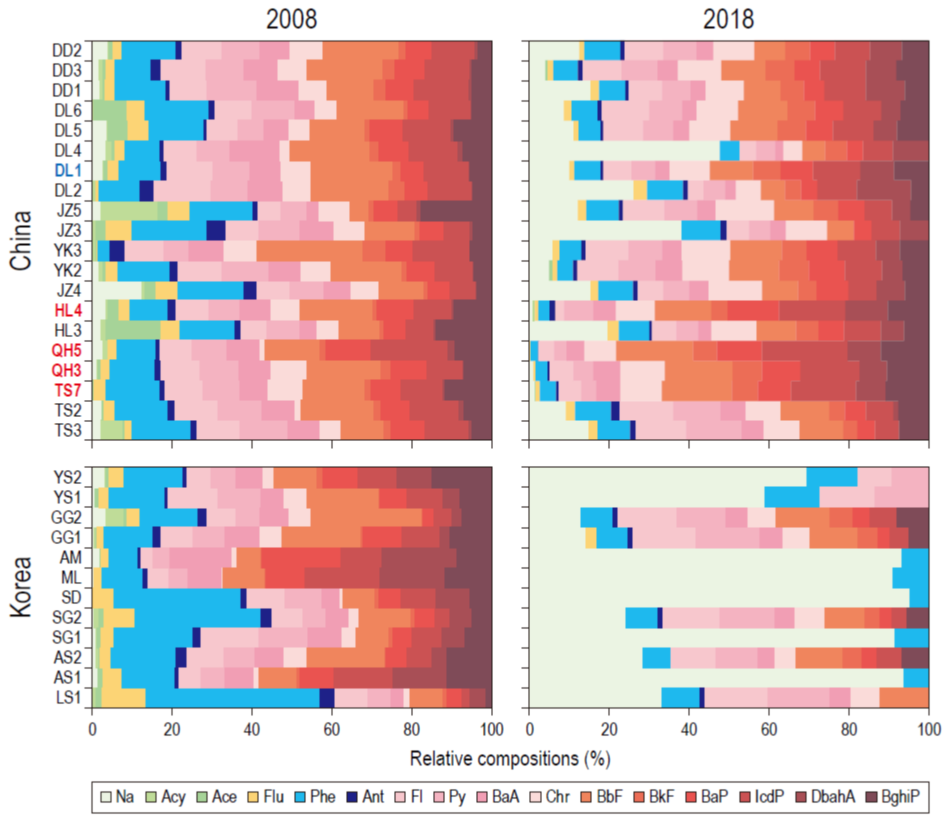

Figure 4.11.
Compositions of 16 PAHs in 2008 and 2018 in sediments of the Yellow and Bohai seas.

4.3.6. Macrobenthic fauna community

A total of 20 macrofaunal species was identified belonging to three major taxonomic groups (Annelida, Arthropoda, and Mollusca), with 1,354 individuals in 63 stations (Figure 4.12). Less than 10 species of macrofauna appeared in all stations, and only species living in the upper intertidal zone appeared. The number of individuals in the range of 1 to 235 appeared (mean: 22 individuals), and at some stations, specific species dominated with relatively high individuals. *Hediste japonica* was the dominant species (30%) in the entire sea area, followed by *Potamocorbula amurensis* (20%), *Macrophthalmus japonicus* (5.2%), *Helice tridens* (4.8%), *and Radix auricularia* (4.7%). Macrobenthic fauna community analyzed by CA and nMDS showed high similarity, without a distinction between the Yellow Sea and the Bohai Sea, and between Korea and China (Figure 4.12). These results indicated that macrofaunal communities in the upper intertidal zone were similar in all regions of the Yellow and Bohai seas. Organic pollutants or enrichment indicator species were found in only one species (*Sinocorophium sinensis*) with low individuals (2% of total individuals). These results suggested that the macrobenthic fauna in the study area represents an uncontaminated environment (Pearson and Rosenberg, 1978; Dauvin et al., 2009).

A distance-based linear model (DistLM) was performed to explore the relationships between the macrofaunal community and environmental variables. Collectively, the three environmental variables, such as salinity, clay, silt, explained 16% of the total variability in macrofauna assemblages (Figure 4.13). *Hediste japonica* was dominated in all regions with less affected by environmental variables, and *R. auricularia* and *Corbicula fluminea* were mainly affected by salinity. *M. japonicus* was dominated in the area with high clay content, while *Scopimera globose* was dominated in the area with low clay and silt content. The inconsistent effect on the macrofaunal community by contamination of PTSs might be attributed to the greater influence of physio-chemical parameters (not pollution). Overall, the distribution of macrofauna in the Yellow and Bohai seas mainly affected physical parameters with minor effects by contamination levels of PTSs.

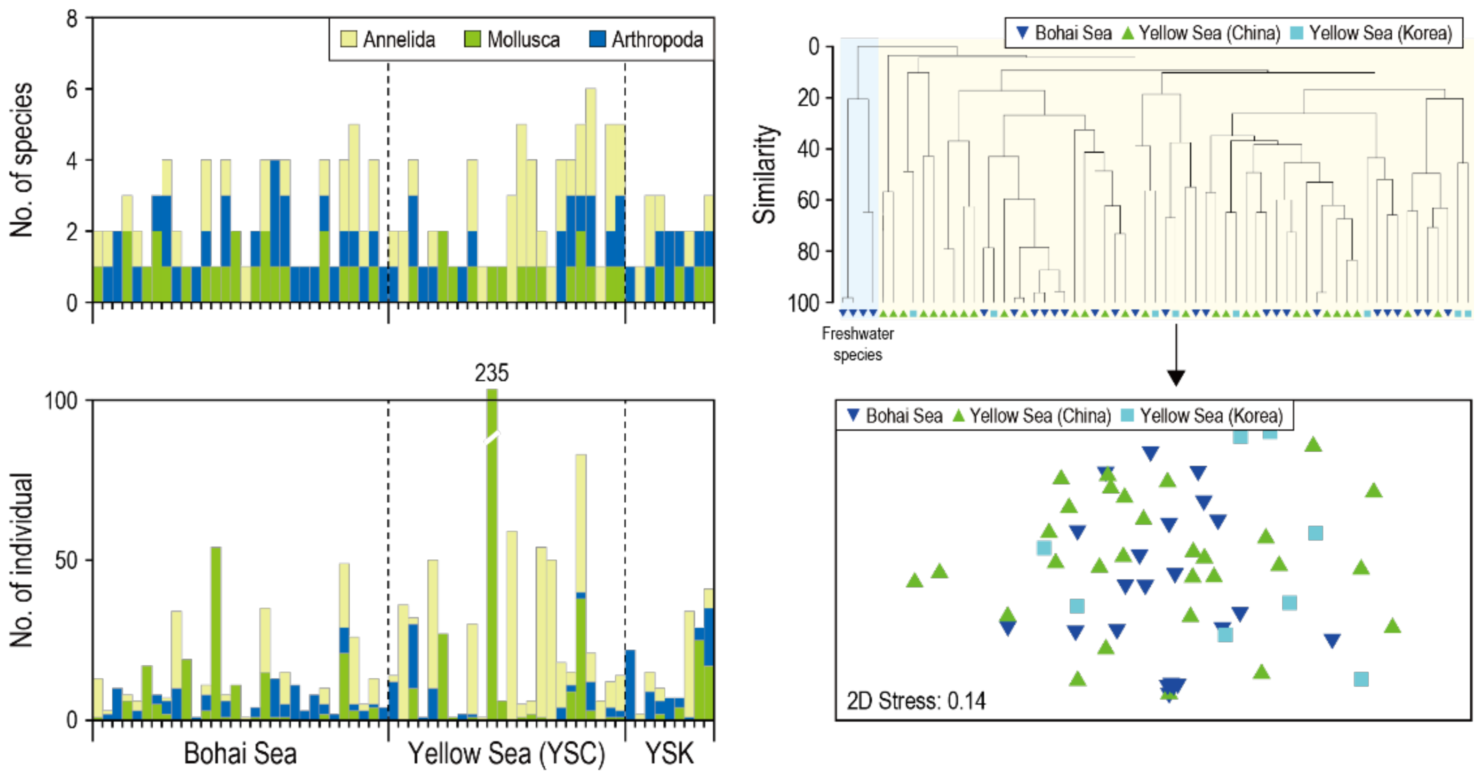

Figure 4.12.
The number of species and individuals of benthic macrofauna in the upper intertidal zone of Yellow and Bohai seas. Cluster analysis showing the two groups of macrofaunal assemblages and non-parametric multi-dimensional scaling (nMDS) ordination plot based on relative abundance except freshwater species.

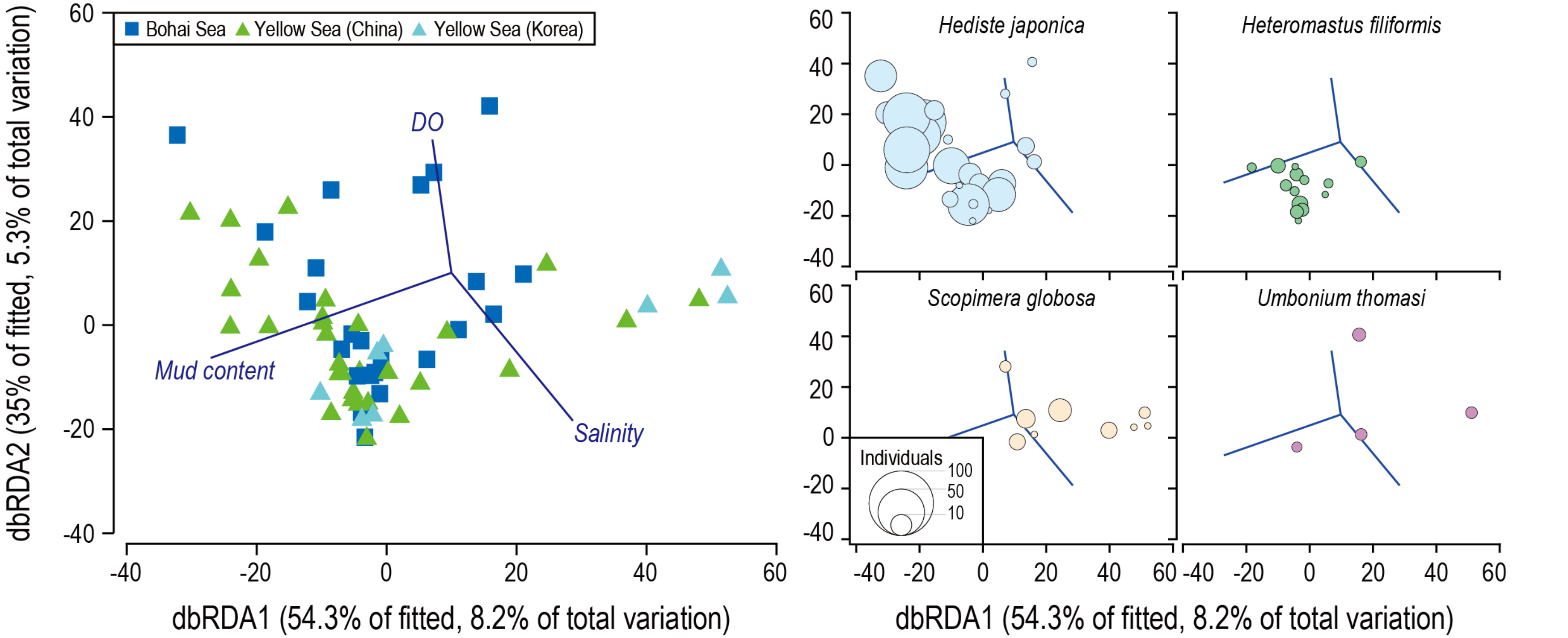

Figure 4.13.
Distance-based redundancy analysis (dbRDA) ordination based on environmental parameters and the relative abundance of macrofauna. Only significant environmental variables were marked as vectors. Representative species distributed according to each environmental variable. The circle size means the number of individuals of each species.

4.4. Summary

In the past decade, the pollution level of Korea has decreased, while China has increased. The concentrations of PAHs were the highest among the PTSs, and the concentrations of PAHs in the hotspot area posed a potential risk to the aquatic organism. The main sources of PAHs were the by-product of gasoline, diesel, biomass combustion, and coke oven, with the different contributions of each source in Korea and China. Relatively high concentrations of PTSs were detected in industrial and municipal areas. Although the concentrations of APs and SOs were relatively low, the fresh inputs of APs and SOs were found that continuously being discharged into the Yellow Sea. Compared with a previous study conducted in the same area in 2008, the concentration of PAHs in Korea has decreased over the past 10 years, but in China, higher concentrations were detected along with sources shifting from mixed sources to the linked by-product of diesel and gasoline. The macrofaunal community of the upper intertidal zone in the Yellow Sea showed no significant differences between regions and countries, and similar species appeared. The macrofaunal community was mainly affected by salinity and sediment grain size, while the impact of persistent pollutants was relatively less. Thus, over the 10 years, the contamination and input of PTSs have been substantial and continuous with high potential risk, especially in China.

CHAPTER 5.

HISTORICAL SEDIMENTARY RECORD AND FLUX OF ClASSIC AND EMERGING PERSISTENT TOXIC SUBSTANCES IN INTERTIDAL SEDIMENT CORES FROM THE YELLOW AND BOHAI SEAS

This chapter was prepared for submission to Environment International.

5.1. Introduction

Persistent toxic substances (PTSs) originated from direct or indirect results of anthropogenic activities are transported to the marine environment via various mechanisms, such as rivers, runoff, and atmospheric deposition. The PTSs finally sunk associating with particle matter to a benthic environment and are deposited in the sediment layer due to their hydrophobic, long-range transport, and slow degradation rates (Witt, 1995; Lohmann et al., 2007). Accumulated PTSs in sediments negatively affect aquatic ecosystems including benthos (Dassenakis et al., 2003; Christophoridis et al., 2009). Various efforts have been performed to improve the benthic environment , and as a result, the contamination by PTSs is decreasing compared to the past (Lee et al., 2017; Lee et al., 2018; Yoon et al., 2020). However, potential biological impacts would increase, and concerns about environmental pollution continued to rise. This is due to contamination by emerging PTSs, but most of the studies on PTSs have been performed on the classic PTSs (Khim and Hong 2014; Meng et al., 2017). Thus, further research is required, but research on emerging PTSs is still insufficient, especially on the historical record.

Classic PTSs such as polycyclic aromatic hydrocarbons (PAHs), alkylphenols (APs), and polychlorinated biphenyls (PCBs) have been well documented over the 30 years. These PTSs originate from anthropogenic activities or natural sources such as incomplete combustion of fossil fuels, municipal wastes, and biomass or use of industrial and household applications (White et al., 1994; Giesy et al., 2010; Hosoda et al., 2014). They were massively produced from the 1930s to recent years, currently, the production or use of PCBs and APs has been banned (Brivik et al., 2004; Kim et al., 2020). But, some of them are still used in developing countries and continuously distributed in the environment from the past to the present (Hornbuckle and Robertson, 2010). Emerging PTSs such as styrene oligomers (SOs), emerging-PAHs (E-PAHs), and halogenated-PAHs (Hl-PAHs) have been reported recently. These PTSs also originate from similar sources of classic PTSs such as industrial applications, incomplete combustion, and vehicle emissions (Horii et al., 2008; Hong et al., 2016; An et al., 2020). Interest in emerging-PTSs has recently increased due to an increase in product usage or their environmental persistence and toxicities (GBI Research, 2012; Ohura et al., 2018). But, despite their potential risks (Kim et al., 2019), research on emerging PTSs is insufficient and they are excluded from environmental monitoring programs.

Reconstruction of the contamination history of PTSs using sediment core can reveal environmental changes over time with socioeconomic development and historical energy consumptions, although the PTSs were degraded (Liu et al., 2012; Zhang et al., 2013). Analyzing emerging-PTSs such as SOs, which are known to be poorly decomposed, with classic PTSs, overcome these limitations and provide a more reliable pollution history. Previous studies focused on contamination history were mainly conducted on a regional scale from the subtidal zone in the estuary, bay, coast, and offshore (Liu et al., 2005; Guo et al., 2006; Yan et al., 2009; Zhang et al., 2009; Hu et al., 2011; Li et al., 2015; Cai et al., 2016; Guerra et al., 2019). Relatively few studies have been conducted in the large marine ecosystem scale and intertidal zone (Zhang et al., 2013; Kaiser et al., 2016; Wang et al., 2017). In addition, these previous studies have mainly been performed on representative classic PTSs such as typical polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), and organic chlorine pesticides (OCPs), and the contamination history of emerging-PTSs such as emerging-PAHs (E-PAHs), and halogenated-PAHs (Hl-PAHs) is largely unknown yet.

The Yellow Sea and the Bohai Sea are semi-enclosed sea areas taking slow water circulation (taking about 30 years to water renovation), which occur slow diffusion and exchange of pollutants than in the open ocean (Luo et al., 2010; Xu et al., 2013). The Yellow and Bohai seas share the border of three countries (South Korea, North Korea, and China) and constitute the Yellow Sea Large Marine Ecosystem (YSLME). The pressure following rapid development has been increasing the emission of land-origin contaminants, and continued environmental issues arose in the Yellow and Bohai seas (Khim et al., 2018b). In previous studies, contamination by classic PTSs has been reported in the Yellow and Bohai seas since the past, and contamination by emerging PTSs has recently been reported (Meng et al., 2017; Khim et al., 2018a; Khim et al., 2018b; Yoon et al., 2020). However, most studies focused only on classic PTSs in regional scales, and determined current pollution levels.

The present study investigated historical sedimentary records of classic and emerging PTSs in the intertidal zone from the Yellow and Bohai seas with macrobenthic fauna. The specific aims of the present study were to: (1) determine historical depositions and fluxes of classic and emerging PTSs, (2) identify compositions and sources of classic and emerging PTSs, and finally (3) evaluate the relationship among macrobenthic fauna, classic and emerging PTSs, and environmental parameters. This study is the first to investigate the historical sedimentary record of emerging PTSs (SOs, E-PAHs, and Hl-PAHs) in intertidal sediments. Thus, this study provides insight as a novel example reporting historical records of emerging-PTSs in the Yellow and Bohai seas.

5.2. Materials and Methods

5.2.1. Sampling

Sediment core sampling was conducted in the intertidal zone from the Yellow and Bohai seas. A total of fifteen sediment core samples were collected in eight provinces (South Korea; Gyeonggi, Chungnam, Jeonbuk, and Jeonnam, China; Liaoning, Hebei, Shandong, and Jiangsu province in China) and Tianjin city in China (Figure 5.1). The fifteen locations were selected based on the result of a previous study in the same area located in estuarine and coastal areas (Yoon et al., 2020). The GPS coordinates and basic water quality parameters of sampling locations were presented in Yoon et al., 2020. The sediment core samples were collected using a stainless steel core (100×40×600 mm) and stored in pre-cleaned glass bottles. All sediment core samples were stored at -20 ℃ until analyses. Macrobenthic fauna samples were collected triplicate using square core (200×120×100 mm) and fixed with 5% buffered formalin.

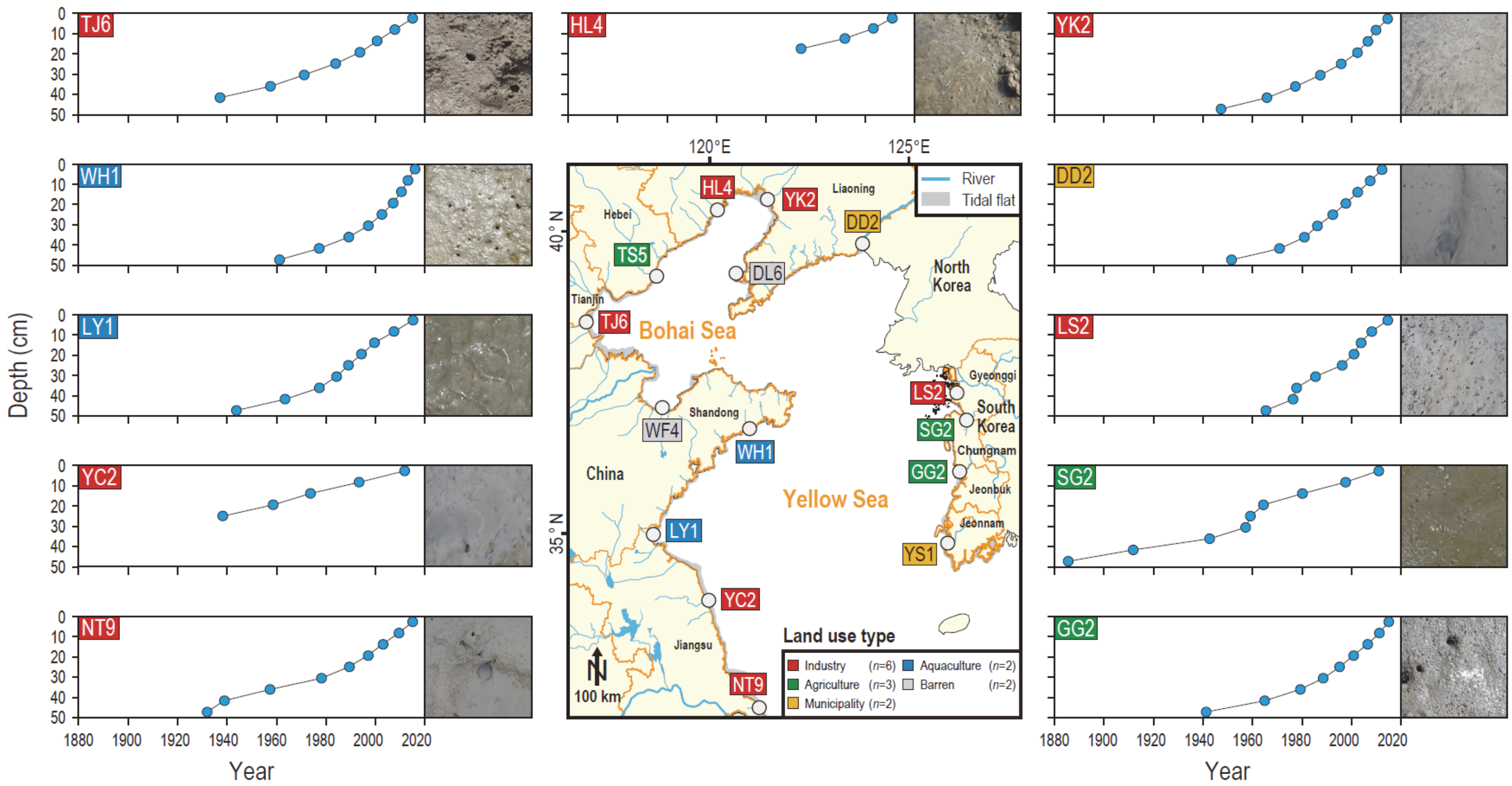

Figure 5.1.
Map showing the study area and sampling sites the Yellow and Bohai seas. The land-use type was referred to in Yoon et al. 2020. Photographs of sediment at each site and date measured by the depth of core sediment are presented.

5.2.2. *Target chemicals*

For analysis of classic PTSs, standard of15 PAHs, 6 APs, and 32 PCBs and surrogated standards were obtained from ChemService (West Chester, PA), Sigma-Aldrich (Saint Louis, MO), and Wellington Laboratories (Guelph, ON). The standard of 10 SOs, 9 E-PAHs, and 30 Hl-PAHs were obtained from Wako Pure Chemical Ind. (Osaka, Japan), Hayashi Pure Chemical Ind. (Osaka, Japan), Tokyo Chemical (Tokyo, Japan), Santa Cruz Biotechnology, Inc. (Dallas, TX), AHH Chemical Co., Ltd. (Changzhou, China), and Chiron (Trondheim, Norway). Detailed information of target compounds is provided in Table 5.1.

5.2.3. *Analyses of persistent toxic substances*

Sediment was prepared to analyze PTSs following previous studies, with minor modifications (Khim et al., 1999; Hong et al., 2016; An et al., 2020; Vuong et al., 2020). In brief, freeze-dried sediment was weighed (approximately 5 g) and extracted using Soxhlet extractor. Before extraction, twelve surrogate standards were added. The extract was concentrated and reacted with activated copper powder (Sigma Aldrich, Saint Louis, MO). The extract was cleaned and fractionated through an activated silica gel column (70−230 mesh, Sigma-Aldrich). First fraction (F1) was eluted for PAHs, PCBs, SOs, E-PAHs, and Hl-PAHs with 60 mL of 20% DCM in hexane (v/v) (Burdick & Jackson, Muskegon, MI). Second fraction (F2) for APs was collected by elution with 50 mL of 60% DCM in acetone (J.T. Baker, Center valley, PA). Eluents were nitrogen-concentrated and added 2-fluorobiphenyl as an internal standard. I quantified classic and emerging PTSs using an Agilent 7890B gas chromatograph equipped with a 5977B mass selective detector (GC-MSD) (Agilent Technologies, Santa Clara, CA). Details of the instrumental conditions are provided in Table S2. The ranges of method detection limits (MDLs) were 0.07–0.89 ng g^{-1} for PAHs, 0.10–0.91 ng g^{-1} for APs, 0.12–0351 ng g^{-1} for PCBs, 0.28–0.94 ng g^{-1} for SOs, 0.12–0.81 ng g^{-1} for E-PAHs, and 0.25–1.27 ng g^{-1} for Hl-PAHs (Table 5.1). Mean recoveries of twelve surrogate standards (acenaphthene-d_{10}, phenanthrene-d_{10}, chrysene-d_{12}, perylene-d_{12}, bisphenol A-d_{16}, and ^{13}C-labeled CB (28, 52, 101, 153, 138, 180, and 209)) were generally acceptable: 78%–106% (Table 5.2).

Table 5.1.
Target compounds, abbreviations, and target ions in the instrumental analysis, method detection limits, and recovery of surrogate standards.

Target compounds	Abbreviation	Target ions (m/z)		Method detection limit (ng g^{-1} dw)
		Quantification ion	Confirmation ion	
Polycyclic aromatic hydrocarbons (PAHs)				
Acenaphthylene	Acl	152	151	0.11
Acenaphthene	Ace	153	154	0.19
Fluorene	Flu	166	165	0.21
Phenanthrene	Phe	178	176	0.13
Anthracene	Ant	178	176	0.07
Fluoranthene	Fl	202	200	0.89
Pyrene	Py	202	200	0.05
Benzo[*a*]anthracene	BaA	228	226	0.11
Chrysene	Chr	228	226	0.09
Benzo[*b*]fluoranthene	BbF	252	253	0.09
Benzo[*k*]fluoranthene	BkF	252	253	0.14
Benzo[*a*]pyrene	BaP	252	253	0.13
Indeno[1,2,3-*cd*]pyrene	IcdP	276	138	0.12
Dibenz[*a,h*]anthracene	DbahA	278	276	0.14
Benzo[*g,h,i*]perylene	BghiP	276	138	0.15
Polychlorinated biphenyls (PCBs)				
2,4'-Dichlorobiphenyl	CB 8	222	224	0.23
2,4,4'-Trichlorobiphenyl	CB 28	256	258	0.34
2,2',5,5'-Tetrachlorobiphenyl	CB 52	292	290	0.16
2,2',4,5'-Tetrachlorobiphenyl	CB 49	292	290	0.22
2,2',3,5'-Tetrachlorobiphenyl	CB 44	292	290	0.25
3,4,4'-Trichlorobiphenyl	CB 37	256	258	0.17
2,4,4',5-Tetrachlorobiphenyl	CB 74	292	290	0.16
2,3',4',5-Tetrachlorobiphenyl	CB 70	292	290	0.12
2,3',4,4'-Tetrachlorobiphenyl	CB 66	292	290	0.3
2,3,4,4'-Tetrachlorobiphenyl	CB 60	292	290	0.29
2,2',4,5,5'-Pentachlorobiphenyl	CB 101	326	328	0.2
2,2',4,4',5-Pentachlorobiphenyl	CB 99	326	328	0.18
2,2',3,4,5'-Pentachlorobiphenyl	CB 87	326	328	0.21
3,3',4,4'-Tetrachlorobiphenyl	CB 77	292	290	0.14
2,2',3,3',4-Pentachlorobiphenyl	CB 82	326	324	0.3
2,3',4,4',5-Pentachlorobiphenyl	CB 118	326	328	0.35
2,3,4,4',5-Pentachlorobiphenyl	CB 114	326	328	0.19
2,2',4,4',5,5'-Hexachlorobiphenyl	CB 153	360	362	0.17
2,3,3',4,4'-Pentachlorobiphenyl	CB 105	326	324	0.16
2,2',3,3',5,6,6'-Heptachlorobiphenyl	CB 179	396	394	0.27
2,2',3,4,4',5'-Hexachlorobiphenyl	CB 138	360	362	0.15
2,3,3',4,4',6-Hexachlorobiphenyl	CB 158	360	362	0.32
3,3',4,4',5-Pentachlorobiphenyl	CB 126	326	328	0.25
2,3,4,4',5,6-Hexachlorobiphenyl	CB 166	360	362	0.17
2,2',3,4',5,5',6-Heptachlorobiphenyl	CB 187	394	396	0.2
2,2',3,4,4',5',6-Heptachlorobiphenyl	CB 183	394	396	0.17
2,2',3,3',4,4'-Hexachlorobiphenyl	CB 128	360	362	0.23
2,3,3',4,4',5-Hexachlorobiphenyl	CB 156	360	362	0.22
2,2',3,4,4',5,5'-Heptachlorobiphenyl	CB 180	394	396	0.3
3,3',4,4',5,5'-Hexachlorobiphenyl	CB 169	360	362	0.27
2,2',3,3',4,4',5-Heptachlorobiphenyl	CB 170	394	396	0.25
2,3,3',4,4',5,5'-Heptachlorobiphenyl	CB 189	394	396	0.27

Table 5.1.
Target compounds, abbreviations, and target ions in the instrumental analysis, method detection limits, and recovery of surrogate standards (continued).

Target compounds	Abbreviation	Target ions (m/z)		Method detection limit
		Quantification ion	Confirmation ion	(ng g^{-1} dw)
Alkylphenols (APs)				
4-*tert*-Octylphenol	OP	207	221	0.12
4-*tert*-Octylphenol monoethoxylate	OP1EO	207	221	0.91
4-*tert*-Octylphenol diethoxylate	OP2EO	251	265	0.10
Nonylphenols (*iso*-)	NPs	251	265	0.46
Nonylphenol monoethoxylates (*iso*-)	NP1EOs	295	309	0.10
Nonylphenol diethoxylates (*iso*-)	NP2EOs	295	309	0.85
Styrene oligomers (SOs)				
1,3-Diphenylpropane	SD1	105	196	0.34
cis-1,2-Diphenylcyclobutane	SD2	78	208	0.65
2,4-Diphenyl-1-butene	SD3	104	208	0.94
trans-1,2-Diphenylcyclobutane	SD4	78	208	0.28
2,4,6-Triphenyl-1-hexene	ST1	117	194	0.57
1e-Phenyl-4e-(1-phenylethyl)-tetralin	ST2	129	207	0.53
1a-Phenyl-4e-(1-phenylethyl)-tetralin	ST3	129	207	0.30
1a-Phenyl-4a-(1-phenylethyl)-tetralin	ST4	129	207	0.49
1e-Phenyl-4a-(1-phenylethyl)-tetralin	ST5	207	105	0.32
1,3,5-Triphenylcyclohexane (isomer mix)	ST6	117	104	0.89
Emerging-Polycyclic aromatic hydrocarbons (E-PAHs)				
2-Methylanthracene	2MA	192	191	0.81
9-Ethylphenanthrene	9EP	191	206	0.06
Benzo[*b*]naphtho[2,3-*d*]furan	BBNF	218	189	0.32
11H-Benzo[b]fluorene	11BF	216	215	0.23
Benzo[*b*]naphtho[2,1-*d*]thiophene	BBNT	234	235	0.12
5-Methylbenzo[*a*]anthracene	5MBA	256	241	0.20
1,12-Dimethylbenzo[c]phenanthrene	BCP	242	241	0.34
Benzo[*j*]fluoranthene	BJF	252	253	0.52
Benzo[*e*]pyrene	BEP	252	250	0.28
Halogenated-Polycyclic aromatic hydrocarbons (Hl-PAHs)				
9-Bromofluorene	9-Br-Flu	165	166	1.07
2-Bromofluorene	2-Br-Flu	256	176	0.58
9-Chlorophenanthrene	9-Cl-Phe	212	176	0.53
2-Chloroanthracene	2-Cl-Ant	212	176	1.21
9-Chloroanthracene	9-Cl-Ant	212	214	0.61
3-Bromophenanthrene	3-Br-Phe	256	176	0.57
9-Bromophenanthrene	9-Br-Phe	256	176	1.01
2-Bromophenanthrene	2-Br-Phe	256	176	0.78
1-Bromoanthracene	1-Br-Ant	256	258	0.51
2-Bromoanthracene	2-Br-Ant	258	256	0.90
9-Bromoanthracene	9-Br-Ant	256	176	0.87
9,10-Dichlorophenanthrene	9,10-Cl-Phe	246	248	0.25
9,10-Dichloroanthracene	9,10-Cl-Ant	246	176	0.57
2,7-Dibromofluorene	2,7-Br-Flu	163	245	0.79
3-Chlorofluoranthene	3-Cl-Fluo	236	200	0.75
1-Chloropyrene	1-Cl-Py	236	200	0.46
3-Bromofluoranthene	3-Br-Fluo	282	280	0.62
1,8-Dibromoanthracene	1,8-Br-Ant	176	336	0.63
9,10-Dibromoanthracene	9,10-Br-Ant	176	336	0.67
2,7-Dibromophenanthrene	2,7-Br-Phe	176	336	0.70
1-Bromopyrene	1-Br-Py	280	282	0.63
1,8-Dichloropyrene	1,8-Cl-Py	270	200	0.53
1,3,6-Trichloropyrene	1,3,6-Cl-Py	304	306	0.54
1,6-Dibromopyrene	1,6-Br-Py	360	200	1.19
1,8-Dibromopyrene	1,8-Br-Py	200	360	1.27

Table 5.1.

Target compounds, abbreviations, and target ions in the instrumental analysis, method detection limits, and recovery of surrogate standards (continued).

Target compounds	**Abbreviation**	**Target ions (m/z)**		**Method detection limit**
		Quantification ion	**Confirmation ion**	**($ng\ g^{-1}$ dw)**
Halogenated-Polycyclic aromatic hydrocarbons (Hl-PAHs)				
7-Bromobenz[*a*]anthracene	7-Br-BaA	226	306	0.41
4-Bromobenz[*a*]anthracene	4-Br-BaA	306	226	0.79
1,3,6,8-Tetrachloropyrene	1,3,6,8-Cl-Py	340	338	0.39
6,12-Dibromochrysene	6,12-Br-Chr	226	286	0.83
6-Bromobenzo[*a*]pyrene	6-Br-BaP	330	332	0.32
Target compounds		**Quantification ion**	**Confirmation ion**	**%Recovery (Mean ± SD)**
Surrogate standards				
Acenaphthene-d_{10}		164	162	78 ± 18
Phenanthrene-d_{10}		188	189	83 ± 9
Chrysene-d_{12}		240	236	94 ± 10
Perylene-d_{12}		264	270	86 ± 12
bisphenol A-d_{16}		368	386	106 ± 13
^{13}C-labeled CB 28		268	270	80 ± 18
^{13}C-labeled CB 52		304	302	80 ± 18
^{13}C-labeled CB 101		338	340	84 ± 18
^{13}C-labeled CB 153		372	374	88 ± 19
^{13}C-labeled CB 138		372	374	90 ± 19
^{13}C-labeled CB 180		406	408	94 ± 20
^{13}C-labeled CB 209		440	442	92 ± 19

Table 5.2.

Instrumental conditions of the gas chromatograph equipped with a mass selective detector for the analyses of classic (PAHs, APs, and PCBs) and emerging (SOs, E-PAHs, and Hl-PAHs) PTSs.

GC/MSD system	**Agilent 7890A GC and 5975C MSD**
Column	DB-5MS UI (30 m long, 0.25 mm i.d., 0.25 μm film thickness)
Gas flow	1 mL/min He
Injection mode	Splitless
Injection volume	2 μL
Injector temperature	300 °C
Ionization	EI mode (70 eV)
MS temperature	180 °C
Detector temperature	230 °C
Oven temperature (PAHs, E-PAHs)	60 °C hold 2 min Increase 6 °C/min to 300 °C 300 °C hold 13 min
Oven temperature (APs)	60 °C hold 5 min Increase 10 °C/min to 100 °C Increase 20 °C/min to 300 °C
Oven temperature (PCBs)	60 °C hold 1 min Increase 5 °C/min to 140 °C hold 1min Increase 30 °C/min to 200 °C hold 1min Increase 4 °C/min to 250 °C hold 5min
Oven temperature (SOs)	60 °C hold 2 min Increase 6 °C/min to 300 °C hold 13min
Oven temperature (Hl-PAHs)	60 °C hold 2 min Increase 15 °C/min to 200 °C hold 20min Increase 4 °C/min to 300 °C hold 2min

5.2.4. *Sediment dating and PTSs flux*

The sediment accumulation rates (SARs) in intertidal sediment cores were assessed in the Yellow and Bohai seas. The dating of sediment cores was performed by the ^{210}Pb method using a gamma-ray spectrometer with a high-purity Germanium detector (Canberra Inc., PIPS) at the Korea Basic Science Institute. A detailed method of analysis of ^{210}pb was provided in Cho et al. (2015). For sediment dating, a constant rate supply (CRS) model was adopted due to the kinked profile of sediment core in the intertidal zone (Appleby, 2008; Kirchner, 2011). Of the 15 samples, available values of ^{210}Pb value were detected in 11 cores (Figure 5.2). The approximate ages of each layer were determined, defined as Eq. (1):

$$t = \frac{1}{\lambda} \ln\left(\frac{A(0)}{Ax}\right) \quad (1)$$

where $A(0)$ is the total residual excess $^{210}Pb_{ex}$ in the sediment core, Ax is the cumulative inventory of $^{210}Pb_{ex}$ in depth x. λ is the radioactive decay constant of $^{210}Pb_{ex}$ (0.03114 yr^{-1}). The bulk density of sediment is calculated using total organic carbon in sediment following the logarithmic equation presented by Avnimelech et al. (2001). Total organic carbon was measured with an Elemental Analyzer (Elementar, Gmbh, and Hanau) after decarbonization treatment. The PTSs fluxes (*F*) were estimated as Eq. (2):

$$\mathrm{F} = \mathrm{S} \times p_x \times C_x \quad (2)$$

Where *S* is the SARs in the sediment core (cm y^{-1}), p_x is the bulk density of *x* depth (g cm^{-3}), and C_x is the concentration of PTSs at *x* depth (ng g^{-1}). The mass inventory (*I*) was estimated as Eq. (3):

$$\mathrm{I} = C_x \times Ai \times p_x \times d \quad (3)$$

Where *Ai* is the area of a given region (km^2) and *d* is the thickness of the sediment sample. The data on the area of each province were using a previous study (Yim et al., 2018). The thickness of sediment in the present study was assumed 50 cm same as core sample depth.

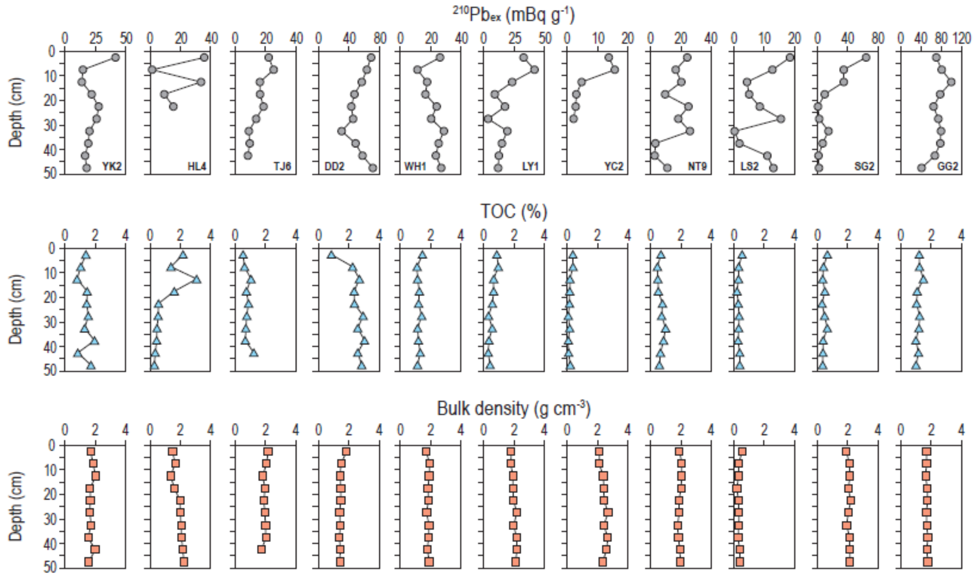

Figure 5.2.
Depth profiles of the unsupported ^{210}Pb ($^{210}Pb_{ex}$), total organic carbon, and bulk density in intertidal sediment cores in the Yellow and Bohai seas.

5.2.5. *Macrobenthic fauna analysis*

Detailed information on macrobenthic fauna analysis was presented in Chapter 2.

5.2.6. *Data analyses*

The positive matrix factorization receptor (PMF) model was performed to assign sources of PAHs using EPA PMF 5.0 software (Norris et al., 2014). A performing procedure of the PMF model referred to a previous study (Yoon et al., 2020). The PMF model result showed that the slope ranged from 0.49 to 1.19, with R^2 value ranging from 0.94 to 0.99, except Flu (0.62). These results demonstrate that the result of the PMF model applied in the present study was acceptable. Statistical analyses were performed using the software SPSS 25.0 (SPSS INC., Chicago, IL), PRIMER 6 (PRIMER-E Ltd., Plymouth, UK). Spearman correlation was carried out to determine a significant relationship between SOs and other PTSs due to non-parametric data distribution. Principle component analysis (PCA) was utilized to assess potential sources of PCBs and interactions between macrobenthic fauna and environmental parameters including PTSs, water quality, and sediment characteristics. For data of metals, water quality, and sediment characteristics, we used data reported in Yoon et al., 2000. To avoid co-linearity, the parameters, which had a high correlation (> 0.7), were excluded before PCA for interactions between macrobenthic fauna and environmental parameters. Cluster analysis (CA) and non-metric multi-dimensional scaling (nMDS) were performed with the Bray-Curtis similarity matrix to group sampling stations.

5.3. Results and Discussion

5.3.1. *Concentrations and fluxes of classic PTSs*

The PAHs and APs were detected in the sediment cores of all stations, while the PCBs were detected in 92% of samples (Figure 5.3). The concentrations of PAHs, APs, and PCBs ranged from 27 to 6,065 ng g^{-1} dw, 6.4 to724 ng g^{-1} dw, and < MDL to 1004 ng g^{-1} dw, respectively. The concentrations of PAHs, APs, and PCBs were significantly correlated with concentration of SOs ($p < 0.01$), indicating that the classic PTSs were hardly decomposed and represent the past. The greatest concentrations were detected in station HL4 in all classic PTSs, indicating the hotspot of contamination. In a previous study, high levels of contamination of PTSs in the surface sediments of HL4 were reported (Yoon et al., 2020), indicating that contamination of HL4 has persisted in the past. The mean concentration of PAHs in the Yellow and Bohai seas was < 300 ng g^{-1} dw (n = 22) before the 1970s, indicating that period of industrial development (Figure 5.4). The concentrations of PAHs were exponentially increased during the periods 1970s–1990s (mean 726 ng g^{-1} dw, n = 35), and have been decreasing from 2000 until recently (mean 460 ng g^{-1} dw, n = 32). These results indicated the exponential increasing emissions of PAHs between the 1970s and 2000s, and decreasing emissions after the 2000s. This could be explained as the impact of rapid industrial development in the 1970s and 1990s, environmental regulations after the 2000s (MOE, 2014; Kim et al., 2019). The same trend was observed in concentrations of APs and PCBs, indicating that the historical input of classic PTSs was similar. The temporal trend of concentrations in each station showed two types that the concentration of classic PTSs has increased since the 1970s, and has decreased or continues to increase since the 2000s. The trend of increasing concentrations since the 1970s and decreasing since the 2000s has been found at stations YK2, HL4, WH1, LY1, NT9, and LS2. In contrast, the stations TJ6, DD2, YC2, SG2, and GG2 stations showed a continuing trend of increasing PTSs concentration. These results indicated that the historical input of PTSs in the Yellow Sea and Bohai was regional-specific with no regional difference between Korea and China.

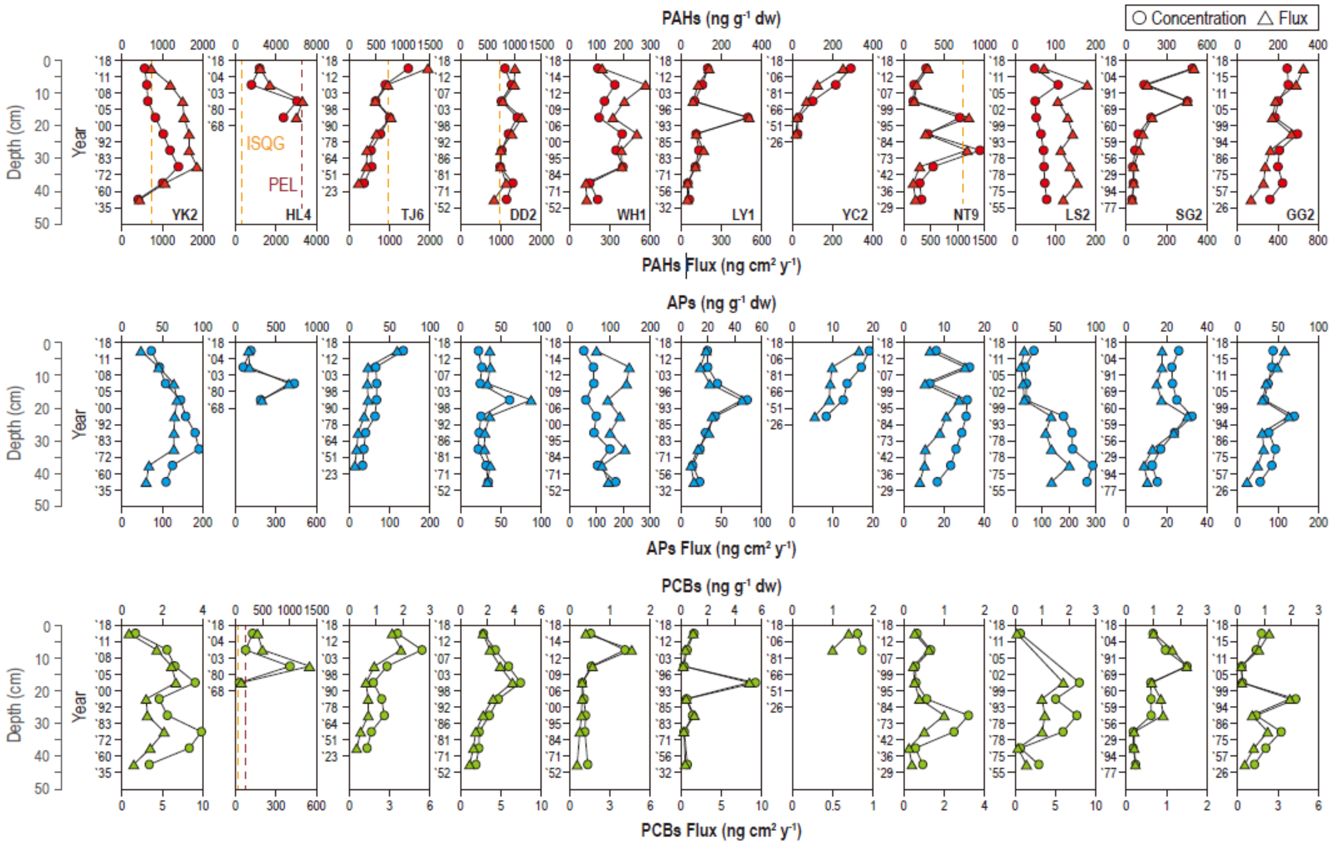

Figure 5.3.

Concentrations and fluxes of classic PTSs (PAHs, APs, and PCBs) in intertidal sediment cores from the Yellow and Bohai seas.

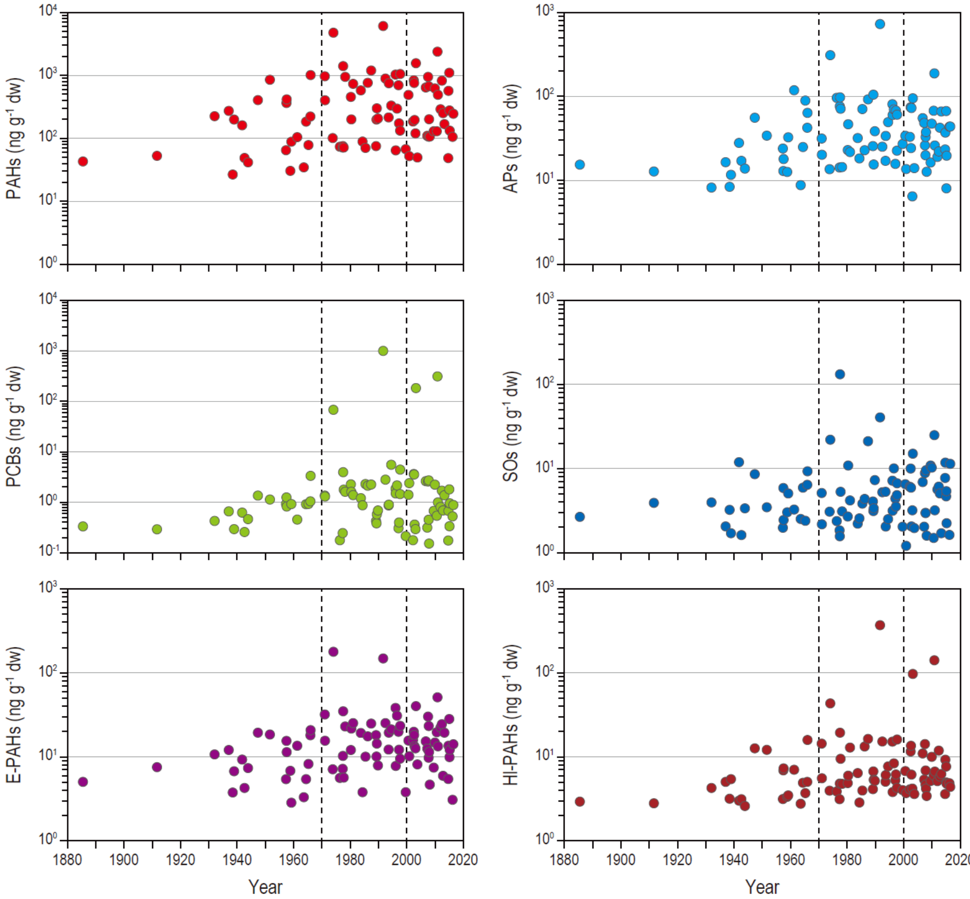

Figure 5.4.
Concentrations of classic and emerging PTSs per 10-year period in intertidal sediment cores from the Yellow and Bohai seas.

The potential ecological risk of classic PTSs was assessed using interim sediment quality guidelines (ISQG) and probable effect levels (PEL) suggested by the Canadian Council of Ministers of the Environment (CCME, 2001, 2002). Of the 89 samples, concentrations of PAHs exceeded ISQG and PEL in 21 samples at stations YK2, HL4, TJ6, DD2, and NT9. The concentrations of APs exceeded the ISQG were not detected in all samples. In PCBs, the concentrations at station HL4 only exceeded ISQG and PEL. These results indicated that PAHs and PCBs were major contaminants in the Yellow and Bohai seas, and the potential risk was great historically in China than in Korea.

The fluxes of classic PTSs were generally similar to concentrations of classic PTSs (Figure 5.3). The fluxes of PAHs, APs, and PCBs ranged from 18 to 3,312 ng cm^2 y^{-1} dw, 5.5 to395 ng cm^2 y^{-1}, and < MDL to 548 ng cm^2 y^{-1}, respectively. The greatest flux was detected in HL4 in all classic PTSs, equal to the PTSs concentration. The mean fluxes of PAHs before the 1970s, 1970s–2000s, and after 2000s were 220 ng cm^2 y^{-1} dw, 757 ng cm^2 y^{-1} dw, and 669 ng cm^2 y^{-1} dw, respectively. Similar patterns of fluxes were found in APs and PCBs. The mean values of fluxes of classic PTSs per 10 years were highest in the Bohai Sea, followed by the Yellow Sea of China and the Yellow Sea of Korea (Fig. 5.5). The decreasing rate of fluxes since the 2000s were relatively lower than the decreasing rate of concentration since the 2000s. These results indicated that, although the concentrations of classic PTSs have been recently decreased, continuous inputs of PTSs have been occurring in the Yellow and Bohai seas (Hornbuckle and Robertson, 2010). The temporal trend of fluxes in each station showed a similar pattern to the concentration of classic PTSs. Overall, the concentrations of classic PTSs in the Yellow and Bohai seas have tended to decrease in recent years, but a continuous influx is still observed.

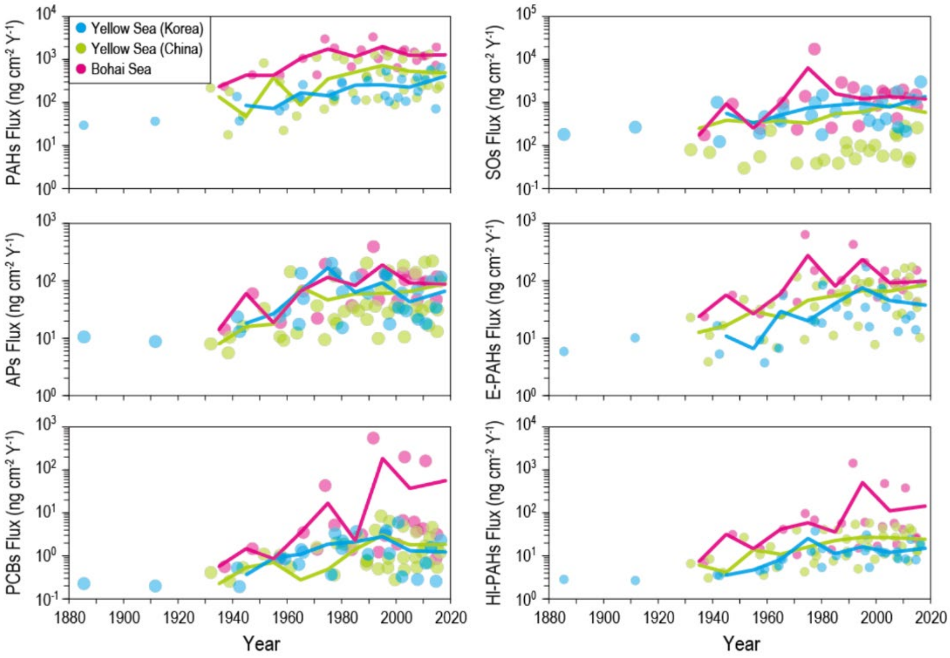

Figure 5.5.

Flux of classic and emerging PTSs of per unit area in the Yellow Sea of Korea, Yellow Sea of China, and the Bohai Sea. The solid lines represent the mean value per 10 years, and the circles represent the individual value.

5.3.2. Concentrations and fluxes of emerging PTSs

The SOs, E-PAHs, and Hl-PAHs were detected in all sediment core samples (Figure 5.6). The concentrations of SOs, E-PAHs, and Hl-PAHs ranged from 1.2 to 133 ng g^{-1} dw, 4.0 to 1002 ng g^{-1} dw, and 3.6 to 2640 ng g^{-1} dw, respectively. The concentrations of E-PAHs and Hl-PAHs were significantly correlated with concentration of SOs ($p < 0.01$), indicating that the substituted PAHs were hardly decomposed and represent the past. The greatest concentration of SOs was detected in station YK2 and the greatest concentrations of E-PAHs and Hl-PAHs were detected in station HL4. These results indicated that YK2 and HL4 were the hotspots of contamination, similar to classic PTSs. The mean concentration of PAHs in the Yellow and Bohai seas was < 5 ng g^{-1} dw (n = 22) before the 1970s, indicating less historical input of SOs (Figure 5.4). The concentrations of SOs were increased during the periods 1970s–1990s (mean 9.9 ng g^{-1} dw, n = 35), and have been decreasing from 2000 until recently (mean 6.3 ng g^{-1} dw, n = 32) (Figure 5.5). These results indicated the increasing emissions of SOs between the 1970s and 2000s, and decreasing emissions after the 2000s. The same trend was observed in concentrations of E-PAHs and Hl-PAHs, indicating that the historical input of classic PTSs was similar. These results showed a similar pattern to classic PTSs and could be explained as similar reasons (MOE, 2014; Kim et al., 2019). The temporal trend of concentrations in each station showed two types that the concentration of classic PTSs has increased since the 1970s, and has decreased or continues to increase since the 2000s. The trend of increasing concentrations since the 1970s and decreasing since the 2000s has been found at stations YK2, HL4, WH1, LY1, NT9, and SG2. In contrast, the stations TJ6, DD2, YC2, NT9, SG2, and GG2 stations showed a continuing trend of increasing concentrations of emerging PTSs. These results indicated that the historical input of emerging PTSs in the Yellow Sea and Bohai was regional-specific with no regional difference between Korea and China.

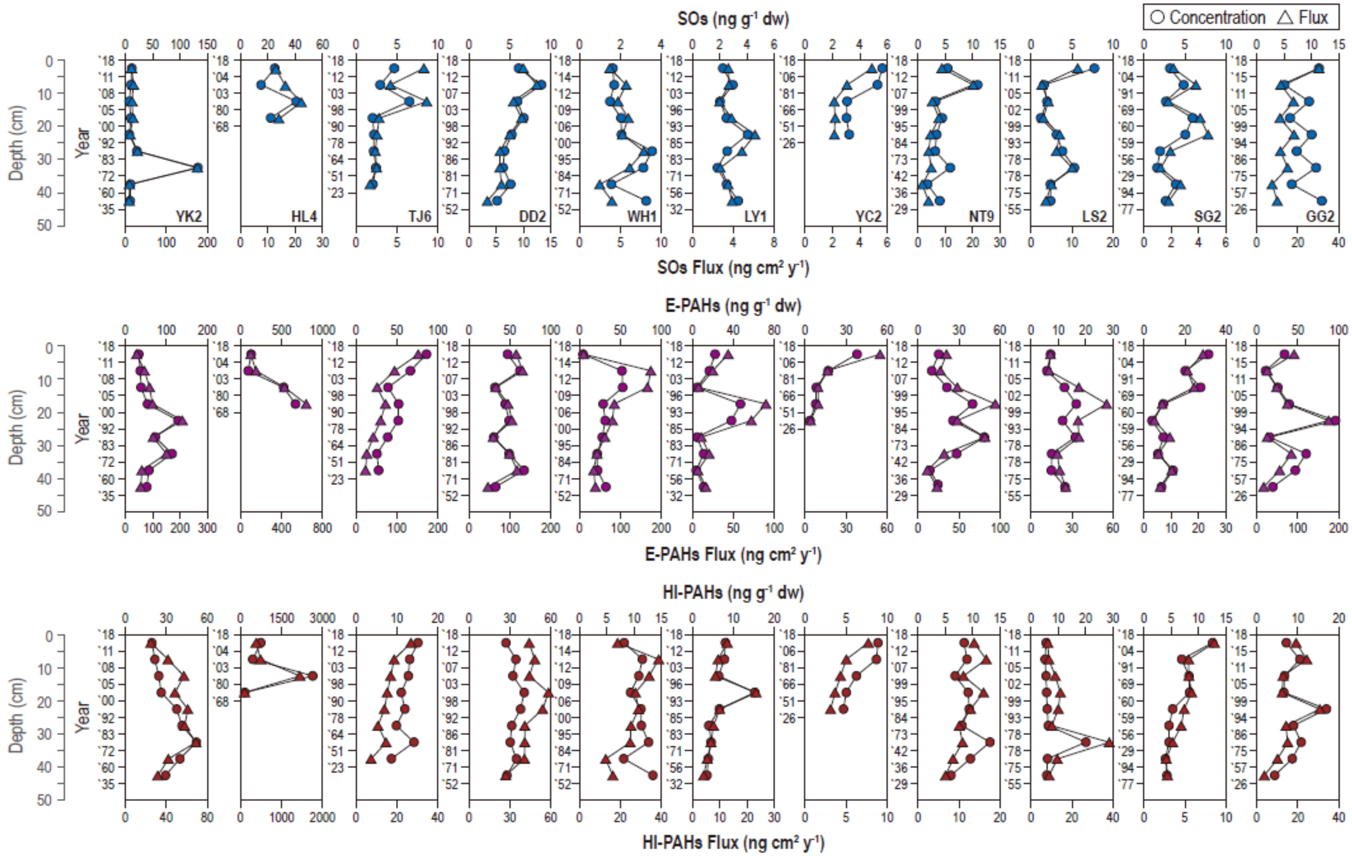

Figure 5.6.
Concentrations and fluxes of emerging PTSs (SOs, E-PAHs, and Hl-PAHs) in intertidal sediment cores from the Yellow and Bohai seas.

The fluxes of emerging PTSs were generally similar to concentrations of emerging PTSs (Figure 5.5). The fluxes of SOs, E-PAHs, and Hl-PAHs ranged from 1.2 to 176 ng cm^2 y^{-1} dw, 3.7 to 639 ng cm^2 y^{-1}, and 2.7 to 1442 ng cm^2 y^{-1}, respectively. The greatest flux of SOs was detected in station YK2 and the greatest fluxes of E-PAHs and Hl-PAHs were detected in station HL4, equal to the concentration of emerging PTSs. The mean fluxes of SOs before the 1970s, 1970s–1990s, and after 2000s were 4.1 ng cm^2 y^{-1} dw, 12 ng cm^2 y^{-1} dw, and 9.9 ng cm^2 y^{-1} dw, respectively. Similar patterns of fluxes were found in E-PAHs and Hl-PAHs. The mean values of fluxes of emerging PTSs per 10 years were highest in the Bohai Sea, followed by the Yellow Sea of China and the Yellow Sea of Korea (Fig. 5.5). The decreasing rate of fluxes since the 2000s were relatively lower than the decreasing rate of concentration since the 2000s. These results indicated that, although the concentrations of classic PTSs have been recently decreased, continuous inputs of PTSs have been occurring in the Yellow and Bohai seas (Khim et al., 2018b; Yoon et al., 2020). The temporal trend of fluxes in each station showed a similar pattern to the concentration of PTSs. Overall, the concentrations of emerging PTSs in the Yellow and Bohai seas, similar to classic PTSs, have tended to decrease in recent years, but a continuous influx is still observed.

5.3.3. Compositional profiles and sources of PTSs

The compositions of classic and emerging PTSs were confirmed (Figure 5.7). In PAHs, 4-ring PAHs generally dominated in the Yellow and Bohai seas (48%), followed by 6-ring-, 3-ring-, and 5-ring-PAHs. The composition of high molecular weight (HMW: 4–6 rings) PAHs after the 1970s was relatively high than before the 1970s, indicating a change of sources of PAHs. In station HL4, LY1, YC2, LS2, and SG2, a relatively high composition of 3-ring PAHs was found with the different historical trends. These results indicated that various historical inputs of PAHs sources were occurrence in the Yellow and Bohai seas with no difference between Korea and China (Hong et al., 2012). Among APs, NPs were the dominant chemical, followed by NP2EOs, NP1EOs, OP1EO, OP2EO, and OP. These compositions were generally similar across the ages of all sediment core samples. Relatively high compositions of OP and OPEOs were found in stations TJ6, LY1, NT9, LS2, SG2, and GG2, indicating more use of OP and OPEOs in Korea (Yoon et al., 2020). Among PCB congeners, tetra-CBs were accounted for 55 ± 35% of total concentration, with great compositions of low chlorinated PCBs (di-, tri, tetra-, and penta-CBs) (82 ± 28%). The compositions of other PCB congeners showed an irregular pattern, because of the low detection frequency of PCBs in sediment cores (1.1–72%, mean 12%). The CB 49 was the most dominant chemical (42%), followed by CB126 (12%), CB8 (6.6%), and CB 153(5.1%). These results indicated low toxic risks of PCBs in the Yellow and Bohai seas, due to the low proportion of dioxin-like PCBs.

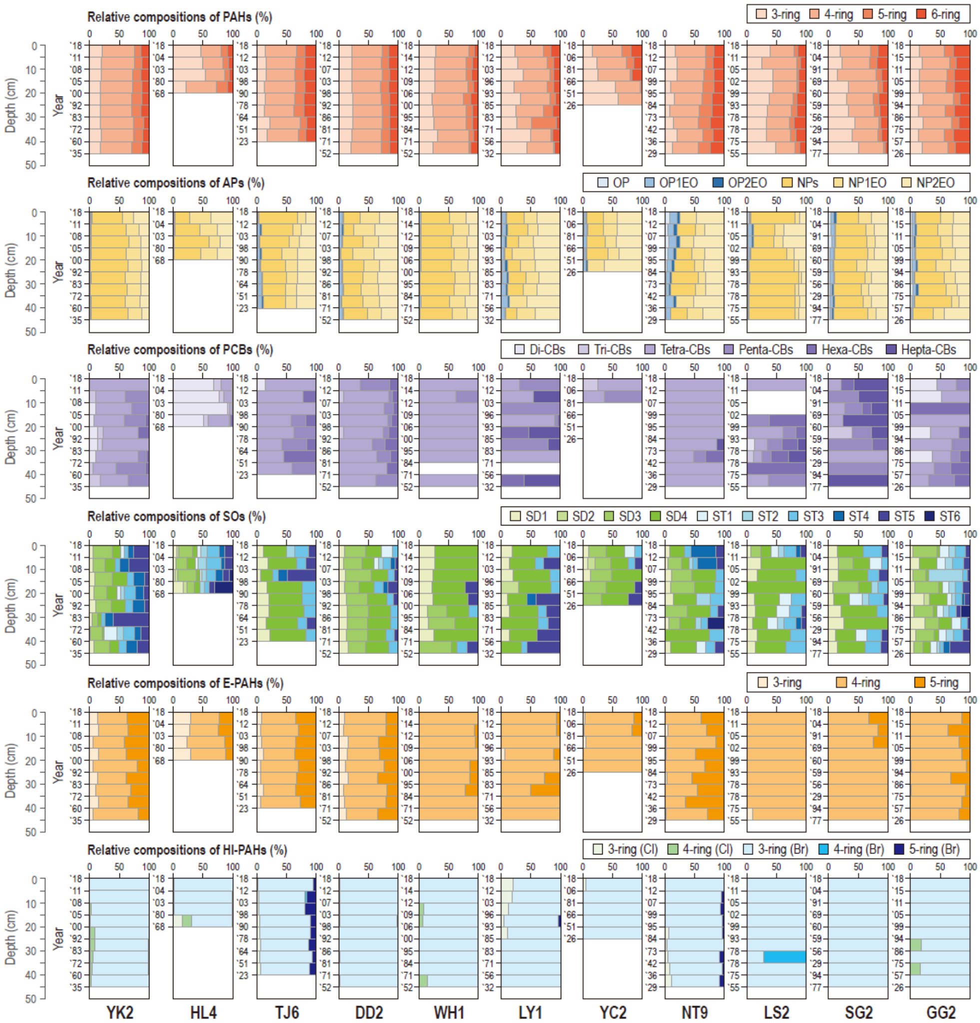

Figure 5.7.
Relative compositions of classic (PAHs, APs, and PCBs) and emerging (SOs, E-PAHs, and Hl-PAHs) PTSs in intertidal sediment cores from the Yellow and Bohai seas.

The relative compositions of SOs were varied in station and ages of sediment cores (Figure 5.7). SD4 was the most dominant chemical (37%), followed by SD3 (15%), ST3 (13%), SD1 (12%), and ST5 (11%), with a similar trend across all periods. In contrast to this trend, relatively high compositions of styrene trimers were found in station YK2, HL4, and GG2. In E-PAHs, 4-ring were accounted for 77 ± 20% of total concentration, followed by 5-ring PAHs (18 ± 16%) and 3-ring PAHs (4.7 ± 7.0%). This result was similar to the compositions of PAHs (4-ring dominated), indicating that e-PAHs were originated from similar sources of PAHs. 11BF was the most dominant compound (50%), followed by BBNF (24%), B*e*P (10%), and B*j*F (8%). Previous studies reported that these E-PAHs were originated from biomass combustion and mobile sources (Benner et al., 1995; bin Abas et al., 1995; Khalili et al., 1995; Wu et al., 2002). Thus, E-PAHs in the Yellow and Bohai seas were mainly originated from biomass combustion and mobile sources. Out of Hl-PAHs, Br-3-ring PAHs was dominant compound (95%), followed by Cl-3-ring- (1.9%), Br-5-ring- (1.5%), Cl-4-ring- (1.2%), and Br-4-ring-PAHs (0.9%). Low molecular weight (LMW: 3-ring) PAHs were dominated in both chlorinated PAHs and brominated PAHs. This result was due to of low detection frequency of Hl-PAHs (12%). 9-Br-Flu was the dominant compound (93.6%), followed by 9,10-Cl-Phe (1.7%) and 6-Br-BaP (1.5%). The brominated-Flu and chlorinated-Phe were the majority compound among the Hl-PAHs in a previous study (Vuong et al., 2019) and originated from industrial sources (Ohurea et al., 2018; Vuong et al., 2019). Thus, the occurrence of Hl-PAHs in sediment cores from the Yellow and Bohai seas could be a typical marker for industrial emission. Overall, compositions of emerging PTSs showed various or irregular patterns due to less detection frequency of emerging PTSs, suggesting that continuous would be needed.

The PMF model results showed that the Q_{True}/Q_{Exp} values of 2–5 factors were 1.55 1.12, 1.09, and 0.94, respectively (Figure 5.8). A large decrease was found in the result of the 3-factor, indicating the great explanatory power of the model (Crilley et al., 2017). Thus, three factors were selected for source identification of PAHs in sediment cores from the Yellow and Bohai seas. The primary source was characterized by Ace (83%), Flu (83%), Phe (71%), and Acl (57%), which were an indicator of coke oven (Khalili et al., 1995). The contribution of the cove oven source was consistently increased until the 1960s and peaked between the 1970s–1990s (Figure 5.9a). But, the contribution of the coke oven has been decreased after the 2000s. The secondary source was dominated by IcdP (65%), BghiP (61%), DbahA (50%), and BaP (47%), suggesting gasoline combustion (Guo et al., 2003). The contribution of gasoline combustion has gradually increased from the past to the present. Finally, the tertiary source was comprised of BaP (53%), Ant (47%), BaA (43%), BbF (42%), and Py (39%). These contributors are linked to biomass and diesel combustion (Harrison et al., 1996; McGrath et al., 2001). The biomass and diesel combustion sources, similar to the coal combustion, had the highest contribution in the 1970s–1990s and has tended to decrease since then. The total contributions of each factor in all ages were similar, with values 107, 103, and 106, respectively, with different contributions depending on the period and region (Figure 5.9b). The contribution of the cove oven source was consistently increased until the 1960s and peaked between the 1970s and 1990s. But, the contribution of the coke oven has been decreased after the 2000s. The increasing trend of each factor consistent with emerging consumption such as coal and oil until the 1990s. But, after the 2000s, the contribution of each factor did not increase compared to energy consumption. A similar result has been reported in the interior of China (Ma et al., 2020), which is indicated to be a positive effect of environmental regulations such as emission standards (Tang et al., 2015). In addition, a relatively high contribution of biomass combustion between the 1970s–1990s could be explained by the household energy usage by biomass combustion in the past (Zhang et al., 2007). Overall, the sources of PAHs in the Yellow and Bohai seas differed over time, but historical contributions were similar.

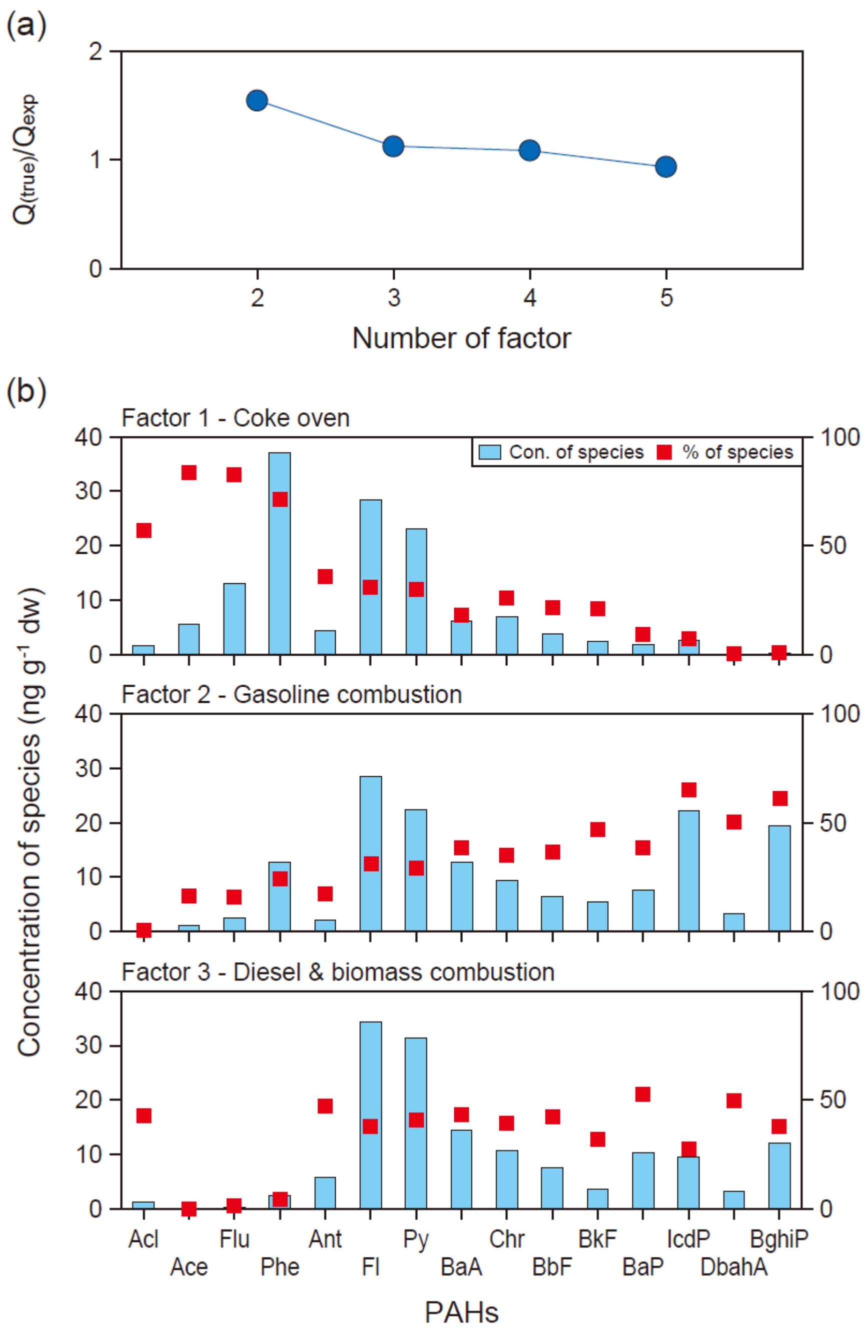

Figure 5.8.

(a) Q_{True}/Q_{Exp} values of the number of factors derived with a PMF receptor model. (b) Fractional source concentrations and percentage source contributions of individual PAH species.

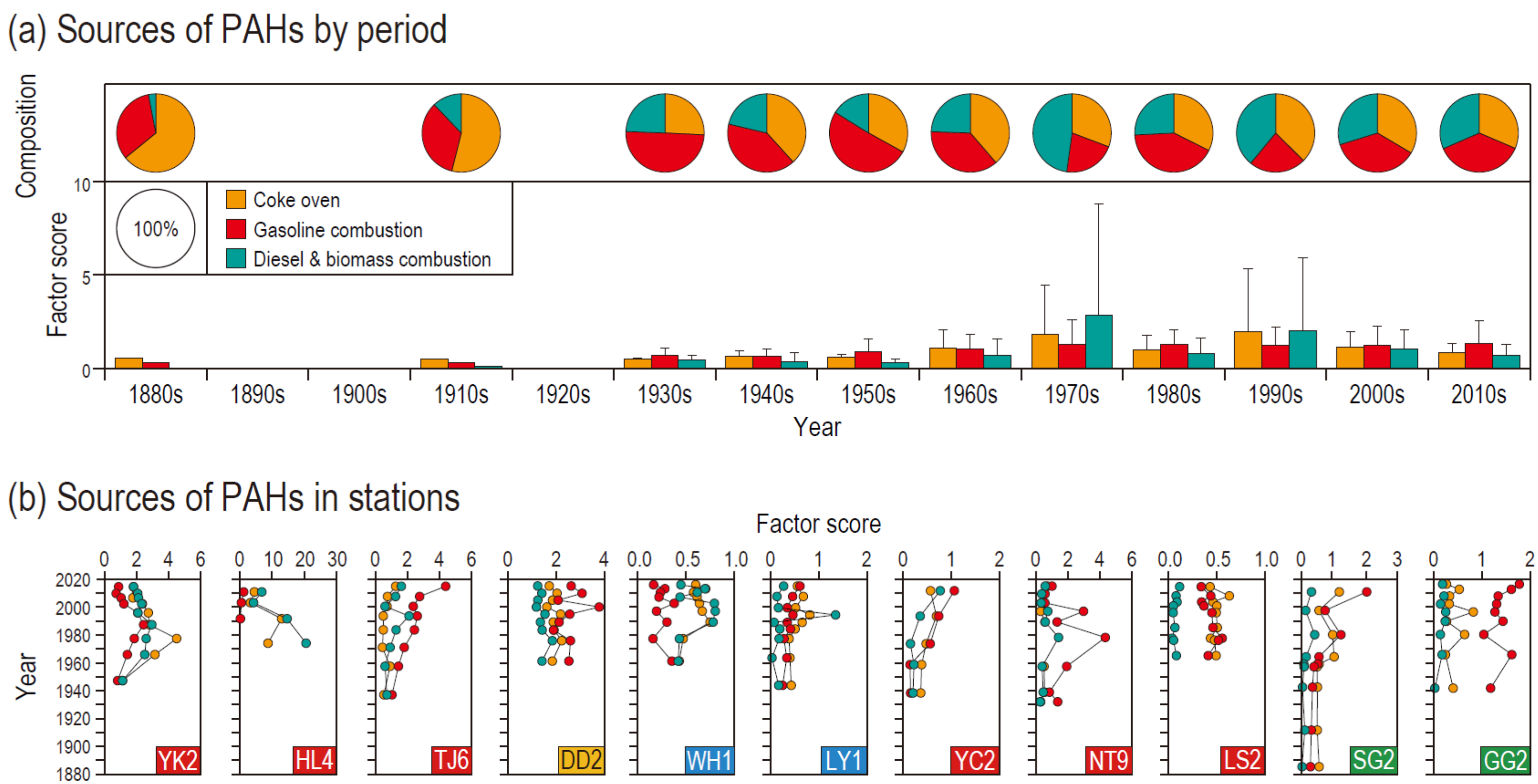

Figure 5.9.
(a) Sources of PAHs by each 10-years in intertidal sediment cores from the Yellow and Bohai seas derived with a PMF receptor model. (b) Sources of PAHs in each station.

The PCB congener of sediment cores in the Yellow and Bohai seas was compared with congener blends of possible sources, such as Aroclors, Kanechlor, and other combustion sources (Figure 5.10) (Kim et al., 2004; Lee et al., 2005; Aries et al., 2006; Takasuga et al., 2006). The PCA result explained 53% of total variation and showed generally less relationship with possible sources. Only PCBs conger in station HL4 showed similar distribution with Hardwood burning (WB), Gaseous emission from cement plant (CP), and some products. This result indicated that sources of PCBs in station HL4 was affected by both industrial and municipal activity. In addition, it supported the result of the high contribution of PAHs in station HL4 to coke oven and wood combustion. Overall, the sources of PCBs in the Yellow and Bohai seas were mixed sources with not a specific source, except for HL4.

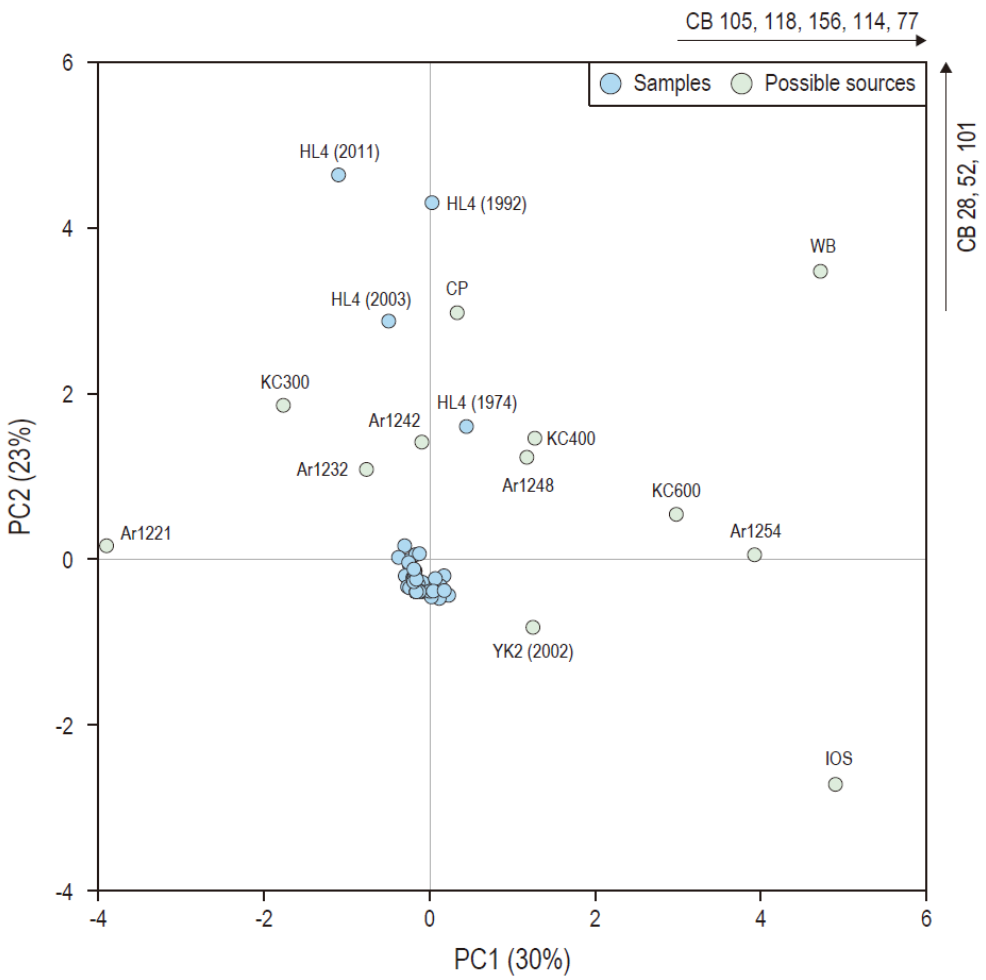

Figure 5.10.
Principal component analysis (PCA) ordination showing the relationship of PCB congener between intertidal sediment core samples and possible sources including commercial product and environmental samples (Kim et al., 2004; Lee et al., 2005; Aries et al., 2006; Takasuga et al., 2006).

5.3.4. *Deposition flux and mass inventory*

The deposition flux and mass inventory in the intertidal zone of the Yellow and Bohai seas varied at the province-scale (Fig. 5.11). The deposition flux of PAHs, APs, PCBs, SOs, E-PAHs, and Hl-PAHs ranged from 20 to 646 T y^{-1}, 2.6 to 61 T y^{-1}, 0.1 to 35 T y^{-1}, 0.4 to 7.9 T y^{-1}, 2.0 to 71 T y^{-1}, 0.8 to 97.8 T y^{-1}, respectively. The highest deposition flux of classic and emerging PTSs was found in Liaoning, followed (in order) by Jiangsu, Jeonbuk + Jeonnam, Shandong, Hebei + Tianjin, Gyeonggi, and Chungnam. In the sea area, deposition flux of classic and emerging PTSs was mainly highest in the Bohai Sea followed by the Yellow Sea of China and Yellow Sea of Korea. These results indicated that the fate of classic and emerging PTSs were similar in all provinces in the Yellow and Bohai seas, with regional specific and less deposition flux in the Yellow Sea of Korea. The mass inventory of classic and emerging PTSs also showed the same tendency as the deposition flux. The mass inventory of PAHs, APs, PCBs, SOs, E-PAHs, and Hl-PAHs ranged from 5.7 to 64 Kt, 0.7 to 4.6 Kt, 0.1 to 3.4 Kt, 0.1 to 0.8 Kt, 0.5 to 7.0 Kt, and 0.3 to 9.7 Kt, respectively. The top two provinces of mass inventory of target PAHs were Liaoning and Jiangsu, followed by the same deposition flux for each compound. Compared to previous studies, mass inventory in the present study showed the highest values (Liu et al., 2005; Guo et al., 2006; Yan et al., 2009; Zhang et al., 2009; Hu et al., 2011; Li et al., 2015; Cai et al., 2016; Guerra et al., 2019). Overall, deposition flux and mass inventory were relatively high in Liaoning and Jiangsu, and the intertidal zone of the Yellow and Bohai seas was moderately polluted than nearby coastal areas.

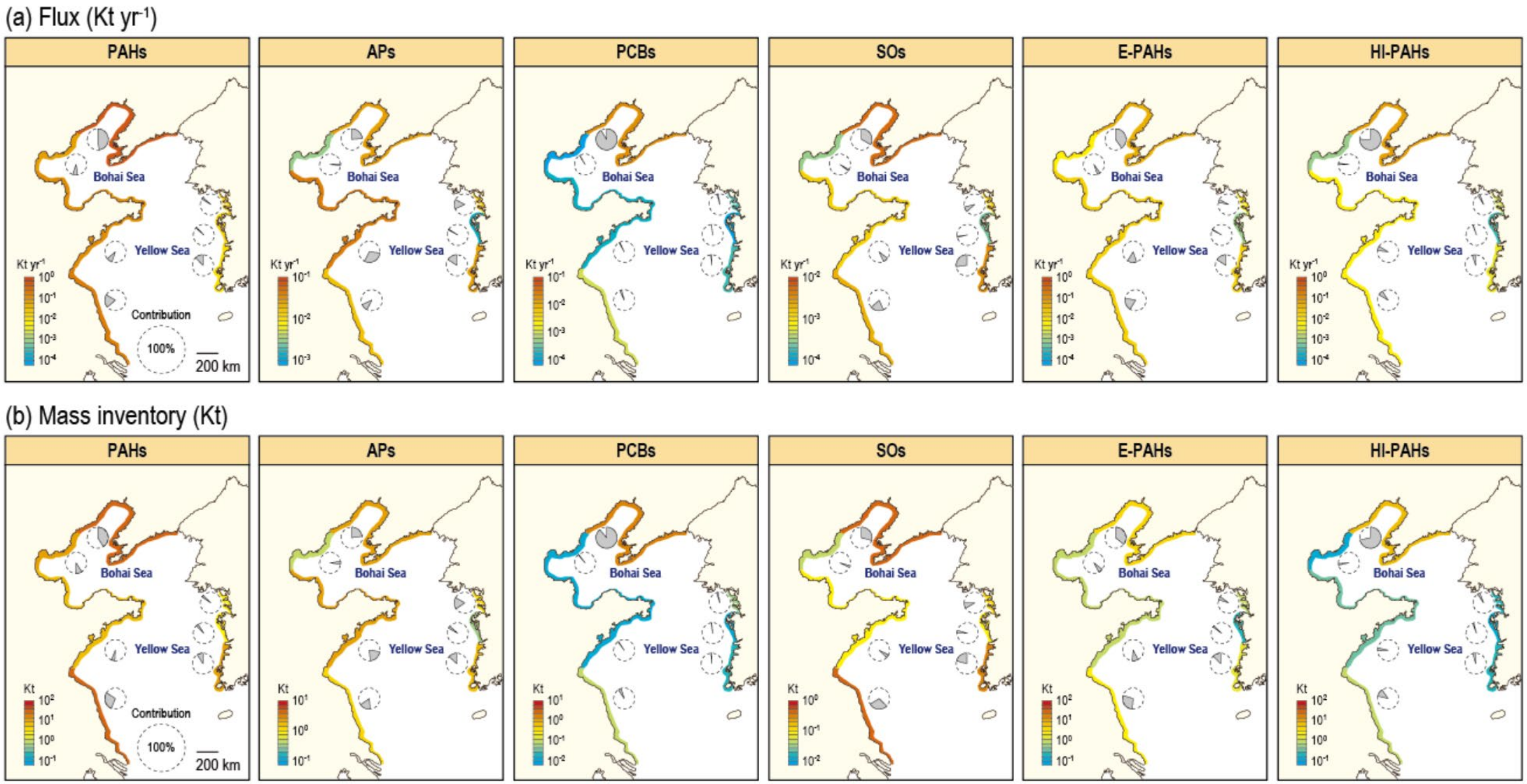

Figure 5.11.
Deposition flux and mass inventory of PAHs, E-PAHs, and HI-PAHs in the intertidal area of the Yellow and Bohai seas. The circles represent the contribution of each province to the concentration.

5.3.5. *Macrobenthic fauna community*

A total of 11 macrofaunal species was identified belonging to three major taxonomic groups (Annelida, Arthropoda, and Mollusca), with 2,730 individuals in 10 stations (Table 5.3). All species appeared below 3 stations, except for *Hediste japonica* from 6 stations and *Macrophthalmus japonicus* from 4 stations. Annelida was dominant group (66%), followed by Arthropoda (22%) and Mollusca (11%). *Hediste japonica* was dominant species (51%), followed by *Macrophthalmus japonicus* (19%), *Sinonovacula constricta* (7.2%), *Chone teres* (6.4%), and *Nephtys polybranchia* (4.7%). Macrobenthic fauna community analyzed by CA and nMDS showed less similarity, without a distinction between the Yellow Sea and the Bohai Sea, and between Korea and China (Figure 5.12a, b). These species are commonly appearing in the upper intertidal zone, and the stations dominated by organic pollutants or enrichment indicator species were not found. These results suggested that the macrobenthic fauna in the study area represents an uncontaminated environment (Pearson and Rosenberg, 1978; Dauvin et al., 2009). PCA was performed to identify the relationship among benthic macrofauna, PTSs, and environmental parameters. The PCA result explained 57% of total variation and showed generally less relationship (Figure 5.12c). This result might be due to insufficient analysis due to the small number of collected organisms. The relationship between the *Hediste japonica* (r = 0.28, p > 0.05) and *Macrophthalmus japonicus* (r = 0.17, p > 0.05), and PAHs, which showed a relatively high contribution to PCA, did not show a significant relationship. Overall, the distribution of macrobenthic fauna in the study area showed site-specific, and the effect of sediment contamination was not confirmed.

Table 5.3.
Macrobenthic fauna (individual m^{-2}) in upper intertidal sediment from the Yellow and Bohai seas.

Taxa	Stations									
	DD2	YK2	WH1	TJ6	LY1	YC2	NT9	LS1	SG2	GG2
Assiminea lutea		42					14			
Glauconome chinensis					14					
Potamocorbula amurensis	14	28							28	
Sinonovacula constricta										238
Sinocorophium sinensis							14			
Helice tridens		42		42			14			
Macrophthalmus japonicus					14			308	56	252
Chone teres						210				
Hediste japonica	168		434		378	602	14			84
Heteromastus filiformis			70		14				56	
Nephtys polybranchia						14	140			

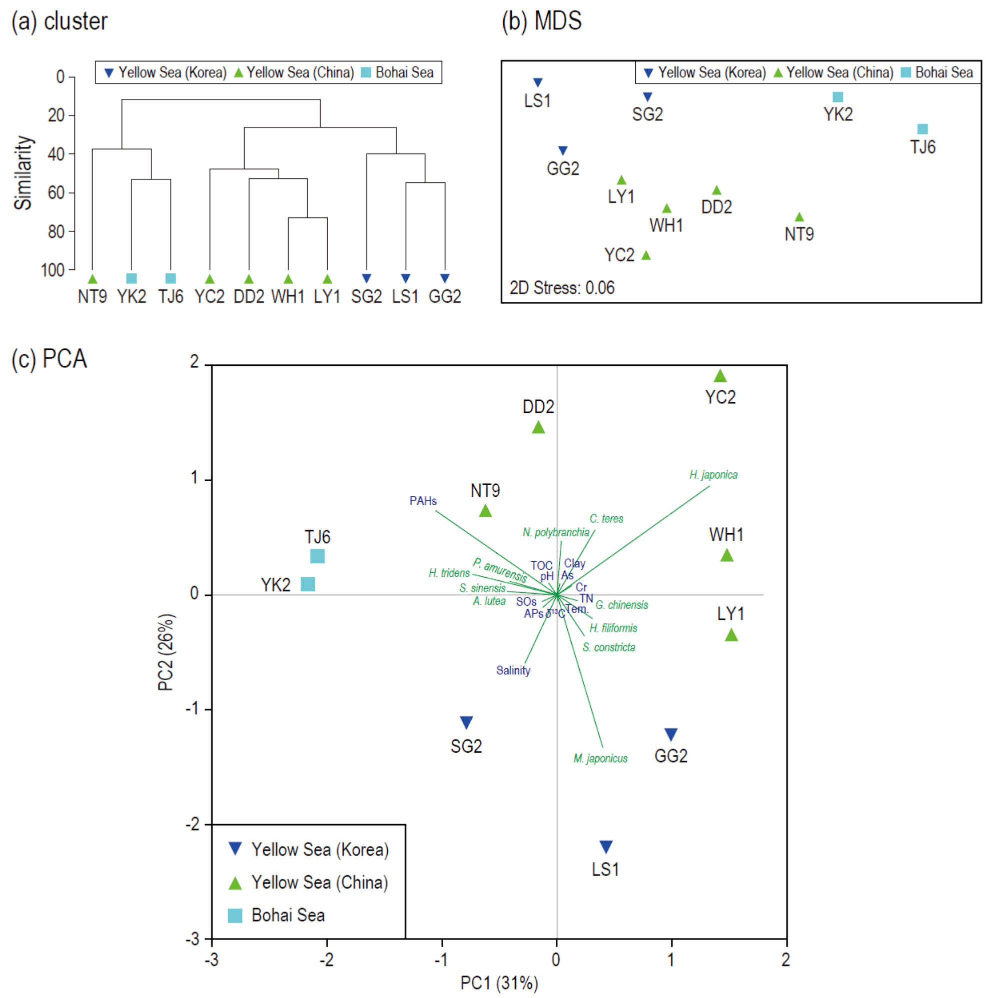

Figure 5.12.

(a) Cluster analysis showing the macrofaunal assemblages. (b) Non-parametric multi-dimensional scaling (nMDS) ordination plot based on relative abundance. (c) Principal component analysis (PCA) ordination showing the relationship between macrobenthic fauna and environmental parameters including PTSs, metals, water quality parameters, and sediment characteristics. Data of previous studies were used for metals, water quality parameters, and sediment characteristics (Yoon et al., 2020).

5.4. Summary

Historical records of classic and emerging PTSs over the 100 years presented a high contamination level from the 1970s to 1990s for both classic and emerging PTSs. Relatively low concentrations of PTSs were detected before the 1970s and the concentrations of PTSs were increased in the 1970s and 1990s. After the 2000s, concentrations showed a tendency to decrease until recently. The fluxes of classic and emerging PTSs also showed a similar tendency to the concentration of PTSs, but since the 2000s, the rate of decrease was relatively low, indicating the continuous input of PTSs into the Yellow Sea. The major sources of PAHs were the combustion of diesel, biomass, and coke oven in the 1970s and 1990s, and the combustion of gasoline was high after the 2000s. The sources of PCBs showed mixed sources in the whole period, indicating the origin of the products and combustion. The distribution of macrobenthic fauna exhibits signs of site-specific, with less relationship with contamination by traditional and emerging PTSs. Overall, the inputs of PTSs and high pollution levels have been confirmed during the half-century in the Yellow Sea, implying the need for management reducing the land-driven pollutants.

CHAPTER 6.

CONCLUSIONS

6.1. Summary

The present study investigated the spatiotemporal distribution of classic and emerging PTSs and their impact on the macrofaunal community to advance our current understanding of sediment contamination and potential ecological impacts on the Yellow Sea ecosystem.

The sediments in the coastal areas of the Yellow Sea were moderately contaminated by classic and emerging PTSs. PAHs had the highest concentrations of all PTSs in the coastal areas of the Yellow Sea. PAH concentrations in hotspots presented a potential risk to aquatic organisms. The main sources of PAHs were the by-products of gasoline, diesel, biomass combustion, and coke oven, with each source contributing differently in Korea and China. Relatively high concentrations of PTSs were detected in industrial and municipal areas. Although the concentrations of APs and SOs were relatively low, fresh inputs of APs and SOs were continuously being discharged into the Yellow Sea. Compared to a previous study conducted in the same area in 2008, the current study showed that PAH concentrations have decreased over the past 10 years in Korea, whereas higher concentrations of PAHs were detected in China, along with sources shifting from mixed sources to being linked to by-products of diesel and gasoline. Thus, over the last 10 years, there has been substantial contamination of PTSs through continuous input, especially in China, generating potential environmental risks.

Historical records of traditional and emerging PTSs over the last 100 years were broadly divided into three periods for both traditional and emerging PTSs. Relatively low concentrations of PTSs were detected before the 1970s, with concentrations increasing in the 1970s and 1990s, and generally declining after the 2000s. Fluxes in traditional and emerging PTSs showed a similar trend to PTS concentrations; however, since the 2000s, the rate of decrease was low, indicating the continuous input of PTSs to the Yellow Sea. The major sources of PAHs were the combustion of diesel, biomass, and coke oven in the 1970s and 1990s, while the combustion of gasoline was high in the 2000s. There were mixed sources of PCBs over the whole period, indicating various origins of products and combustion. Overall, the inputs of

PTSs and high pollution levels have been confirmed during the last half-century in the Yellow Sea, implying the need for management to reduce pollutants originating from terrestrial sources.

The impacts of PTSs on the macrofaunal community were evaluated in relation to community structure and associated environmental parameters. The most dominant taxon was polychaetes along the Saemangeum Coast and Geum River Estuary. *Heteromastus filiformis* was the most dominant species and is a potential indicator of the accumulation of organic matter. PTS concentrations were below the minimum thresholds of sediment quality guidelines and showed low correlations with the macrofaunal community. The macrofaunal community was mainly affected by the origin of organic matter, particularly with respect to the number of species, with PTSs showing no distinct effect. Relatively low species and density were detected in areas with terrestrial origins of organic matter. In comparison, the number of species and populations increased in sediments of marine origin in organic matter. Over a year, the macrobenthic community in the Geum River Estuary was separated into the inner and outer parts of the estuary, regardless of the season. *Heteromastus filiformis* was predominant in both the inner and outer parts of the estuary, while *Potamocorbula amurensis and Sinocorophium sinensis* represented opportunistic species in the inner part of the estuary. Even where PTS (Cu and Zn) concentrations were high, impacts on the macrofaunal community were weak. The key factors influencing the macrofaunal community were salinity and chlorophyll-*a*, with the effects of PTSs being relatively low. A similar result was found in the upper intertidal zone of the Yellow Sea where PTS concentrations were high. Even when PTS concentrations were high (especially PAHs), the impact on the macrofaunal community was low. The macrofaunal community of the upper intertidal zone in the Yellow Sea was mainly affected by sediment grain size and salinity.

In summary, first, the pollution level of sedimentary PTSs in the coastal areas of the Yellow Sea has continuingly decreased compared to past levels, but the potential ecological risk was found in hotspots. Second, the macrofaunal community was more directly affected by physio-chemical environmental factors, such as salinity and sediment grain size, in the habitat compared to by PTS contamination. Although the impacts on the macrofaunal community were weaker than those of non-polluting environmental parameters, when the potential impacts of classic PTSs were quantified, a clear difference was detected between Korea and China (Figure 6.1). In Korea, only low potential impacts on aquatic life were detected for both PAHs and alkylphenols, whereas moderate and severe potential impacts of PAHs were detected in China. These results indicated that potential ecological risks exist for the macrofaunal community in China. However, unlike the potential impact, no distinct differences were found for the actual impact on the macrofaunal community. As the concentration of PAHs, SOs, Zn, and As increased, the EQR tended to decrease slightly, but was not significant ($P > 0.05$) (Figure 6.2). Except for SOs (which do not have environmental guidelines), PTSs exceeded the sediment quality guidelines of CCME, but no clear difference in EQR values was observed. Thus, contamination by PTSs in the sediments had a low impact on the macrofaunal community. The impacts of PTSs also significantly differed between Korea and China ($P > 0.05$). Although the overall concentration of PTSs was comparatively lower in Korea compared to China, EQR ranges were similar. Thus, while sediment pollution levels were relatively higher in China, the impacts on the macrofaunal community were similar. However, the results only identified about 20 macrofaunal species in the upper intertidal zone of Korea and China; thus, future studies should quantify sediment contamination levels and access potential impacts on the macrofaunal community in the whole coastal area of Korea and China.

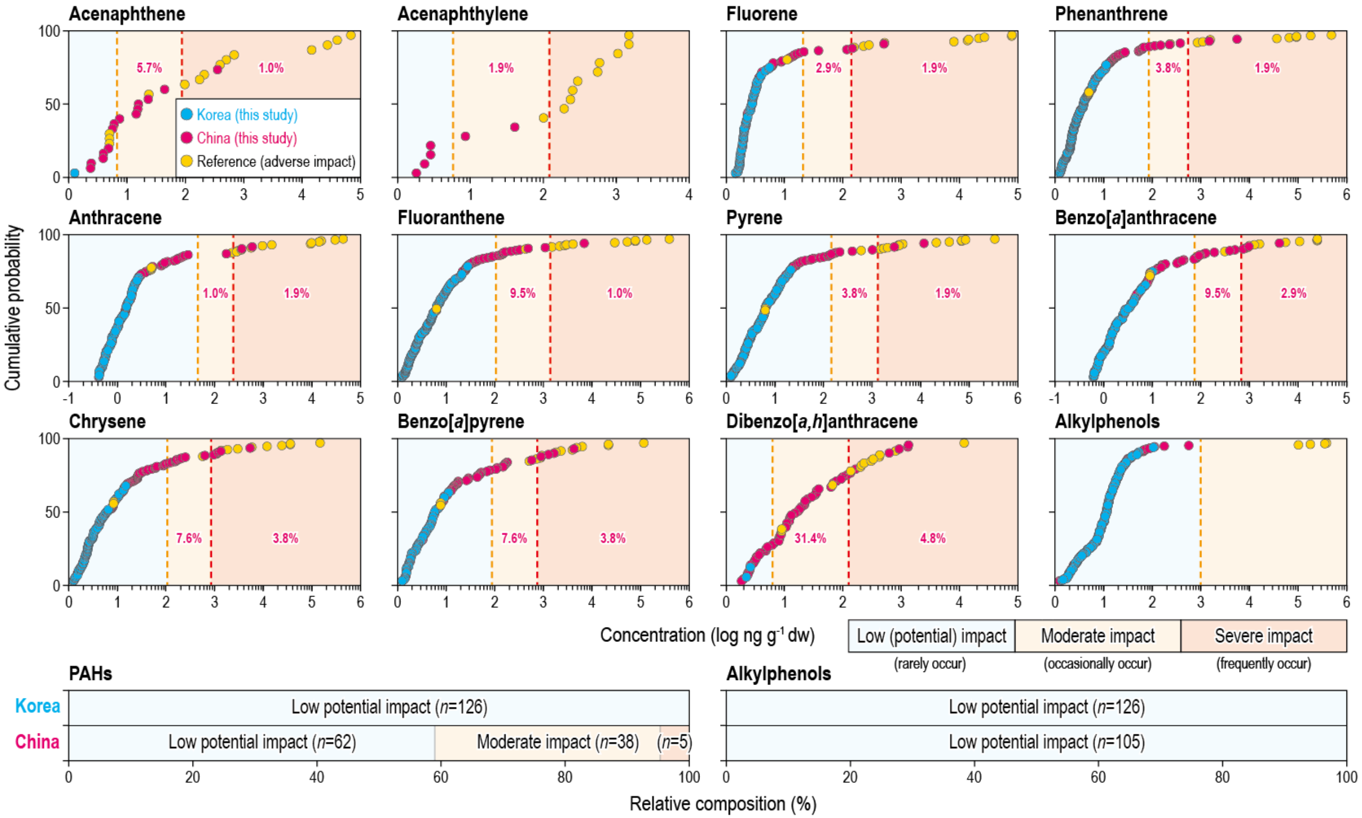

Figure 6.1.
Quantification of potential ecological impacts of PAHs and APs on aquatic life in the coastal areas of the Yellow Sea. Relative composition of the potential impact of PAHs and APs in Korea and China is presented.

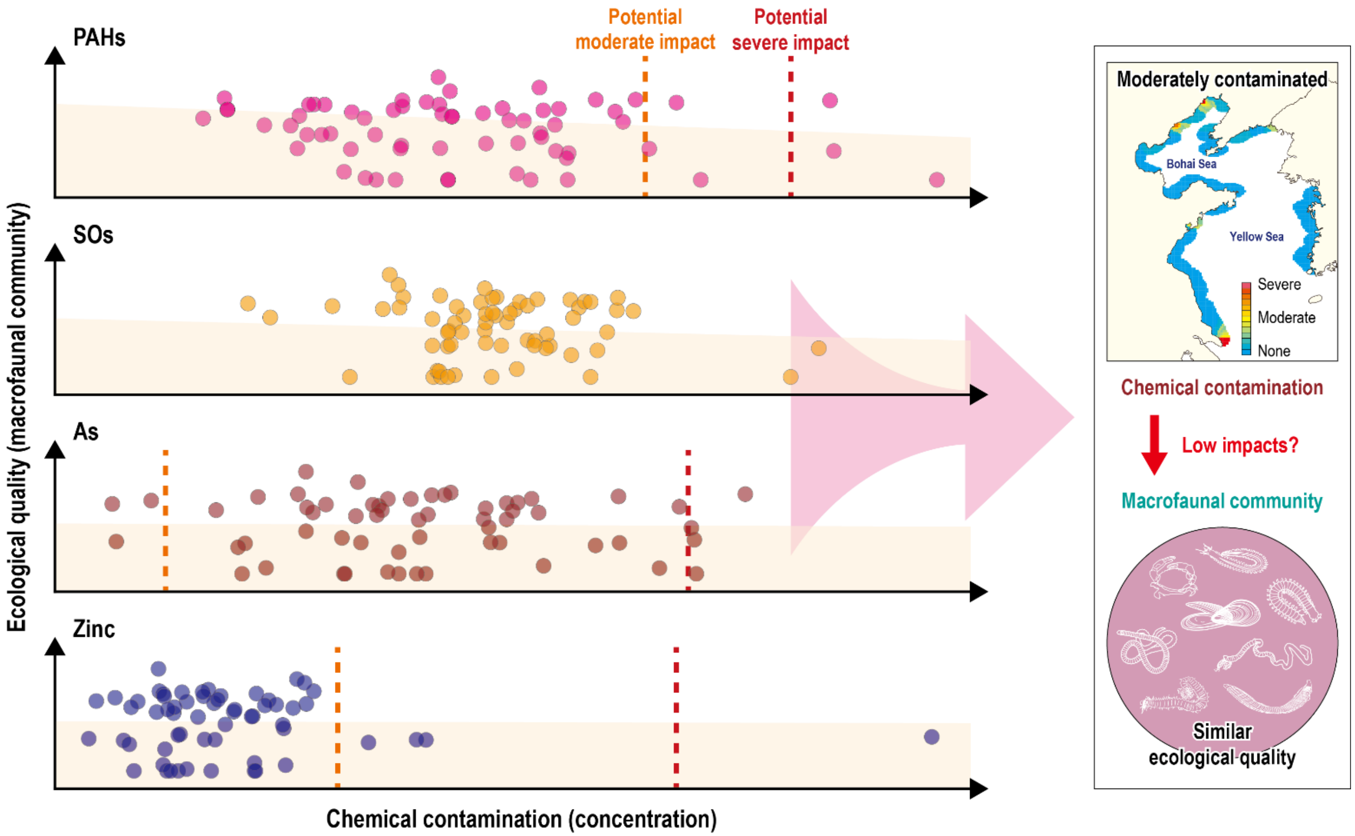

Figure 6.2.
Relationships between the chemical contamination (concentrations) of PTSs and ecological quality (macrofaunal community) in the Yellow Sea. Potential impacts on the macrofaunal community indicated by sediment quality guidelines (TEL and PEL, CCME).

The potential impacts of PTSs on aquatic life over time also differed in Korea and China (Figure 6.3). During the 2010s in Korea, a moderate ecological impact was expected in about 6.3% of the samples; however, concentrations with moderate and severe ecological impacts of about 20% were detected in China from the 1940s to the present. Potential risks have recently increased in Korea, with risks being steadily discovered in China; thus, the concentrations of PTSs should be continuously monitored in the future. The macrofaunal community appeared to be more affected by PTS concentrations in the region, regardless of the spatial scale. The temporal scale represents the exposure duration of organisms to PTSs. In the current study, only one study (Ch. 2) was conducted for changes to the macrofaunal community over one year at the regional scale. The results of Ch. 2 showed that the macrofaunal community had geographically distinct features, regardless of the seasonal distribution of PTSs. Thus, the impacts of PTSs at spatial and temporal scales appeared to be more dependent on PTS contamination compared to the scale itself. However, since data to confirm each perspective was not sufficient (regional scale area and insufficient data), further studies are required in the future to quantify spatial (space) and temporal (time) impacts. Overall, the coastal areas of the Yellow Sea have been moderately contaminated by classic and emerging PTSs over the last half-century; however, impacts on the macrofaunal community were low (Figure 6.4).

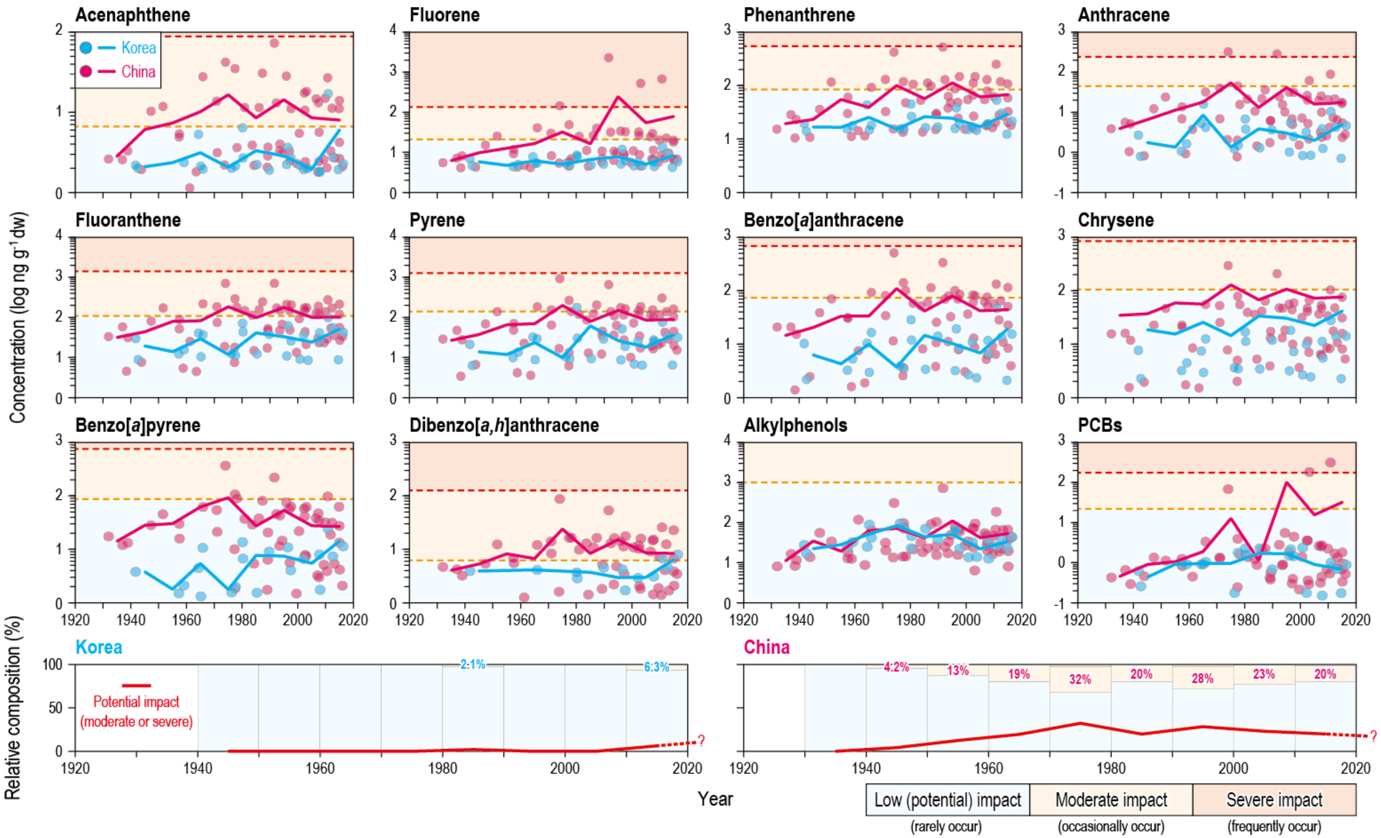

Figure 6.3.
Potential ecological impacts of PAHs and APs on aquatic life in the coastal areas of the Yellow Sea in different periods. The relative composition of the potential impact of PTSs, including PAHs, APs, and PCBs, in Korea and China, is presented.

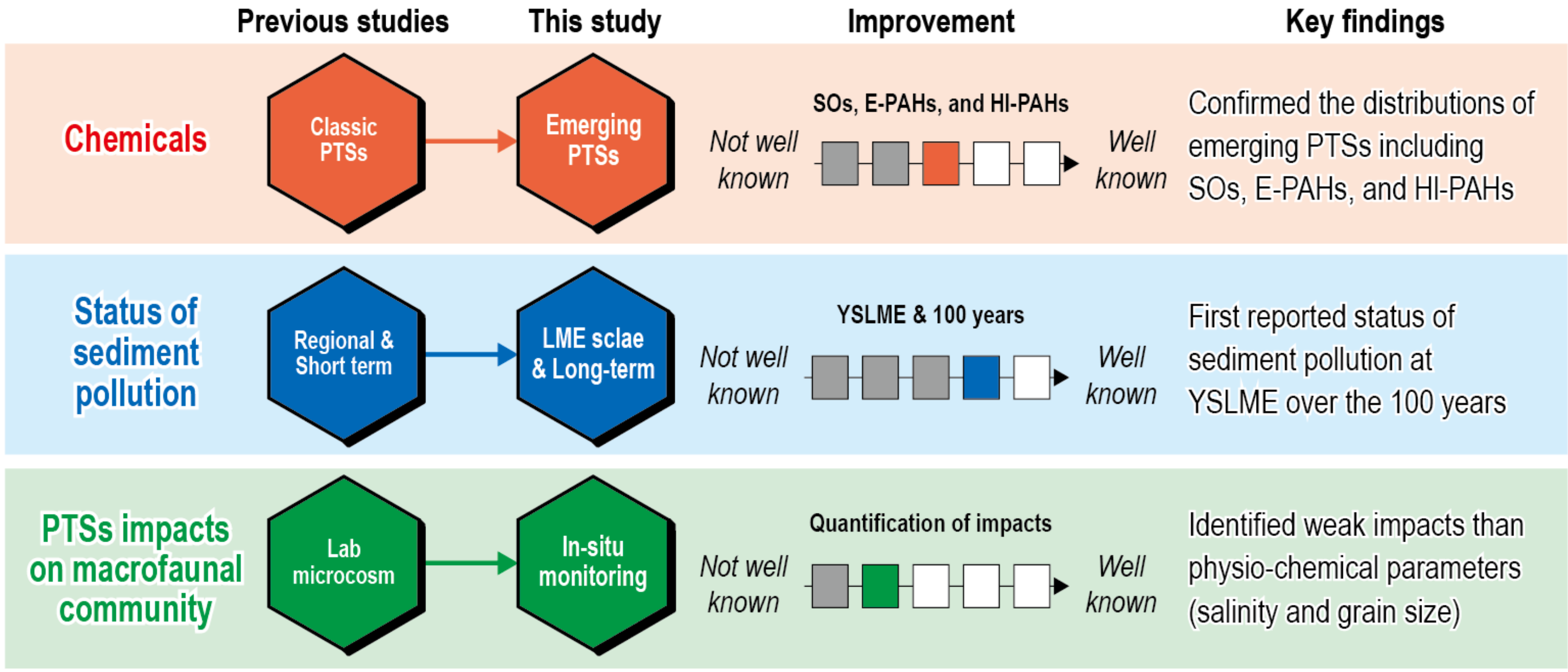

Figure 6.4.
Summary of the present study regarding multiple aspects. Research results are presented that advance our current understanding in terms of chemicals, the status of sediment pollution, and PTS impacts on the macrofaunal community.

6.2. Environmental implications and Limitations

One of the greatest challenges of the present study was related to the use of many sediment samples to assess large-scale and long-term changes (or differences) in the distribution of classic and emerging PTSs. The results showed that extremely high concentrations of PAHs presented high risks to aquatic ecosystems in the hotspot areas of some rivers and coasts in China. The by-products of diesel and gasoline combustion of industrial and municipal activities contribute to more than half of PAH contamination in the sediments of the Yellow Sea. In particular, there was a significant decline in PAH concentrations in South Korea from 2008 to 2018. In contrast, PAH concentrations have increased in the sediments of some regions in China, due to environmental regulations not being enforced. Temporal trends of historical contaminations (since 1900) by classic and emerging PTSs were determined. Historical compositions of PTSs were site-specific with no difference in Korea and China. Contributions of sources of PAHs (coke oven, gasoline combustion, and diesel and biomass combustion) differed over time. Overall, the present study showed that PTS pollution in the coastal environment of the Yellow Sea was prevalent, posing potential adverse effects within the benthic ecosystem. The results identified hotspots and potential sources of contaminants, which are expected to provide valuable information for implementing pollution reduction policies (e.g., dredging of polluted sediments, total pollution loads management), which would contribute towards improving sediment quality in the Yellow Sea.

The present study contributed to the existing database on the community responses of benthic macrofauna to the pollution of classic and emerging PTSs. The community assemblages of benthic macrofauna were primarily controlled by salinity, sediment grain size, the origin of organic matter, and food sources, including chlorophyll-*a*, regardless of contamination levels. These natural variables primarily drove the spatial variation of macrofaunal assemblages, regardless of the season. Consequently, the present study indicated that the responses of macrofaunal assemblages were mainly influenced by the physio-chemical parameters (not contaminants) in the surrounding environment. The response of benthic macrofaunal communities to anthropogenic toxic substances at a 1-year timescale in an estuarine area demonstrated the presence of anthropogenic pressure, including the estuary dam, where freshwater was irregularly discharged. Thus, the present study provided baseline information on the key factors controlling benthic macrofaunal communities in coastal environments.

The results of this study could contribute to marine environment conservation policies. Marine sediments are becoming increasingly polluted by industrial, coastal, and port development, combined with social and economic damage from contaminated sediments continue. The systematic management of contaminated sediments in Korea is not sufficient, because only local and temporary purification projects have been carried out to resolve regional complaints. It is necessary to establish a nationwide polluted marine sediment management system, systematic planning, and follow-up management of polluted sediment purification and restoration projects. In addition, the establishment of sediment database and a mid-to-long-term comprehensive plan for the management of marine polluted sediments led by the government is also necessary. In this respect, the results of this study could be used as baseline data to establish a database of marine polluted sediments.

The results of this study could also be used in policy settings for coastal area management. By diagnosing and evaluating the current state of the coastal areas of the Yellow Sea ecosystem, this study could provide a scientific basis for implementing a policy setting plan for pollution by carrying out future predictions. It is possible to establish a management direction to quickly respond to new issues, including newly emerging environmental pollution, such as persistent toxic substances, and marine ecosystem services. In addition, it could contribute to implementing active marine ecosystem conservation and management policies that reduce the emission of pollutants from the land driven. This information could help promote marine ecosystem improvements, such as reducing the influx of pollutants by expanding the Total Pollution Loads Management System (TPLMS) in specially managed areas or coastal areas in the future. In addition, marine ecosystem protection standards for persistent pollutants have been established and could be used as baseline data to prepare measures that reduce persistent pollutants by tracking major sources.

Because the environment of Korea and China was evaluated in parallel, this information could contribute towards enhancing the marine environmental management policies of both countries. As environmental cooperation projects are currently in progress, the two countries are attempting to manage the sea area more effectively by securing baseline data on the marine environment of the Yellow Sea. The main goals include: 1) developing sustainable aquaculture technology, 2) sharing and evaluating information related to marine protected areas, 3) establishing marine waste management guidelines, and 4) establishing coastal disaster response plans due to climate change. However, joint research on coastal pollution is required in coastal areas of the Yellow Sea. Thus, the results of this study could prove important in setting policies for the management of the coastal areas of the Yellow Sea. In addition, our analysis of historical pollution records could be applied towards making future predictions, providing a scientific basis for implementing policy plans on pollution. In the future, it might be possible to establish a management direction to quickly respond to new issues, including emerging environmental pollution and marine ecosystem services, in the Yellow Sea in both Korea and China.

The present study had some limitations (Table 6.1). First, the distribution and specific sources of PTSs in various media (such as water, suspended particle matter, and biota) were not investigated. For the quantitative measure of the fate of PTSs and the potential risk to coastal ecosystems, the matrix in all media should be evaluated. However, due to the limitations of the research scope, only sediment contamination was measured to detect the most representative PTSs. Second, when the process of examining the response of the benthic macrofaunal community to PTS pollution, multiple environments were not evaluated. The response of the macrofaunal community to contamination in the intertidal and subtidal zones was confirmed; however, data on various parameters (such as grain size, depth, salinity, oxygen demand, hypersaline, and the origin of organic matter in given habitats) could not be confirmed. Consequently, large datasets that can be compared in various environments over long time frames are required. Future research directions on assessing PTSs and community responses are identified in the next section based on current knowledge and limitations.

Table 6.1.
Strengths and weaknesses of the present study on the distribution of persistent toxic substances and their impact on the macrofaunal community.

Strength / Weakness	Persistent toxic substances	Response of the macrofaunal community
Strength	Large-scale area (Yellow Sea)	Various habitats (intertidal zone, estuary, and coast)
	Long-term (about 100 years)	Response to contaminants with environmental parameters (e.g., source of organic matter and water quality parameters)
	Emerging PTSs (SOs, E-PAHs, and Hl-PAHs)	Distribution of macrofauna on the gradient of key environmental factors (salinity and sediment grain size)
Weakness	Lack of fate of emerging PTSs in various media (seawater, suspended particle matter, and food sources)	Limited environmental parameters (e.g., wave exposure, hypersaline, trace elements)
	Lack of data on bioaccumulation	Limitation of analysis to feeding type and taxonomic rank (multiple levels of the ecological community)
	Limited data on ecotoxicity	Lack of known mechanisms on PTSs toxicity

There is limited information on adverse outcome pathways (AOPs), which have negative effects. Current studies mostly measure various endpoints to determine their effectiveness. Dioxin like PTSs (PAHs, E-PAHs, Hl-PAHs, PCBs, and SOs) are the most well-known mechanisms for cytotoxicity, with toxicity being induced through the Aryl hydrocarbon receptor (AhR). AhR is a transcription factor that exists inside the cell. After binding to contaminants, such as dioxins, AhR enters the nucleus and binds to the AhR nuclear translocator (ARNT) to act as a transcription factor. AhR bind to specific DNA regulatory regions, such as the AhR-response element (AHRE), Dioxin-response element (DRE), and Xenobiotics-response element (XRE); thus, promoting the expression of various genes that are mainly located downstream (Whitlock et al., 1996; Rowlands and Gustafsson, 1997). As a result, various proteins are expressed, with cytotoxicity occurring if gene expression proceeds abnormally. In addition, metabolism proceeds by cytochrome P450 in the expressed protein, and intermediate metabolites generated in the metabolic process are sometimes more toxic, causing direct DNA damage or cytotoxicity (Behnisch et al., 2001).

Metals cause oxidative cell damage by inducing the impairment of electron transfer chains and depletion of antioxidants (Regoli and Giuliani, 2014). Through activating oxidoreductase and flavoenzymes, cysteine responses and changes to the chemical speciation of metals increase the intracellular generation of reactive oxygen species (ROS) (Corsini et al., 1999; Shi et al., 2004). Generated ROS affects cell signaling pathways by causing DNA damage and impacting gene expression, proliferation, apoptosis, and transformation to intracellular genes. Antioxidants are defended through metallothioneins (MTs) and sulfhydrylrich proteins, which bind vital and non-vital elements in vertebrates; however, this process is not well induced in marine invertebrates (Viarengo et al., 2000).

When macrofauna are exposed to harmful substances such as PTSs, they biotransform the substances in the body to remove accumulated PTSs. Some crabs biotransform and excrete PAHs as polar metabolites (Nudi et al., 2007; Nudi et al., 2010). The biotransformation of invertebrates to metabolize PTSs is, in principle, similar to the two-step process observed in vertebrates. In Phase I, Cytochrome P450 enzymes (CYP enzymes) introduce functional groups to increase the water solubility of PAHs. Subsequently, phase II catalyzes the covalent bonding of polar groups, which increases water solubility (Jorgensen et al., 2008). However, our understanding of the mechanism after inducing CYP enzyme activity in Phase 1, and enzyme activity and mechanism in Phase 2, is insufficient.

Most studies on the negative effects of PTS on macrofauna have been to confirm the intensity of the effect by the endpoint. Negative effects include the inhibition of enzyme activity, changes to behavior/activity, mortality, imposex, abnormalities in embryos, changes to RNA-to-DNA ratios, and malformation in laboratory or field experiments (Mackey and Hodgkinson, 1996; Modassir, 2000; Roach and Wilson, 2009; Saha et al., 2009; Paixao et al., 2011; Penha-Lopes et al., 2011). However, there is insufficient information on the mechanisms driving these various negative effects. Future studies should investigate the effect of PTSs on macrofauna by identifying the involved mechanisms.

6.3. Future research directions

This study examined the spatiotemporal distribution of classic and emerging PTSs and their impacts on the macrofaunal community in the coastal areas of the Yellow Sea. The scale used in this study was effective at evaluating the pollution status and responses of the macrofaunal community in coastal areas. However, some parameters require further research to elucidate community responses to contamination by PTSs.

Future studies should investigate more emerging PTSs to determine potential responses of the benthic community. The 28 known classic and emerging chemicals are currently listed and are under management within the framework of the Stockholm Convention. Countries affiliated with this convention intend to reduce and eradicate these chemicals worldwide. However, studies are required on relatively recently identified contaminants (emerging PTSs), with the number of regulated chemicals continuing to increase. Thus, research on these emerging PTSs must be implemented, including quantifying their fate in environmental media. Understanding the fate of PTS in various environmental media (such as water, suspended particle matter, sediment, and food sources in habitats) facilitates more accurate assessments of their impacts on the ecological community (Ciffroy et al., 2016). In addition, bioaccumulation measurements of PTSs and toxicity testing of environmental media samples could prove useful in determining the impacts on the ecological community. Although the concentration of PTSs in environmental media can only be used to infer indirect effects on the ecological community, bioaccumulation or toxicity tests can directly determine potential effects on organisms (Stephansen et al., 2016). Thus, determining the bioaccumulation and toxicity level of PTSs, allows both direct and indirect responses of the ecological community to be assessed. Overall, an integrated approach, including evaluating the distribution of PTSs in various environmental media, bioaccumulation, and toxicity assessments is needed to improve our current understanding of the mechanisms and response of ecological communities.

Furthermore, non-contaminant parameters (such as wave exposure, surface, depth, hypersaline, sediment oxygen demand, nutrients, trace elements, and grain size of sediments in habitats) could provide useful information on community responses (Bae et al., 2018). These physio-chemical parameters (not contaminants) might cause direct or indirect changes to benthic community structure in relation to contaminant parameters. It is also necessary to analyze the relationship between the ecological community and environmental parameters with respect to different habitat types, feeding types, and taxon levels (Denis-Roy et al., 2020). The resolution of sorted samples could greatly impact the outcome of analyses. In addition, associations of multiple levels of the ecological community (such as microbiomes, microfauna, meiofauna, and macrofauna) could be used to address the overall quality of sediments (Khim et al., 2018b). The interaction of each ecological community with contaminants and environmental parameters could lead to a variety of effects in natural habitats. Thus, it is necessary to examine the community responses of various contaminants and environmental parameters within various habitats to evaluate potential ecological impacts and to elucidate its impacts on the entire marine ecosystem.

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ABSTRACT (IN KOREAN)

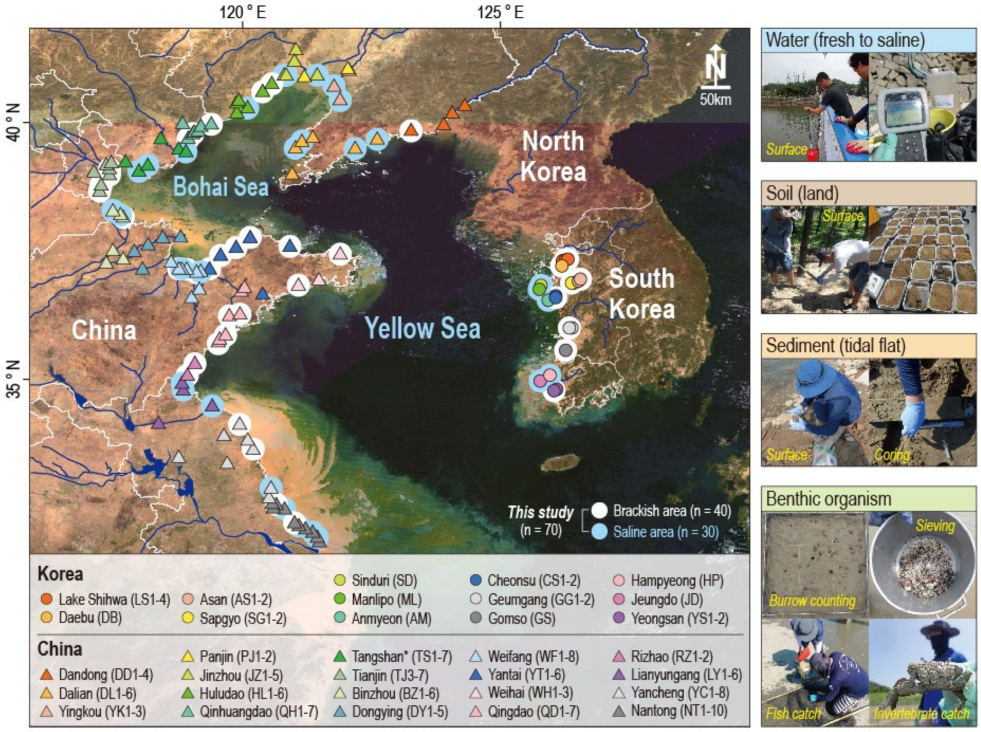
황해 연안지역 퇴적물은 지난 30여년간 잔류성오염물질에 의해 오염되어 왔다. 본 연구에서는 최초로 황해 전체 연안지역 퇴적물 내 기존 (다환방향족탄화수소, 알킬페놀, 폴리염화비페닐, 중금속) 및 신규 (스티렌올리고머와 아미노, 알킬 또는 할로겐으로 치환된 다환방향족탄화수소) 잔류성오염물질의 시공간분포와 대형저서동물 군집에 미치는 영향을 평가하였다. 잔류성오염물질의 분포는 화합물과 정점에 따라 다양하게 나타났고, 다환방향족탄화수소의 농도가 상대적으로 높게 나타났다. 특히, 중국의 후루다오, 친황다오, 난통지역 내 다환방향족탄화수소의 농도는 수 생태계에 잠재적 위해성을 가지는 것으로 확인되었다. 지난 10여년간 한국에서 다환방향족탄화수소 농도는 감소하였지만, 중국에서는 유입원의 변화와 함께 최근 더 높은 농도가 검출되었다. 연대가 측정된 주상퇴적물 분석한 결과, 지난 100여년간 기존 및 신규 잔류성오염물질이 존재하였고, 1970년대부터 1990년대에 가장 높은 농도로 분포한 것이 확인되었다. 잔류성오염물질의 유입량은 1990년대 이후에도 상대적으로 높게 나타나, 황해 연안지역의 오염이 지속되고 있음을 시사하였다. 잔류성오염물질에 의한 영향은 농도나 지역에 관계없이 상대적으로 작다는 것이 확인되었다. 상부조간대, 하구, 연안 지역에 서식하는 대형저서동물 군집은 환경요인 중 잔류성오염물질 보다 염분, 퇴적물 입자크기에 가장 영향을 받았다. 하지만 일부 지역에서 잔류성오염물질의 잠재적 위험도가 높게 나타나 지속적인 관찰이 요구된다. 이상의 연구결과를 종합 요약하면, 첫째, 황해 연안 퇴적물내 잔류성오염물질은 과거에 비해 최근 감소했으나, 일부 지역에서 여전히 높은 오염도를 보였고, 둘째, 대형저서동물의 군집구조는 잔류성오염물질보다는 서식지 내 물리 화학적 환경요인에 의해 더 영향을 받는 것으로 나타났다. 결과적으로, 본 연구는 황해 연안 지역의 오염과 생태학적 영향에 대한 정보를 제공하며, 향후 한국과 중국의 오염관리를 위한 우선순위 선택 및 오염감소 정책 실행이 필요함을 시사한다.

주제어: 퇴적물, 오염물질, 연안 오염, 해양 대형저서동물, 환경영향평가, 잠재적 위해성 평가

학 번: 2015-20469

APPENDIX

Map, field records, and sample photos for Chapter 4–5.

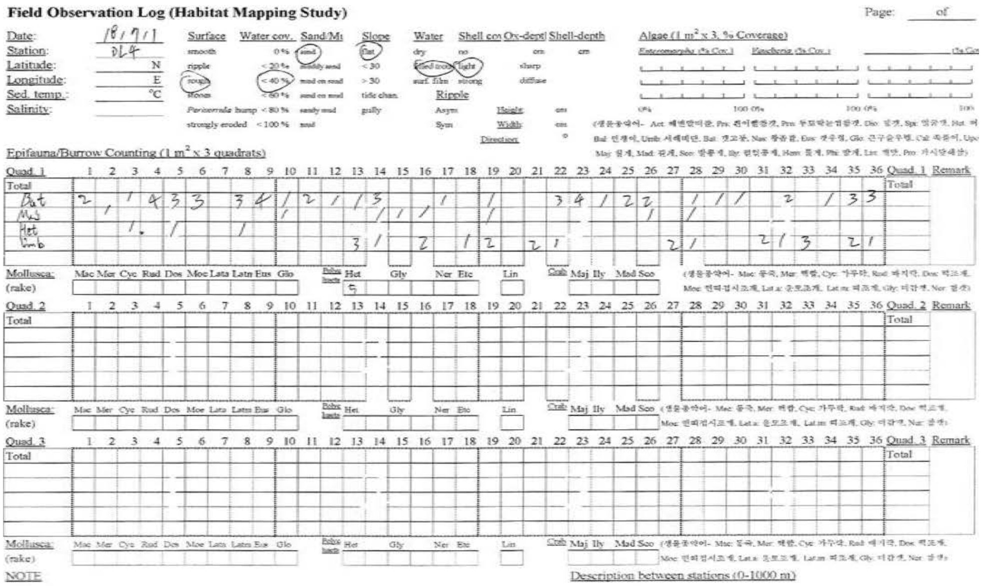


* Not exist TS4 in Tangshan area, i.e., total six sites; TS1-3, (without TS4), and TS5-7.

YES sampling information [this study]

Country	Site	Water	Soil	Sediment (*n*)		Benthic organism (*n*)				
	(*n*)	(*n*)	(*n*)	surface	core	micro	MPB	chl-*a*	meio	macro
China	105 [56]	105 [56]	105	105 [56]	88	97	83	84 [56]	84 [55]	57 [??]
Korea	21 [14]	21 [14]	20	20 [14]	13	19	18	14 [14]	19 [13]	12 [??]
Total	**126** [70]	**126** [70]	**125**	**125** [70]	**101**	**116**	**101**	**98** [70]	**103** [68]	**69** [??]

Yellow Sea Ecosystem Study						
Site-ID	DL4	Date	07/01/2018		Weather	Cloudy
Location (GPS)	Latitude	38.98444 ° N			Arrival time	Departure time
	Longitude	121.51028 ° E			9:50 am	10:30 am
Recorded by	Yunqiao Zhou Bo He		Sampled by		Yunqiao Zhou Bo He Taewoo Kim Beomgi Kim	
In situ Measurement of Riverwater or Seawater quality (Mixed water)						
Color/odor	Bad smelling					
Width/depth/velocity	A drainage ditch, width ~5m					
HACH 40d data	pH	Temp (°C)		DO (mg/L)	Salinity (mS/cm)	
	7.82	26.1		9.09	2.50	
Corresponding soil information						
Site location	Latitude	° N		Landuse	Municipal	
	Longitude	° E				


Field Observation Log (Habitat Mapping Study)

Date: 18/7/1
Station: DL4
Latitude: N
Longitude: E
Sed. temp.: °C
Salinity:

Epifauna/Burrow Counting (1 m² x 3 quadrats)

Quad. 1: Bat, Mac, Het, Umb

Quad. 2

Quad. 3

NOTE

Description between stations (0-1000 m)

Field Log and Sample Checklist

Yellow Sea Ecosystem Study							
Site-ID	DL4	Date	18.7.14		Weather	흐림(cloudy)	
Location (GPS)	Latitude	° 38	' 59	"N 04	Arrival time	Departure time	
	Longitude	° 121	' 20	"E 37	9:50	11:00	
Recorded by	강범기(KBG)		Sampled by		김태원, 강범기 (KTW, KBG)		

In situ Measurement of Porewater quality				
Color/odor	무색무취			
YSI data	pH	Temp (°C)	DO (mg/L)	Salinity
	7.82	26.1	9.09	0.19 ‰

In situ Measurement of Seawater quality				
Color/odor				
Width/depth/velocity				
YSI data	pH	Temp (°C)	DO (mg/L;	Salinity

Checklists of Collected Samples

Seawater	
POCs	HMs
ch	ch

Sediment		
General property	POCs	HMs
√	√	√

Biota			
MPB assemblage	Chl-*a*	Meiofauna & Microbiome	Macrofauna
√	√	√	√

Graphical Descrip:ion & Remark

DL4 (38.9840325,121.3397650)

배출수 인근 해변

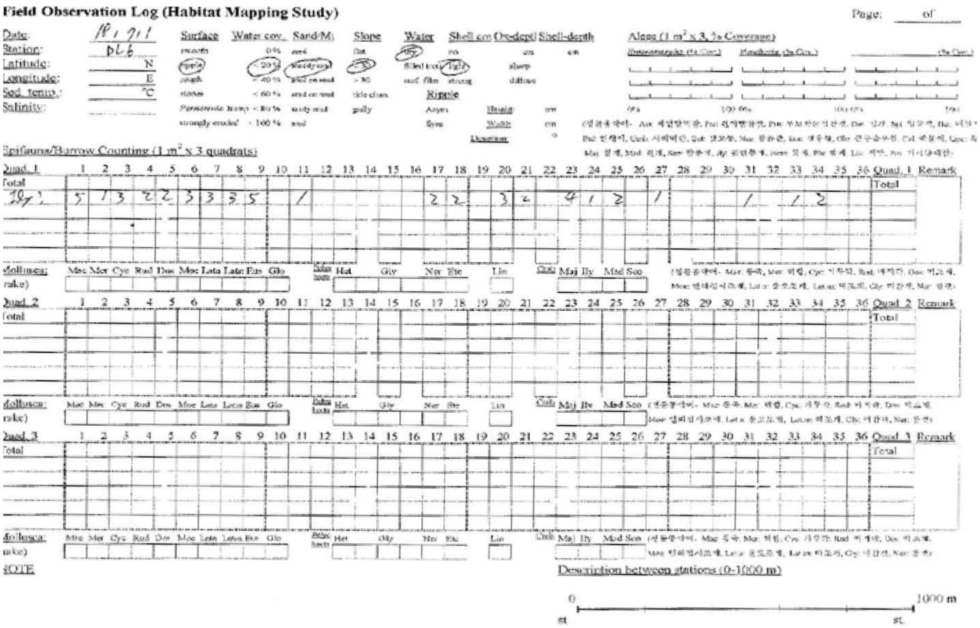
냄새가 많이 남

환원층이 표층부터 있었음

사질 앞 니질 정점에서는 갯지렁이 구멍이 많음

사람들이 많이 채집을 하고 있음

Yellow Sea Ecosystem Study					
Site-ID	DL6	Date	07/01/2018	Weather	Sunny
Location (GPS)	Latitude	39.50583 ° N		Arrival time	Departure time
	Longitude	121.40333 ° E		13:38 pm	14:05 pm
Recorded by	Yunqiao Zhou Bo He	Sampled by		Yunqiao Zhou Bo He Taewoo Kim Beomgi Kim	
In situ Measurement of Riverwater or Seawater quality (Seawater)					
Color/odor					
Width/depth/velocity	Coastal area				
HACH 40d data	pH	Temp (°C)	DO (mg/L)	Salinity (mS/cm)	
	7.89	26.4	8.03	58.0	
Corresponding soil information					
Site location	Latitude	° N	Landuse	Unused land	


Field Observation Log (Habitat Mapping Study)

Page: of

Date: 18.7.1

Station: DL6

Latitude: N

Longitude: E

Sed. temp.: °C

Salinity:

Surface | Water cov. | Sand/Mud | Slope | Water | Shell cov. | Ore-depth | Shell-depth | Algae (1 m² x 3, % Coverage)

Ripple | Height cm | Width cm | Direction °

Epifauna/Burrow Counting (1 m² x 3 quadrats)

Quad. 1	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	Quad. 1 Total	Remark
[illegible]	5	1	3	2	2	3	3	3	5		1						2	2		3	2		4	1	2		1				1		1	2				

Mollusca (rake): Mac Mer Cyc Rud Dos Moc Lata Latu Bus Glo | Het | Gly | Ner Ete | Lin | Maj Ily Mad Soo

Quad. 2 | Total | Remark

Quad. 3 | Total | Remark

NOTE

Description between stations (0-1000 m)

0 — 1000 m

st — st

Field Log and Sample Checklist

Yellow Sea Ecosystem Study						
Site-ID	DL6	Date	18.9.1		Weather	Sunny
Location (GPS)	Latitude	° 39	' 30	"N 21	Arrival time	Departure time
	Longitude	° 121	' 24	"E 12	13:38	14:50
Recorded by	KBG		Sampled by		KTW, KBG	

In situ Measurement of Porewater quality				
Color/odor				
YSI data	pH	Temp (°C)	DO (mg/L)	Salinity

In situ Measurement of Seawater quality				
Color/odor				
Width/depth/velocity				
YSI data	pH	Temp (°C)	DO (mg/L)	Salinity
	7.87	26.4	8.03	36‰

Checklists of Collected Samples

Seawater	
POCs	HMs
Ch	Ch

Sediment		
General property	POCs	HMs
√	√	√

Biota			
MPB assemblage	Chl-a	Meiofauna & Microbiome	Macrofauna
√	√	√	√

Graphical Description & Remark

DL6 (39.5013000, 121.4148000)

앞에 조선소

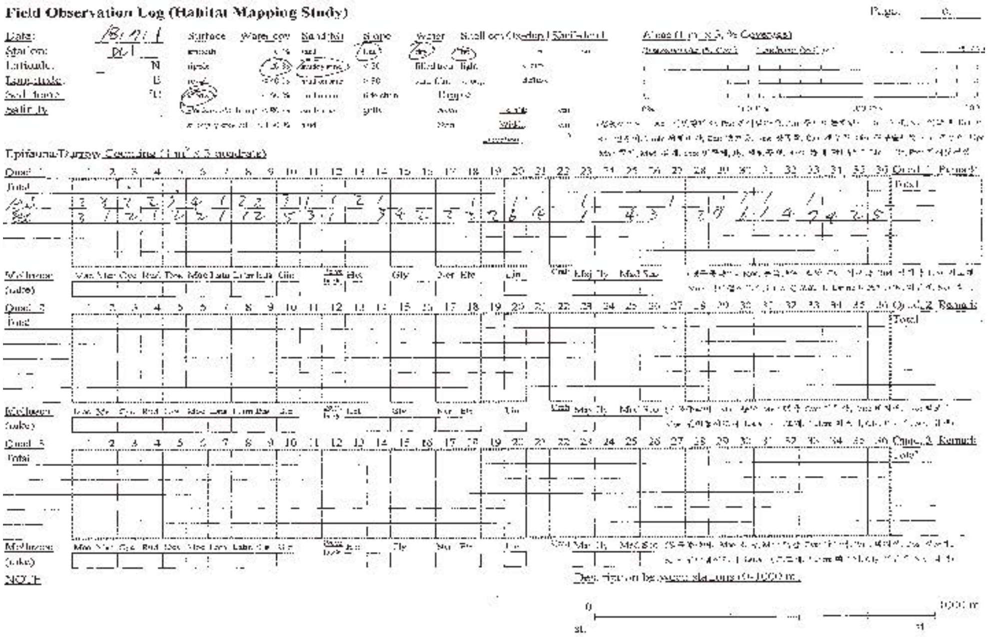
생물 서식굴 거의 없음

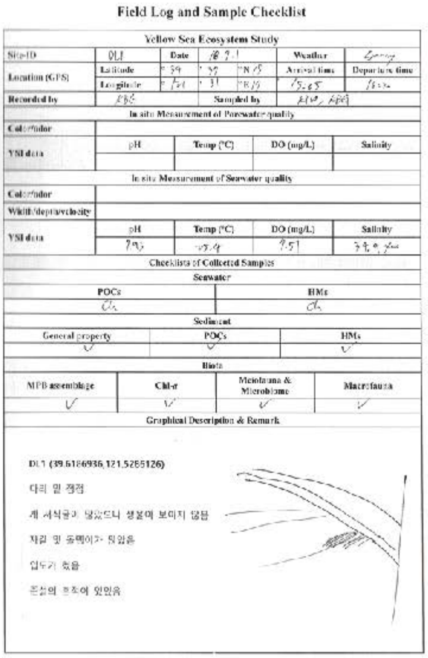
패각 거의 없음

인근 어업 활동이 있었음

상부 조간대는 니사질이나 외해로 나갈 수록 니질임

Yellow Sea Ecosystem Study					
Site-ID	DL1	**Date**	07/01/2018	**Weather**	Cloudy
Location (GPS)	**Latitude**	39.62083 ° N		**Arrival time**	**Departure time**
	Longitude	121.52139 ° E		15:05 pm	15:40 pm
Recorded by	Yunqiao Zhou Bo He	**Sampled by**	Yunqiao Zhou Bo He Taewoo Kim Beomgi Kim		
In situ Measurement of Riverwater or Seawater quality (Seawater)					
Color/odor					
Width/depth/velocity	**Fuzhou River, estuary, width ~ 50m**				
HACH 40d data	**pH**	**Temp (°C)**	**DO (mg/L)**	**Salinity (mS/cm)**	
	7.93	25.4	7.51	53.3	
Corresponding soil information					
Site location	**Latitude**	° N	**Landuse**	**Municipal**	


Field Observation Log (Habitat Mapping Study)



Field Log and Sample Checklist

Yellow Sea Ecosystem Study							
Site-ID	DL1	Date	'18.9.1			Weather	Sunny
Location (GPS)	Latitude	° 39	' 37	"N 15		Arrival time	Departure time
	Longitude	° 121	' 31	"E 19		15:05	16:30
Recorded by	KBG		Sampled by	KHJ, KBG			

In situ Measurement of Porewater quality				
Color/odor				
YSI data	pH	Temp (°C)	DO (mg/L)	Salinity

In situ Measurement of Seawater quality				
Color/odor				
Width/depth/velocity				
YSI data	pH	Temp (°C)	DO (mg/L)	Salinity
	7.95	25.4	7.51	34.0‰

Checklists of Collected Samples

Seawater	
POCs	HMs
Ch	Ch

Sediment		
General property	POCs	HMs
✓	✓	✓

Biota			
MPB assemblage	Chl-a	Meiofauna & Microbiome	Macrofauna
✓	✓	✓	✓

Graphical Description & Remark

DL1 (39.6186936,121.5265126)

다리 밑 정점

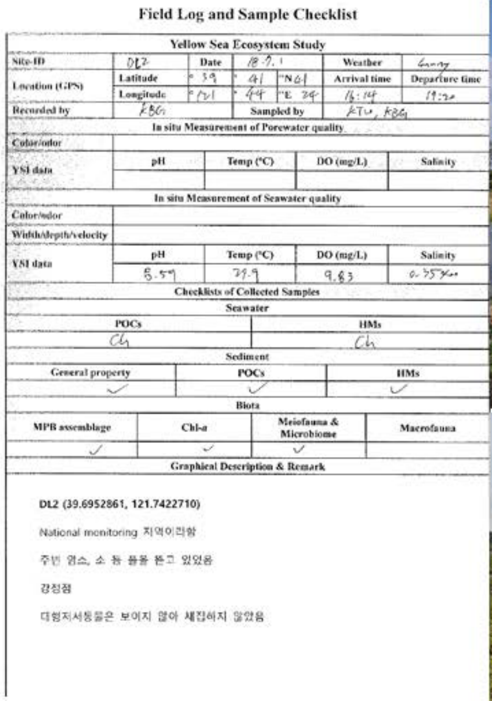
게 서식굴이 많았으나 생물이 보이지 않음

자갈 및 돌멩이가 덮었음

입도가 컸음

준설의 흔적이 있었음

Yellow Sea Ecosystem Study					
Site-ID	DL2	Date	07/01/2018	Weather	Sunny
Location (GPS)	Latitude	39.69472 ° N		Arrival time	Departure time
	Longitude	121.74000 ° E		16:14 pm	16:50 pm
Recorded by	Yunqiao Zhou Bo He	Sampled by		Yunqiao Zhou Bo He Taewoo Kim Beomgi Kim	
In situ Measurement of Riverwater or Seawater quality (Freshwater)					
Color/odor					
Width/depth/velocity	Fuzhou River, upstream, width ~ 20m				
HACH 40d data	pH	Temp (°C)		DO (mg/L)	Salinity (mS/cm)
	8.59	27.9		9.83	0.76
Corresponding soil information					
Site location	Latitude	° N		Landuse	Agricultural



Field Log and Sample Checklist

Yellow Sea Ecosystem Study						
Site-ID	DL2	Date	18.7.1		Weather	Sunny
Location (GPS)	Latitude	° 39	' 41	" N 61	Arrival time	Departure time
	Longitude	° 121	' 44	" E 24	16:14	19:20
Recorded by	KBG		Sampled by		KTW, KBG	
In situ Measurement of Porewater quality						
Color/odor						
YSI data	pH		Temp (°C)		DO (mg/L)	Salinity
In situ Measurement of Seawater quality						
Color/odor						
Width/depth/velocity						
YSI data	pH		Temp (°C)		DO (mg/L)	Salinity
	8.59		27.9		9.83	0.757‰

Checklists of Collected Samples			
Seawater			
POCs		HMs	
Ch		Ch	
Sediment			
General property	POCs	HMs	
✓	✓	✓	
Biota			
MPB assemblage	Chl-a	Meiofauna & Microbiome	Macrofauna
✓	✓	✓	
Graphical Description & Remark			

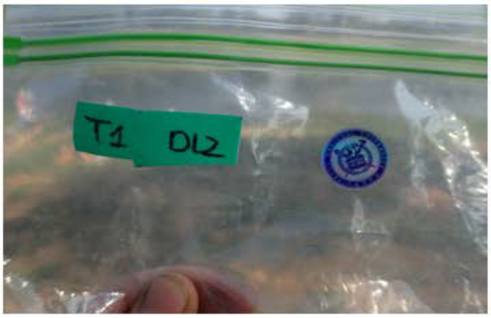
DL2 (39.6952861, 121.7422710)

National monitoring 지역이라함

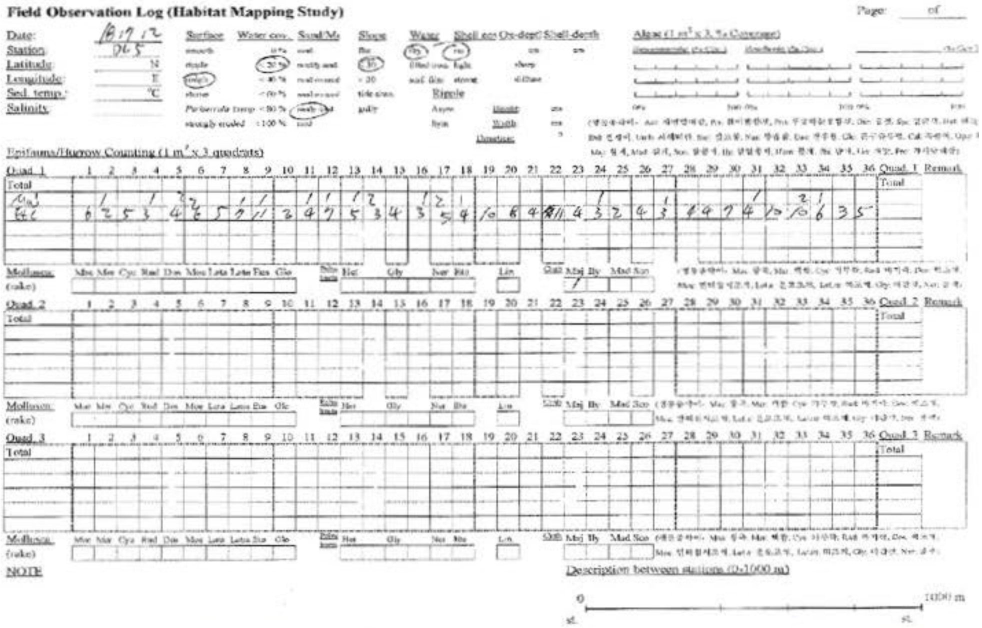
주변 염소, 소 등 풀을 뜯고 있었음

강정점

대형저서동물은 보이지 않아 채집하지 않았음



Yellow Sea Ecosystem Study					
Site-ID	DL5	Date	07/02/2018	Weather	Cloudy
Location (GPS)	Latitude	39.48167° N		Arrival time	Departure time
	Longitude	122.55917° E		9:46 am	10:46 am
Recorded by	Yunqiao Zhou Bo He	Sampled by	Yunqiao Zhou Bo He Taewoo Kim Beomgi Kim		
In situ Measurement of Riverwater or Seawater quality (Seawater)					
Color/odor					
Width/depth/velocity	Biliu River, estuary, width ~100m				
HACH 40d data	pH	Temp (°C)	DO (mg/L)	Salinity (mS/cm)	
	7.84	24.5	7.35	51.9	
Corresponding soil information					
Site location	Latitude	° N	Landuse	Agricultural	



Field Log and Sample Checklist

Yellow Sea Ecosystem Study						
Site-ID	DL5	Date	18.7.2		Weather	Cloudy
Location (GPS)	Latitude	° 39	' 28	"N 54	Arrival time	Departure time
	Longitude	° 122	' 33	"E 33	9:46	10:38
Recorded by	KBG		Sampled by		KTW, KBG	

In situ Measurement of Porewater quality				
Color/odor				
YSI data	pH	Temp (°C)	DO (mg/L)	Salinity

In situ Measurement of Seawater quality				
Color/odor				
Width/depth/velocity				
YSI data	pH	Temp (°C)	DO (mg/L)	Salinity
	7.84	24.5	7.35	34.6 ‰

Checklists of Collected Samples

Seawater	
POCs	HMs
Ch	Ch

Sediment		
General property	POCs	HMs
✓	✓	✓

Biota			
MPB assemblage	Chl-a	Meiofauna & Microbiome	Macrofauna
✓	✓	✓	✓

Graphical Description & Remark

DL5 (39.4822536, 122.5639785)

캔코어 2번 시행, 10:45 departure time

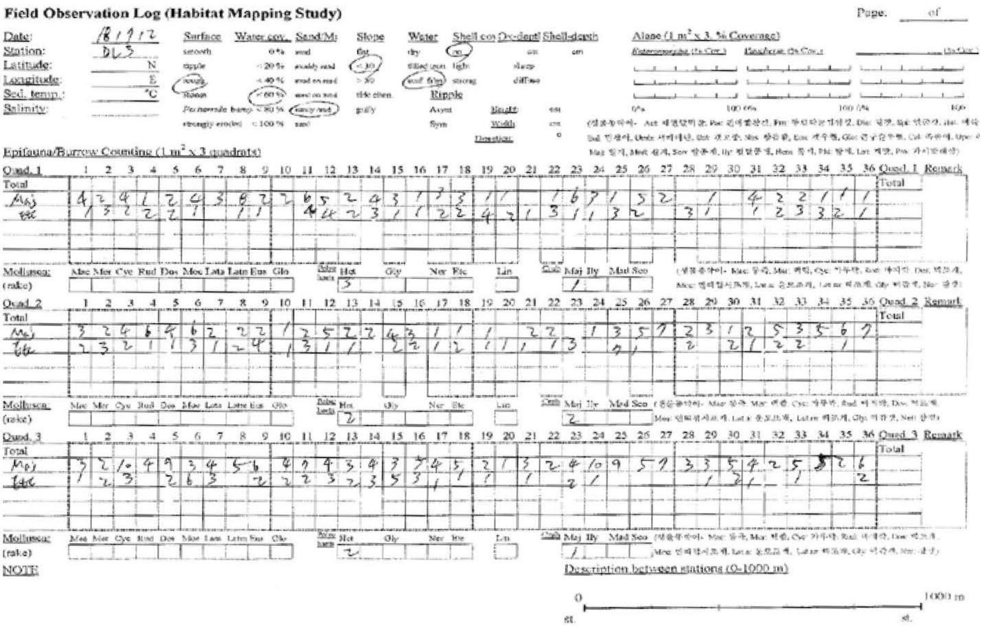
주변에 작은 조선소가 있음

칠면초 군락이 형성되어 있었음

방게, 세스랑게? 등의 서식굴이 많았음

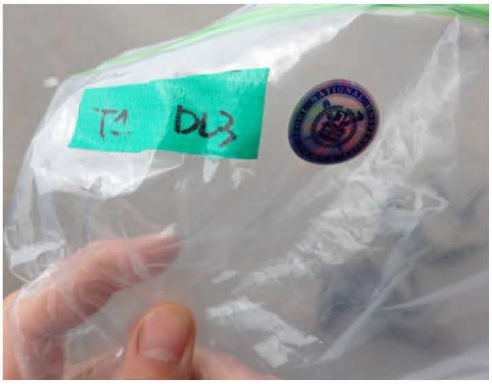
캔코어 2번 진행

Yellow Sea Ecosystem Study					
Site-ID	DL3	Date	07/02/2018	Weather	Sunny
Location (GPS)	Latitude	39.66333 ° N		Arrival time	Departure time
	Longitude	122.99389 ° E		13:47 pm	15:05 pm
Recorded by	Yunqiao Zhou Bo He	Sampled by		Yunqiao Zhou Bo He Taewoo Kim Beomgi Kim	
In situ Measurement of Riverwater or Seawater quality (Seawater)					
Color/odor					
Width/depth/velocity	Zhuang River, estuary				
HACH 40d data	pH	Temp (°C)		DO (mg/L)	Salinity (mS/cm)
	7.69	26.2		6.09	50.2
Corresponding soil information					
Site location	Latitude	° N		Landuse	Municipal


Field Observation Log (Habitat Mapping Study)

Date: 18.7.2
Station: DL3

Epifauna/Burrow Counting (1 m² x 3 quadrats)



Field Log and Sample Checklist

Yellow Sea Ecosystem Study							
Site-ID	DL 3	Date	18. 7. 2			Weather	Sunny
Location (GPS)	Latitude	°39	′39	″N 68		Arrival time	Departure time
	Longitude	°122	′59	″E 36		13:41	15:05
Recorded by	KBG		Sampled by			KTW, KBG	

In situ Measurement of Porewater quality				
Color/odor				
YSI data	pH	Temp (°C)	DO (mg/L)	Salinity

In situ Measurement of Seawater quality				
Color/odor				
Width/depth/velocity				
YSI data	pH	Temp (°C)	DO (mg/L)	Salinity
	7.67	26.2	6.09	31.8‰

Checklists of Collected Samples

Seawater	
POCs	HMs
✓ Ch	Ch

Sediment		
General property	POCs	HMs
✓	✓	✓

Biota			
MPB assemblage	Chl-a	Meiofauna & Microbiome	Macrofauna
✓	✓	✓	✓

Graphical Description & Remark

DL3 (39.6634661, 122.9939232)

잔코어 3번 시행

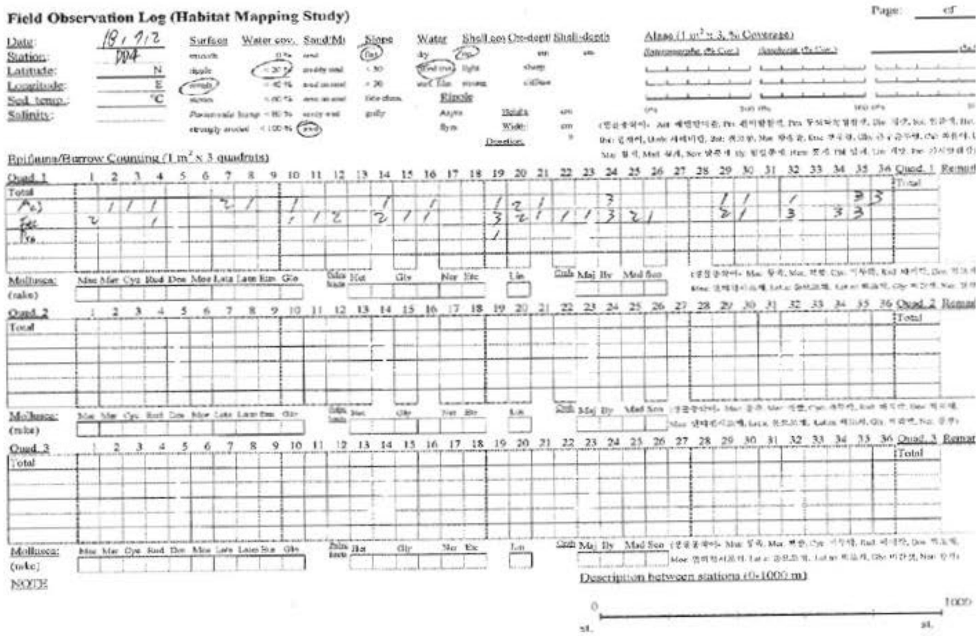
공원 옆

서식굴 많았고 게류 많았음

만조에서 물이 빠질 때 샘플링

갯골이 깊게 형성되어있음

Yellow Sea Ecosystem Study					
Site-ID	DD4	Date	07/02/2018	Weather	Sunny
Location (GPS)	Latitude	39.83833 ° N		Arrival time	Departure time
	Longitude	123.65278 ° E		16:50 pm	18:10 pm
Recorded by	Yunqiao Zhou Bo He	Sampled by		Yunqiao Zhou Bo He Taewoo Kim Beomgi Kim	
In situ Measurement of Riverwater or Seawater quality (Mixed water)					
Color/odor					
Width/depth/velocity	Dayang River, estuary, width ~500m,				
HACH 40d data	pH	Temp (°C)		DO (mg/L)	Salinity (mS/cm)
	8.36	25.0		6.62	16.8
Corresponding soil information					
Site location	Latitude	° N		Landuse	Agricultural


Field Observation Log (Habitat Mapping Study)

Page: of

Date: 18.7.12

Station: DD4

Latitude: N

Longitude: E

Sed. temp.: °C

Salinity:

Epifauna/Burrow Counting (1 m² x 3 quadrats)

Quad. 1

Quad. 2

Quad. 3

Mollusca: (ruler)

NOTE

Description between stations (0-1000 m)

Field Log and Sample Checklist

Yellow Sea Ecosystem Study						
Site-ID	DD4	Date	18.7.2		Weather	Sunny
Location (GPS)	Latitude	° 39	' 50	"N 18	Arrival time	Departure time
	Longitude	° 123	' 39	"E 10	16:50	18:10
Recorded by	KBG		Sampled by		KTW, KBG	

In situ Measurement of Porewater quality				
Color/odor				
YSI data	pH	Temp (℃)	DO (mg/L)	Salinity

In situ Measurement of Seawater quality				
Color/odor				
Width/depth/velocity				
YSI data	pH	Temp (℃)	DO (mg/L)	Salinity
	8.36	25	6.62	9.85‰

Checklists of Collected Samples

Seawater	
POCs	HMs
Ch	Ch

Sediment		
General property	POCs	HMs
✓	✓	✓

Biota			
MPB assemblage	Chl-*a*	Meiofauna & Microbiome	Macrofauna
✓	✓	✓	✓

Graphical Description & Remark

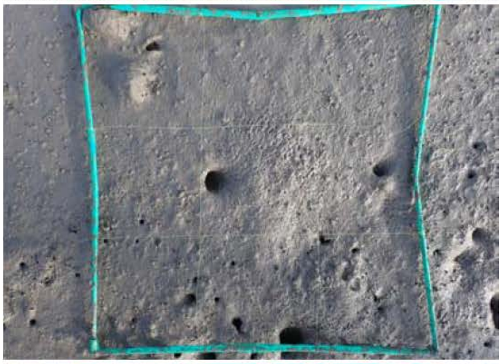
DD4 (39.8303000, 123.6537000)

캔코어 3번 시행

칠면초 군락이 넓게 퍼지있음

상부 조간대는 니질 갯벌이지만 하부 조간대로 갈수록 사질로 바뀜

상부 조간대는 방게, 갯지렁이 등의 서식굴이, 하부 조간대는 달랑게 등의 서식굴이 관찰됨



Yellow Sea Ecosystem Study					
Site-ID	DD3	Date	07/03/2018	Weather	Sunny
Location (GPS)	Latitude	40.33444 ° N		Arrival time	Departure time
	Longitude	124.71361 ° E		11:27 am	12:00 am
Recorded by	Yunqiao Zhou Bo He	Sampled by		Yunqiao Zhou Bo He Taewoo Kim Beomgi Kim	
In situ Measurement of Riverwater or Seawater quality (Freshwater)					
Color/odor					
Width/depth/velocity	Yalu River, upstream, width ~100m				
HACH 40d data	pH	Temp (°C)	DO (mg/L)	Salinity (mS/cm)	
	8.32	25.0	9.52	0.24	
Corresponding soil information					
Site location	Latitude	° N	Landuse	Agricultural	

Field Log and Sample Checklist

Yellow Sea Ecosystem Study						
Site-ID	DD3	Date	18.7.3		Weather	Sunny
Location (GPS)	Latitude	° 40	' 20	"N 01	Arrival time	Departure time
	Longitude	° 124	' 42	"E 47	11:27	12:00
Recorded by	KBG		Sampled by		KTW, KBM	
In situ Measurement of Porewater quality						
Color/odor						
YSI data	pH	Temp (°C)	DO (mg/L)	Salinity		
In situ Measurement of Seawater quality						
Color/odor						
Width/depth/velocity						
YSI data	pH	Temp (°C)	DO (mg/L)	Salinity		
	8.32	25	9.52	0.12‰		

Checklists of Collected Samples			
Seawater			
POCs		HMs	
C4		C4	
Sediment			
General property	POCs	HMs	
✓	✓	✓	
Biota			
MPB assemblage	Chl-a	Meiofauna & Microbiome	Macrofauna
✓	✓	✓	
Graphical Description & Remark			

DD3 (40.3122350, 124.6968410)

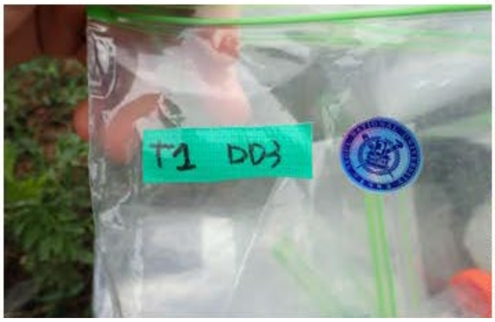
압록강 상류 정점

마크로x

중국-북한 경계

인근주민 어업활동 지역

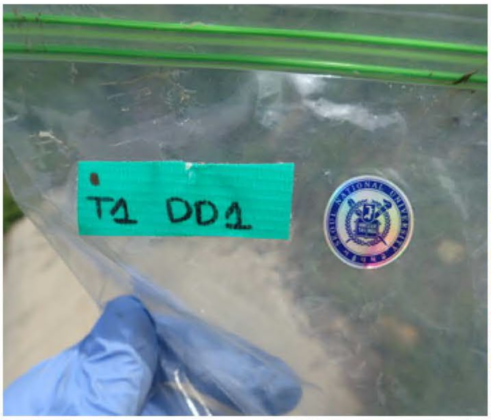
코어 13cm 수령

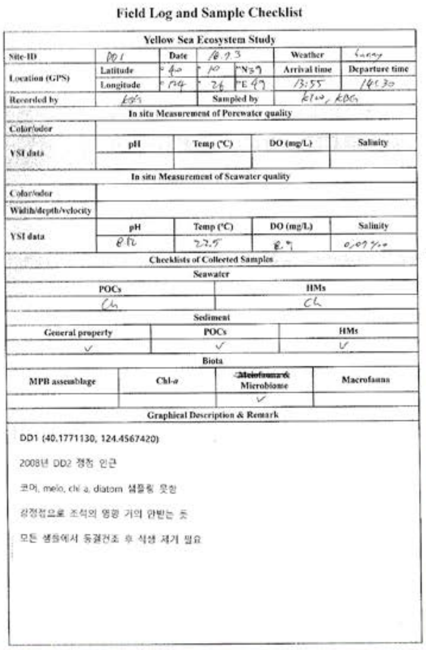






Yellow Sea Ecosystem Study					
Site-ID	DD1	Date	07/03/2018	Weather	Sunny
Location (GPS)	Latitude	40.17750 ° N		Arrival time	Departure time
	Longitude	124.44694 ° E		13:55 pm	14:30 pm
Recorded by	Yunqiao Zhou Bo He		Sampled by	Yunqiao Zhou Bo He Taewoo Kim Beomgi Kim	
In situ Measurement of Riverwater or Seawater quality (Freshwater)					
Color/odor					
Width/depth/velocity	Yalu River, upstream, width ~50m				
HACH 40d data	pH	Temp (^{o}C)	DO (mg/L)	Salinity (mS/cm)	
	8.12	22.5	8.90	0.15	
Corresponding soil information					
Site location	Latitude	° N	Landuse	Municipal	





Field Log and Sample Checklist

Yellow Sea Ecosystem Study						
Site-ID	DD1	Date	18.7.3		Weather	Sunny
Location (GPS)	Latitude	° 40	′ 10	″N 37	Arrival time	Departure time
	Longitude	° 124	′ 26	″E 47	13:55	14:30
Recorded by	KBG		Sampled by	KTW, KBG		

In situ Measurement of Porewater quality				
Color/odor				
YSI data	pH	Temp (°C)	DO (mg/L)	Salinity

In situ Measurement of Seawater quality				
Color/odor				
Width/depth/velocity				
YSI data	pH	Temp (°C)	DO (mg/L)	Salinity
	8.12	22.5	8.7	0.07‰

Checklists of Collected Samples

Seawater	
POCs	HMs
Ch	Ch

Sediment		
General property	POCs	HMs
✓	✓	✓

Biota			
MPB assemblage	Chl-*a*	~~Meiofauna &~~ Microbiome	Macrofauna
		✓	

Graphical Description & Remark

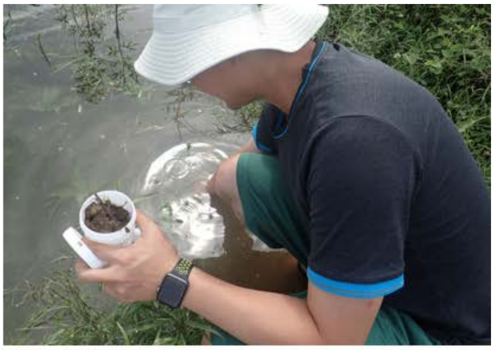
DD1 (40.1771130, 124.4567420)

2008년 DD2 정점 인근

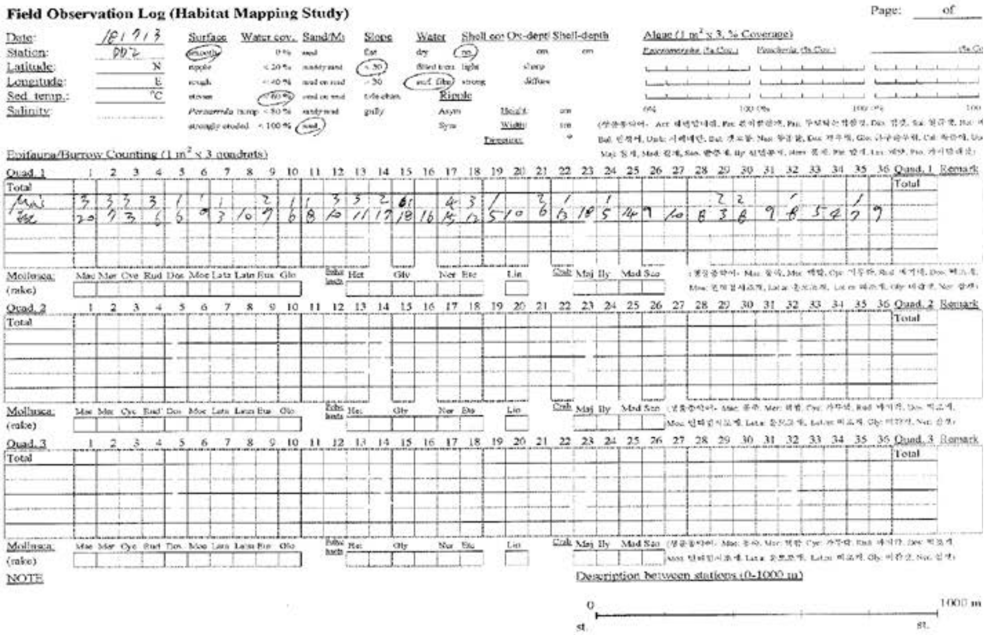
코어, meio, chl a, diatom 샘플링 못함

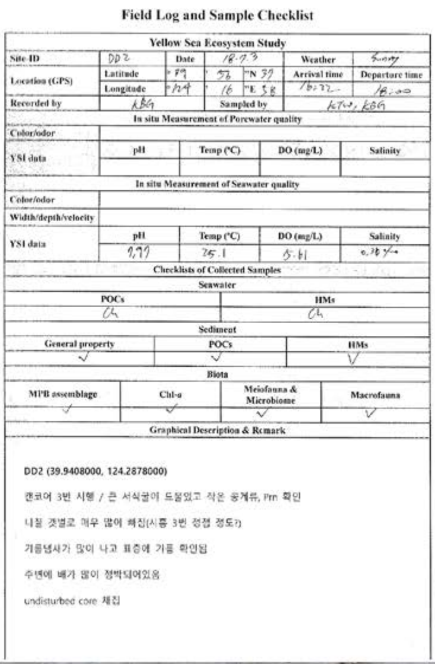
강정점으로 조석의 영향 거의 안받는 듯

모든 샘플에서 동결건조 후 식생 제거 필요



Yellow Sea Ecosystem Study					
Site-ID	DD2	Date	07/03/2018	Weather	Sunny
Location (GPS)	Latitude	39.94361 ° N		Arrival time	Departure time
	Longitude	124.28278 ° E		16:22 pm	18:00 pm
Recorded by	Yunqiao Zhou Bo He	Sampled by		Yunqiao Zhou Bo He Taewoo Kim Beomgi Kim	
In situ Measurement of Riverwater or Seawater quality (Freshwater)					
Color/odor					
Width/depth/velocity	Yalu River, estuary				
HACH 40d data	pH	Temp (°C)	DO (mg/L)	Salinity (mS/cm)	
	7.97	25.1	5.61	0.75	
Corresponding soil information					
Site location	Latitude	° N	Landuse	Municipal	





Field Log and Sample Checklist

Yellow Sea Ecosystem Study						
Site ID	DD2	Date	18.7.3		Weather	Sunny
Location (GPS)	Latitude	° 39	' 56	" N 37	Arrival time	Departure time
	Longitude	° 124	' 16	" E 58	16:22	18:00
Recorded by	KBG		Sampled by		KTW, KBG	
In situ Measurement of Porewater quality						
Color/odor						
YSI data	pH	Temp (°C)	DO (mg/L)		Salinity	
In situ Measurement of Seawater quality						
Color/odor						
Width/depth/velocity						
YSI data	pH	Temp (°C)	DO (mg/L)		Salinity	
	7.77	25.1	5.61		0.38‰	
Checklists of Collected Samples						
Seawater						
POCs			HMs			
Ch			Ch			
Sediment						
General property		POCs		HMs		
✓		✓		✓		
Biota						
MPB assemblage	Chl-a		Meiofauna & Microbiome		Macrofauna	
✓	✓		✓		✓	
Graphical Description & Remark						

DD2 (39.9408000, 124.2878000)

캔코어 3번 시행 / 큰 서식굴이 드물었고 작은 농게류, Pm 확인

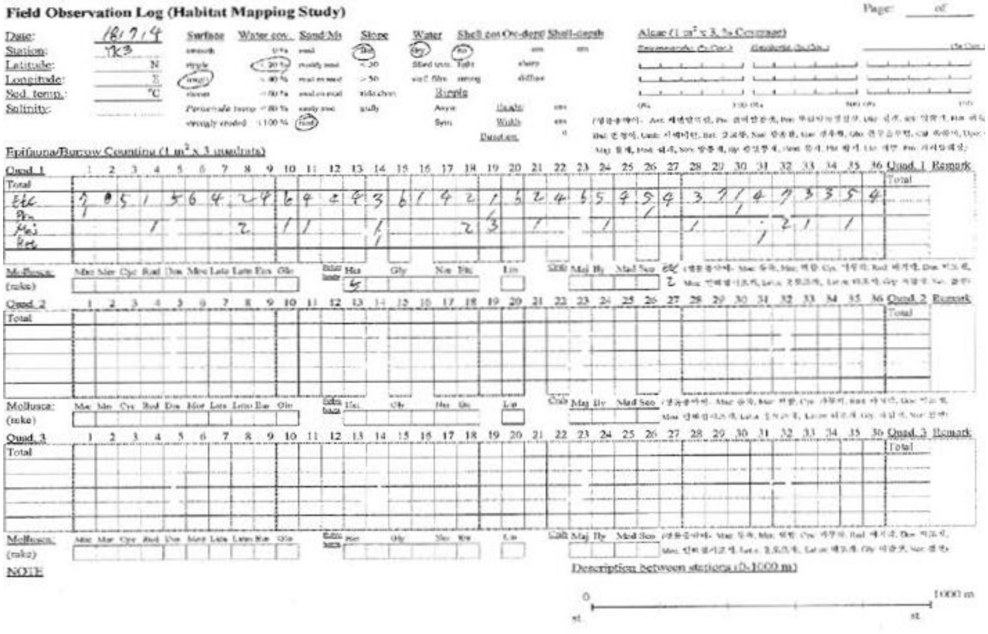
니질 갯벌로 매우 많이 빠짐(시흥 3번 정점 정도?)

기름냄새가 많이 나고 표층에 기름 확인됨

주변에 배가 많이 정박되어있음

undisturbed core 채집

Yellow Sea Ecosystem Study					
Site-ID	YK3	Date	07/04/2018	Weather	Sunny
Location (GPS)	Latitude	40.42500 ° N		Arrival time	Departure time
	Longitude	122.28444 ° E		8:25 am	9:26 am
Recorded by	Yunqiao Zhou Bo He	Sampled by		Yunqiao Zhou Bo He Taewoo Kim Beomgi Kim	
In situ Measurement of Riverwater or Seawater quality (Seawater)					
Color/odor					
Width/depth/velocity	Daqing River, width ~10m				
HACH 40d data	pH	Temp (°C)	DO (mg/L)	Salinity (mS/cm)	
	7.82	27.9	4.81	61.0	
Corresponding soil information					
Site location	Latitude	° N	Landuse	Agricultural	



Field Observation Log (Habitat Mapping Study)

Date: 18.7.4
Station: YK3

Epifauna/Burrow Counting (1 m² x 3 quadrats)

Designed by Coastal Ecosystem Engineering Lab. (Anyang U.) and Laboratory of Marine Benthic Ecology. (Seoul National U.)

Field Log and Sample Checklist

Yellow Sea Ecosystem Study						
Site-ID	YK3	Date	18.7.4		Weather	Sunny
Location (GPS)	Latitude	° 40	′ 25	″N 30	Arrival time	Departure time
	Longitude	° 122	′ 17	″E 04	8:25	9:26
Recorded by	KBG		Sampled by		KTW, KBG	

In situ Measurement of Porewater quality

Color/odor				
YSI data	pH	Temp (°C)	DO (mg/L)	Salinity

In situ Measurement of Seawater quality

Color/odor				
Width/depth/velocity				
YSI data	pH	Temp (°C)	DO (mg/L)	Salinity
	7.82	29.9	9.61	28.5‰

Checklists of Collected Samples

Seawater

POCs	HMs
Ch	Ch

Sediment

General property	POCs	HMs
✓	✓	✓

Biota

MPB assemblage	Chl-a	Meiofauna & Microbiome	Macrofauna
✓	✓	✓	✓

Graphical Description & Remark

YK3 (40.4268000, 122.2768000)

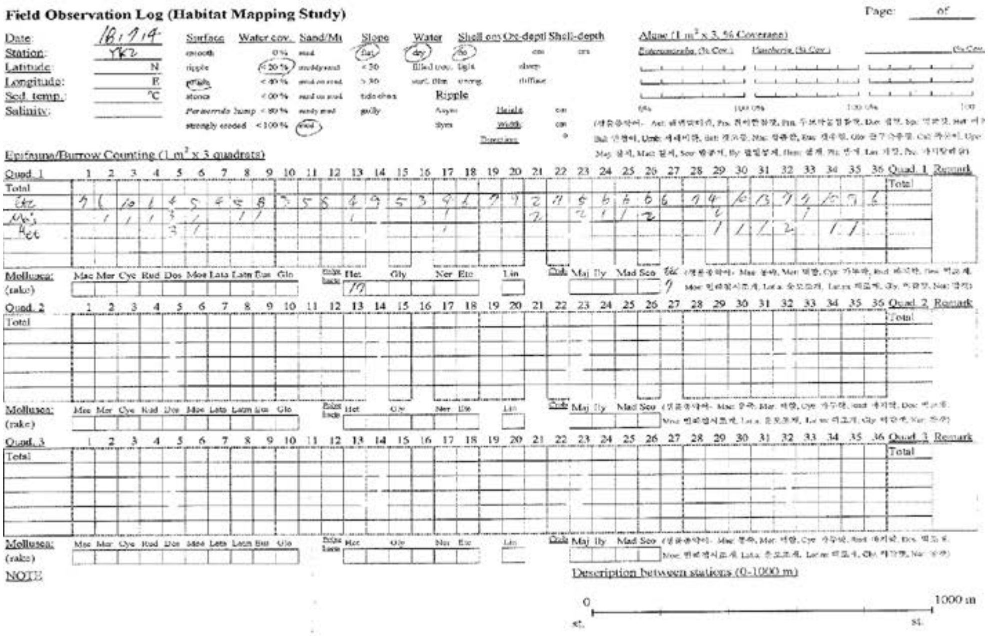
펜코어 3번 시행 / 생물 매우 많았고 니질 갯벌로 매우 들러붙고 시빙 힘들었음

갯골이 크고 넓게 발달

에마 노출 시간이 길어 퇴적물이 단단한 경향

만에서 가까운 하구 지역으로 다리 옆에서 샘플링

Yellow Sea Ecosystem Study					
Site-ID	YK2	Date	07/04/2018	Weather	Sunny
Location (GPS)	Latitude	40.69000 ° N		Arrival time	Departure time
	Longitude	122.12917 ° E		10:44 am	12:10 pm
Recorded by	Yunqiao Zhou Bo He	Sampled by		Yunqiao Zhou Bo He Taewoo Kim Beomgi Kim	
In situ Measurement of Riverwater or Seawater quality (Seawater)					
Color/odor					
Width/depth/velocity	Daliao River, width ~1000m				
HACH 40d data	pH	Temp (°C)	DO (mg/L)	Salinity (mS/cm)	
	8.30	29.1	7.20	57.7	
Corresponding soil information					
Site location	Latitude	° N	Landuse	Municipal	


Field Observation Log (Habitat Mapping Study)

Page: of

Date: 18.7.14
Station: YK2
Latitude: N
Longitude: E
Sed. temp.: °C
Salinity:

Surface / Water cov. / Sand/Mu / Slope / Water / Shell ons / Ox-depth / Shell-depth

Ripple

Epifauna/Burrow Counting (1 m^2 x 3 quadrats)

Quad. 1 / Quad. 2 / Quad. 3

Mollusca: (rake)

NOTE

Description between stations (0-1000 m)

0 st. — 1000 m st.

Field Log and Sample Checklist

Yellow Sea Ecosystem Study						
Site-ID	YK2	Date	18.9.4		Weather	Sunny
Location (GPS)	Latitude	° 40	° 41	°N 24	Arrival time	Departure time
	Longitude	° 122	° 07	°E 45	10:44	12:40
Recorded by	KBG		Sampled by		KJW, KBG	

In situ Measurement of Porewater quality				
Color/odor				
YSI data	pH	Temp (°C)	DO (mg/L)	Salinity

In situ Measurement of Seawater quality				
Color/odor				
Width/depth/velocity				
YSI data	pH	Temp (°C)	DO (mg/L)	Salinity
	8.30	29.1	7.20	38.6‰

Checklists of Collected Samples

Seawater	
POCs	HMs
Ch	Ch

Sediment		
General property	POCs	HMs
√	√	√

Biota			
MPB assemblage	Chl-a	Meiofauna & Microbiome	Macrofauna
√	√	√	√

Graphical Description & Remark

YK2 (40.6896680, 122.1526480)

캔코어 3번 시행 / 서식굴 많았으며 게류와 Het 다수 관찰

강 입구와 안쪽의 하구 지역으로 칠면초, 갈대 등 염생식물 군락 발달

상부쪽은 크고 깊게 발달한 갯골을 통해 물이 유입되는 듯 보이며 만조 때 잠깐 잠기는 듯 함

니질 퇴적물 내부에 지푸라기와 비닐 조각 등이 많았음

undisturbed core 채집

Yellow Sea Ecosystem Study					
Site-ID	YK1	Date	07/04/2018	Weather	Sunny
Location (GPS)	Latitude	40.99639 ° N		Arrival time	Departure time
	Longitude	122.46389 ° E		15:40 pm	16:30 pm
Recorded by	Yunqiao Zhou Bo He	Sampled by		Yunqiao Zhou Bo He Taewoo Kim Beomgi Kim	
In situ Measurement of Riverwater or Seawater quality (Freshwater)					
Color/odor					
Width/depth/velocity	Taizi River, upstream of the Daliao River, width ~100m				
HACH 40d data	pH	Temp (°C)	DO (mg/L)	Salinity (mS/cm)	
	8.84	30.4	13.84	0.64	
Corresponding soil information					
Site location	Latitude	° N	Landuse	Agricultural	

Field Log and Sample Checklist

Yellow Sea Ecosystem Study						
Site-ID	YK1	Date	18.7.4		Weather	Sunny
Location (GPS)	Latitude	° 40	' 59	" N 47	Arrival time	Departure time
	Longitude	° 122	' 27	" E 50	15:40	16:30
Recorded by	KBG		Sampled by		KTW, KBG	

In situ Measurement of Porewater quality				
Color/odor				
YSI data	pH	Temp (°C)	DO (mg/L)	Salinity

In situ Measurement of Seawater quality				
Color/odor				
Width/depth/velocity				
YSI data	pH	Temp (°C)	DO (mg/L)	Salinity
	8.84	30.4	13.84	0.28 ‰

Checklists of Collected Samples

Seawater	
POCs	HMs
Ch	Ch

Sediment		
General property	POCs	HMs
V	V	V

Biota			
MPB assemblage	Chl-a	Meiofauna & Microbiome	Macrofauna
V	V	V	X

Graphical Description & Remark

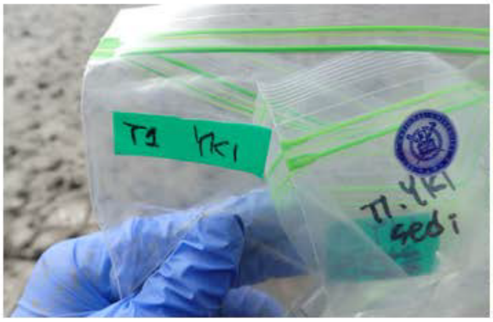
YK1 (40.9980000, 122.4555000)

강 정점으로 옥수수밭 끝 절벽 아래에서 샘플링

밭 곳곳에 농약으로 추정되는 병들 다수 확인

드러난 퇴적물 위에 조그마한 이매패류들이 줄지어 있었으나 대부분 죽어있음->채집만, 멸균x

잘 빠지는 사니질 퇴적물

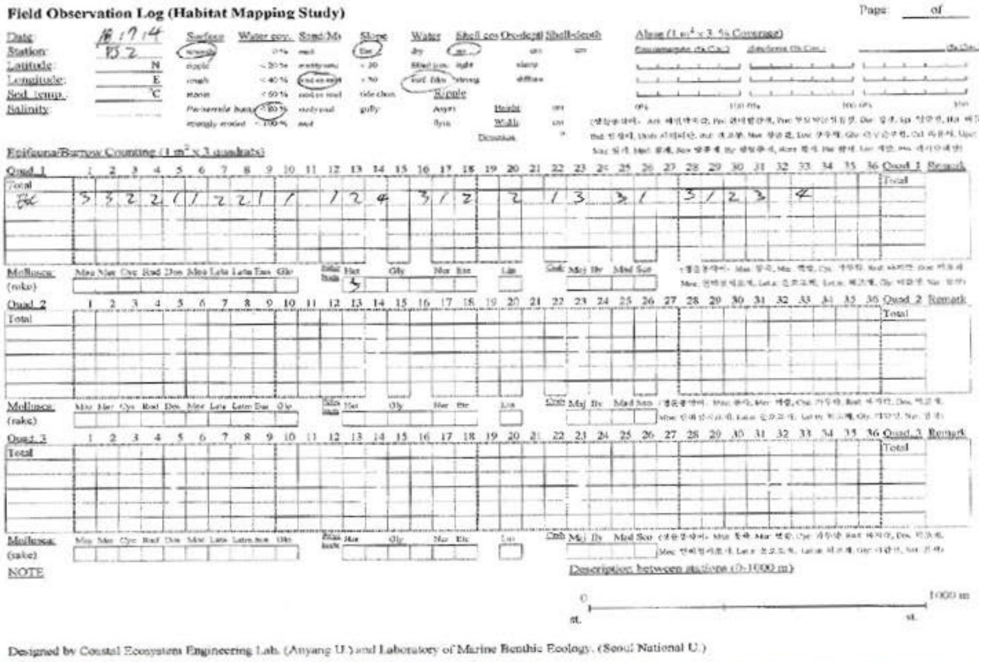








Yellow Sea Ecosystem Study					
Site-ID	PJ2	Date	07/04/2018	Weather	Sunny
Location (GPS)	Latitude	41.02389 ° N		Arrival time	Departure time
	Longitude	122.43389 ° E		17:31 pm	18:40 pm
Recorded by	Yunqiao Zhou Bo He		Sampled by	Yunqiao Zhou Bo He Taewoo Kim Beomgi Kim	
In situ Measurement of Riverwater or Seawater quality (Freshwater)					
Color/odor					
Width/depth/velocity	Hun River, upstream of the Daliao River, width ~100m				
HACH 40d data	pH	Temp (°C)	DO (mg/L)	Salinity (mS/cm)	
	8.11	29.5	4.77	0.81	
Corresponding soil information					
Site location	Latitude	° N	Landuse	Agricultural	


Field Observation Log (Habitat Mapping Study)

Date: 7.14
Station: PJ2
Latitude: N
Longitude: E
Sed. temp.: °C
Salinity:

Epifauna/Burrow Counting (1 m² x 3 quadrats)

Quad. 1 — Total: 3 3 2 2 1 1 2 2 1 1 1 2 4 3 1 2 2 1 3 3 1 3 1 2 3 4

Mollusca (rake)

Quad. 2 — Total

Mollusca (rake)

Quad. 3 — Total

Mollusca (rake)

NOTE

Description between stations (0-1000 m)

Designed by Coastal Ecosystems Engineering Lab. (Anyang U.) and Laboratory of Marine Benthic Ecology. (Seoul National U.)

Field Log and Sample Checklist

Yellow Sea Ecosystem Study							
Site-ID	PJ2	Date	18 7/24		Weather	흐림 Cloudy	
Location (GPS)	Latitude	° 41	′ 01	″N 26	Arrival time	Departure time	
	Longitude	° 122	′ 26	″E 02	14:31	16:40	
Recorded by	KBG		Sampled by		KTW, KBG		
In situ Measurement of Porewater quality							
Color/odor							
YSI data	pH		Temp (°C)		DO (mg/L)	Salinity	
	8.11		29.5		4.77	0.36‰	
In situ Measurement of Seawater quality							
Color/odor							
Width/depth/velocity							
YSI data	pH		Temp (°C)		DO (mg/L)	Salinity	
Checklists of Collected Samples							
Seawater							
POCs				HMs			
Ch				Ch			
Sediment							
General property		POCs			HMs		
✓		✓			✓		
Biota							
MPB assemblage		Chl-a		Meiofauna & Microbiome		Macrofauna	
✓		✓		✓		✓	
Graphical Description & Remark							

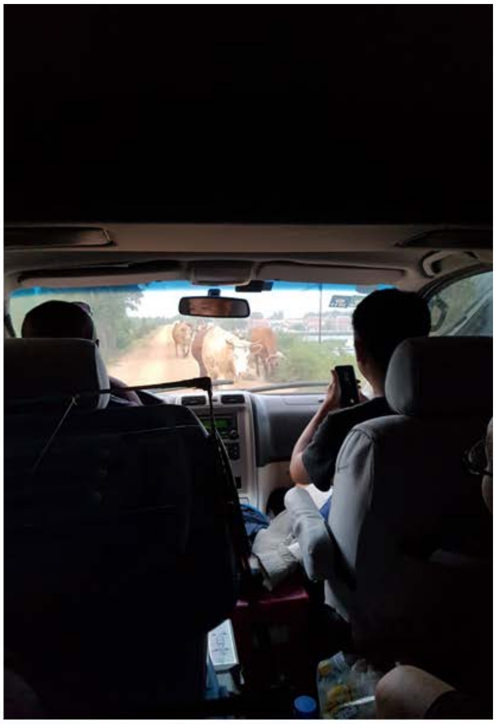
PJ2 (41.0195000, 122.4342000)

랩핑 1, 한코어 3 시편 / 서식굴은 매우 작았으며 대다 Het의 것으로 보임

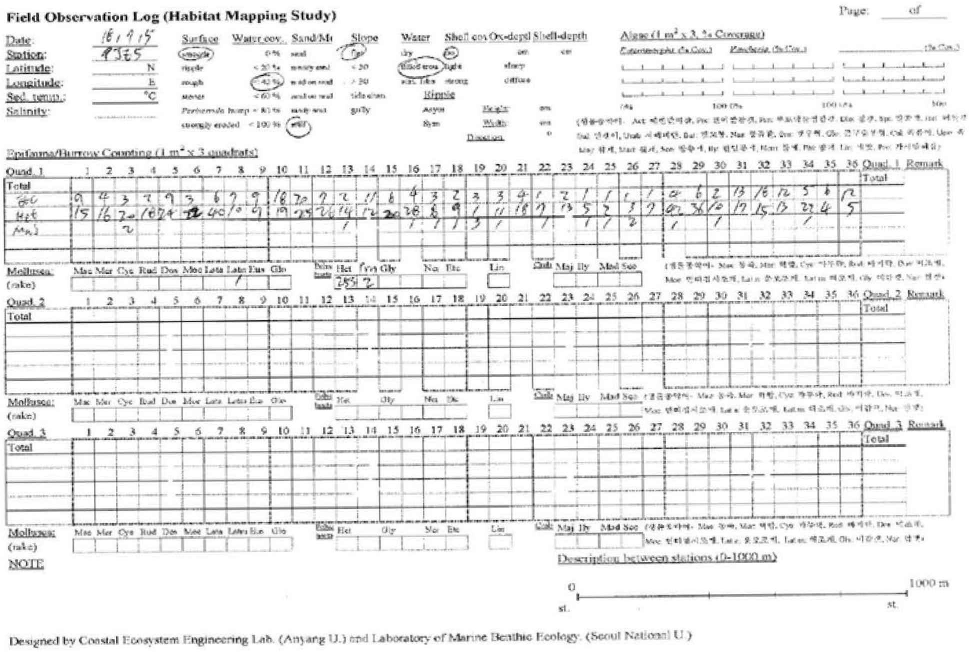
옥수수밭과 갈대 사이를 뚫고 지나가 강 옆에서 샘플링

녹색 조류가 표면을 덮고있었고 표층에 드문드문 복족류 서식

환원층이 표층부터 나타나는 사질 퇴적물로 냄새가 났고 이매패류의 패각 확인



Yellow Sea Ecosystem Study					
Site-ID	JZ5	Date	07/05/2018	Weather	Sunny
Location (GPS)	Latitude	40.90917 ° N		Arrival time	Departure time
	Longitude	121.81917 ° E		10:50 am	12:05 pm
Recorded by	Yunqiao Zhou Bo He	Sampled by		Yunqiao Zhou Bo He Taewoo Kim Beomgi Kim	
In situ Measurement of Riverwater or Seawater quality (Seawater)					
Color/odor					
Width/depth/velocity	Shuangtaizi River, estuary				
HACH 40d data	pH	Temp (°C)	DO (mg/L)	Salinity (mS/cm)	
	7.96	29.0	7.41	59.5	
Corresponding soil information					
Site location	Latitude	° N	Landuse	Municipal	


Field Observation Log (Habitat Mapping Study)

Page: of

Date: 18.7.5

Station: 석JZ5

Latitude: N

Longitude: E

Sed. temp.: °C

Salinity:

Surface Water cov. Sand/Mud Slope Water Shell cov Ox-depth Shell-depth

Algae (1 m² x 3, % Coverage)

Epifauna/Burrow Counting (1 m² x 3 quadrats)

Quad. 1 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 Quad. 1 Total Remark

Mollusca: (rake) Mac Mer Cyc Rud Dos Moc Lata Latm Eus Glo Het Gly Nas Ete Lin Crab Maj Ily Mad Sco

Quad. 2 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 Quad. 2 Total Remark

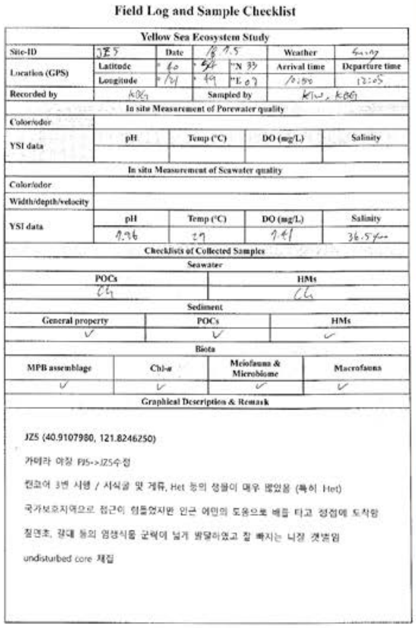
Quad. 3 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 Quad. 3 Total Remark

NOTE

Description between stations (0-1000 m)

0 st. 1000 m st.

Designed by Coastal Ecosystem Engineering Lab. (Anyang U.) and Laboratory of Marine Benthic Ecology. (Seoul National U.)



Field Log and Sample Checklist

Yellow Sea Ecosystem Study						
Site-ID	JZ5	Date	18.7.5		Weather	Sunny
Location (GPS)	Latitude	° 40	' 54	"N 33	Arrival time	Departure time
	Longitude	° 121	' 49	"E 07	10:50	12:05
Recorded by	KBG		Sampled by		KTW, KBG	

In situ Measurement of Porewater quality				
Color/odor				
YSI data	pH	Temp (°C)	DO (mg/L)	Salinity

In situ Measurement of Seawater quality				
Color/odor				
Width/depth/velocity				
YSI data	pH	Temp (°C)	DO (mg/L)	Salinity
	7.96	27	7.41	36.5‰

Checklists of Collected Samples

Seawater	
POCs	HMs
Ch	Ch

Sediment		
General property	POCs	HMs
✓	✓	✓

Biota			
MPB assemblage	Chl-a	Meiofauna & Microbiome	Macrofauna
✓	✓	✓	✓

Graphical Description & Remark

JZ5 (40.9107980, 121.8246250)

카메라 이장 PJ5->JZ5수정

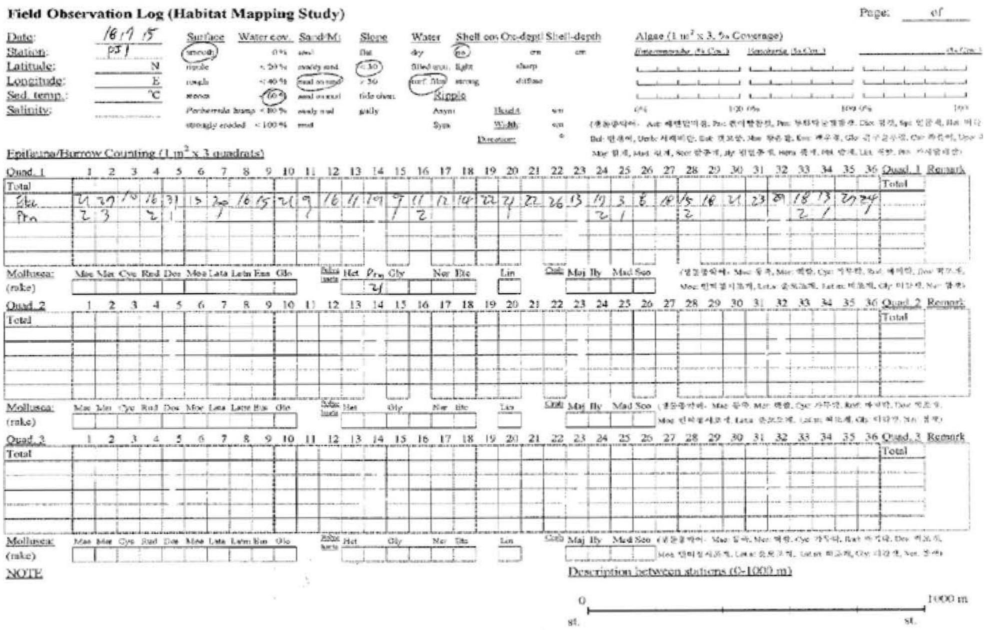
핀코어 3번 시행 / 서식굴 및 게류, Het 등의 생물이 매우 많았음 (특히 Het)

국가보호지역으로 접근이 힘들었지만 인근 어민의 도움으로 배를 타고 정점에 도착함

칠면초, 갈대 등의 염생식물 군락이 넓게 발달하였고 잘 빠지는 니질 갯벌임

undisturbed core 채집

Yellow Sea Ecosystem Study					
Site-ID	PJ1	Date	07/05/2018	Weather	Sunny
Location (GPS)	Latitude	40.88222 ° N		Arrival time	Departure time
	Longitude	121.57139 ° E		14:30 pm	15:20 pm
Recorded by	Yunqiao Zhou Bo He	Sampled by		Yunqiao Zhou Bo He Taewoo Kim Beomgi Kim	
In situ Measurement of Riverwater or Seawater quality (Freshwater)					
Color/odor					
Width/depth/velocity	Daling River, estuary, width ~30m				
HACH 40d data	pH	Temp (°C)	DO (mg/L)	Salinity (mS/cm)	
	8.54	31.8	10.27	1.13	
Corresponding soil information					
Site location	Latitude	° N	Landuse	Agricultural	


Field Observation Log (Habitat Mapping Study)

Date: 18/7/15
Station: PJ1
Latitude:
Longitude:
Sed. temp.:
Salinity:

Epifauna/Burrow Counting (1 m² x 3 quadrats)

Quad. 1 | Quad. 2 | Quad. 3

Mollusca: (rake)

NOTE

Description between stations (0-1000 m)

Field Log and Sample Checklist

Yellow Sea Ecosystem Study						
Site-ID	PJ1	Date	18.7.5		Weather	Sunny
Location (GPS)	Latitude	° 40	′ 52	″N 38	Arrival time	Departure time
	Longitude	° 121	′ 34	″E 17	10:30	15:20
Recorded by	KBG		Sampled by		KMJ, KBG	

In situ Measurement of Porewater quality				
Color/odor				
YSI data	pH	Temp (°C)	DO (mg/L)	Salinity

In situ Measurement of Seawater quality				
Color/odor				
Width/depth/velocity				
YSI data	pH	Temp (°C)	DO (mg/L)	Salinity
	8.44	31.8	10.27	0.89 ‰

Checklists of Collected Samples	
Seawater	
POCs	HMs
Ch	Ch

Sediment		
General property	POCs	HMs
✓	✓	✓

Biota			
MPB assemblage	Chl-a	Meiofauna & Microbiome	Macrofauna
✓	✓	✓	✓

Graphical Description & Remark

PJ1 (40.8775000, 121.5813000)

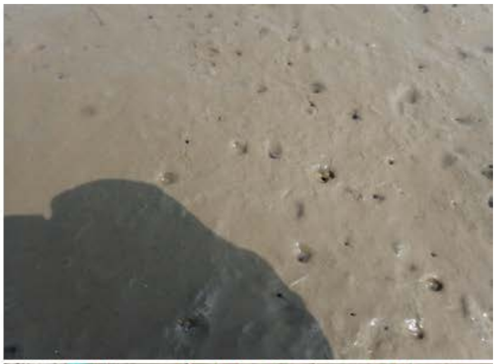
캔코어 3번 시행 / 작은 콩게류의 Pm이 우점, 개체 크기는 작은 유생부터 성체까지 다양

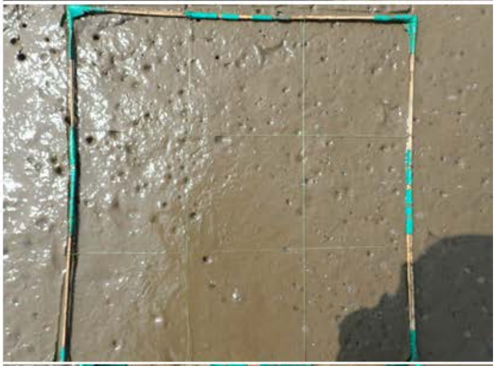
수력발전기기와 인접한 강 하구 정점

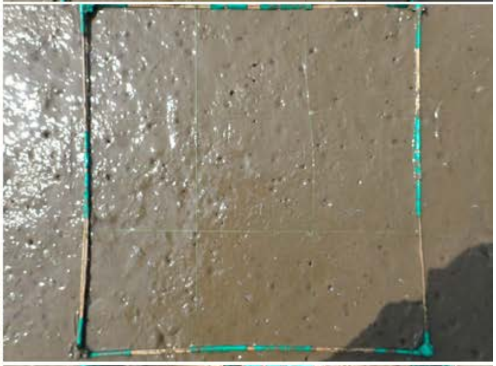
환원층이 깊었고 준설이 흔적이 많았음

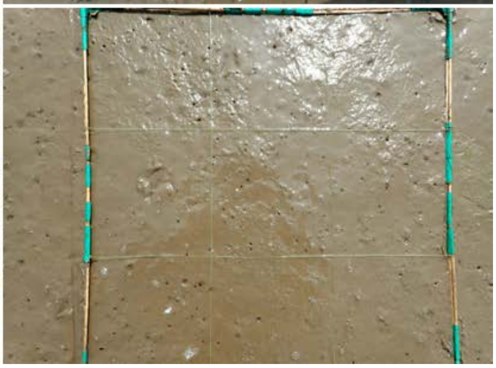
퇴적물 상부는 니질에 함수율도 높았지만 그 밑은 사질로 이루어짐

칠면초 등의 염생식물 관찰됨

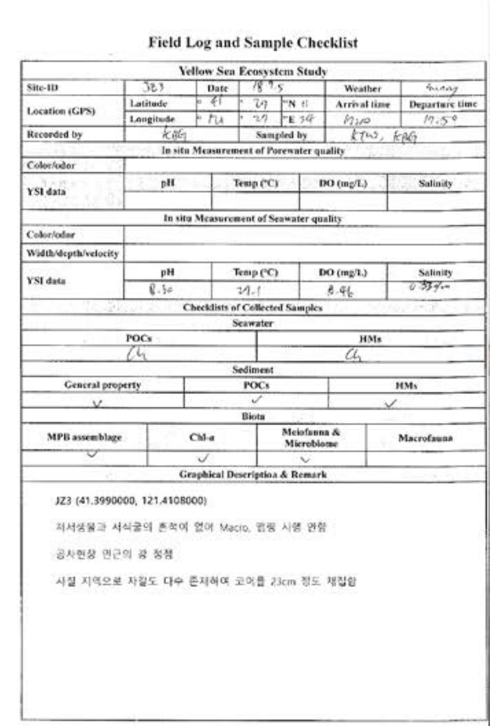








Yellow Sea Ecosystem Study					
Site-ID	JZ3	Date	07/05/2018	Weather	Sunny
Location (GPS)	Latitude	41.45306 ° N		Arrival time	Departure time
	Longitude	121.45944 ° E		17:10 pm	17:50 pm
Recorded by	Yunqiao Zhou Bo He	Sampled by		Yunqiao Zhou Bo He Taewoo Kim Beomgi Kim	
In situ Measurement of Riverwater or Seawater quality (Freshwater)					
Color/odor					
Width/depth/velocity	Daling River, upstream, width ~40m				
HACH 40d data	pH	Temp (°C)	DO (mg/L)	Salinity (mS/cm)	
	8.30	27.1	8.46	0.71	
Corresponding soil information					
Site location	Latitude	° N	Landuse	Agricultural	



Field Log and Sample Checklist

Yellow Sea Ecosystem Study						
Site-ID	JZ3	Date	18.7.5		Weather	Sunny
Location (GPS)	Latitude	° 41	' 27	"N 11	Arrival time	Departure time
	Longitude	° 121	' 27	"E 34	17:10	17:50
Recorded by	KBG		Sampled by		KTW, KBG	
In situ Measurement of Porewater quality						
Color/odor						
YSI data	pH	Temp (°C)	DO (mg/L)	Salinity		
In situ Measurement of Seawater quality						
Color/odor						
Width/depth/velocity						
YSI data	pH	Temp (°C)	DO (mg/L)	Salinity		
	8.30	27.1	8.46	0.33‰		
Checklists of Collected Samples						
Seawater						
POCs			HMs			
Ch			Ch			
Sediment						
General property		POCs		HMs		
✓		✓		✓		
Biota						
MPB assemblage	Chl-a	Meiofauna & Microbiome	Macrofauna			
✓	✓	✓				
Graphical Description & Remark						

JZ3 (41.3990000, 121.4108000)

저서생물과 서식굴의 흔적이 없어 Macro. 컴핑 시행 안함

공사현장 인근의 강 정점

사질 지역으로 자갈도 다수 존재하여 코어를 23cm 정도 채집함


JZ-3
JZ-3
JZ-3
JZ-3

Yellow Sea Ecosystem Study					
Site-ID	JZ4	Date	07/05/2018	Weather	Sunny
Location (GPS)	Latitude	41.17528 ° N		Arrival time	Departure time
	Longitude	121.37639 ° E		19:15 pm	19:35 pm
Recorded by	Yunqiao Zhou Bo He	Sampled by		Yunqiao Zhou Bo He Taewoo Kim Beomgi Kim	
In situ Measurement of Riverwater or Seawater quality (Freshwater)					
Color/odor					
Width/depth/velocity	Daling River, upstream, width ~500m				
HACH 40d data	pH	Temp (°C)	DO (mg/L)	Salinity (mS/cm)	
	8.25	28.1	9.36	0.76	
Corresponding soil information					
Site location	Latitude	° N	Landuse	Municipal	

Field Log and Sample Checklist

Yellow Sea Ecosystem Study					
Site-ID	JZ4	Date	18.7.5	Weather	Cloudy
Location (GPS)	Latitude	° 41 ' 10 " N 51		Arrival time	Departure time
	Longitude	° 121 ' 22 " E 35		19:15	19:35
Recorded by	ZBG	Sampled by		WTW, KBG	
In situ Measurement of Porewater quality					
Color/odor					
YSI data	pH	Temp (°C)	DO (mg/L)	Salinity	
In situ Measurement of Seawater quality					
Color/odor					
Width/depth/velocity					
YSI data	pH	Temp (°C)	DO (mg/L)	Salinity	
	8.25	28.1	9.36	0.35 ‰	
Checklists of Collected Samples					
Seawater					
POCs			HMs		
Ch			Ch		
Sediment					
General property		POCs		HMs	
✓		✓		✓	
Biota					
MPB assemblage	Chl-a	Meiofauna & Microbiome		Macrofauna	
✓	✓	✓			
Graphical Description & Remark					

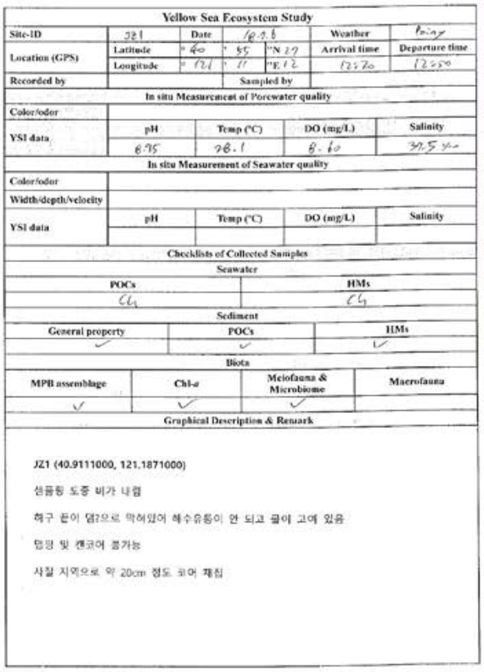
JZ4 (41.1763894, 121.3792166)

저서생물과 서식굴의 흔적이 없어 Macro. 샘플 시행 안함

강 본류로 다리 밑에서 샘플링

사질 지역이며 자갈 및 돌멩이 등으로 인해 코어 채집 불가능

Yellow Sea Ecosystem Study					
Site-ID	JZ1	Date	07/06/2018	Weather	Rainy
Location (GPS)	Latitude	40.92417 ° N		Arrival time	Departure time
	Longitude	121.18667 ° E		12:20 pm	12:50 pm
Recorded by	Yunqiao Zhou Bo He		Sampled by	Yunqiao Zhou Bo He Taewoo Kim Beomgi Kim	
In situ Measurement of Riverwater or Seawater quality (Seawter)					
Color/odor					
Width/depth/velocity	Xiaoling River, estuary, width~500m				
HACH 40d data	pH	Temp (°C)	DO (mg/L)	Salinity (mS/cm)	
	8.95	28.1	8.60	60.0	
Corresponding soil information					
Site location	Latitude	° N	Landuse	Agricultural	



Field Log and Sample Checklist

Yellow Sea Ecosystem Study						
Site-ID	JZ1	Date	18.7.6		Weather	Rainy
Location (GPS)	Latitude	° 40	' 55	" N 27	Arrival time	Departure time
	Longitude	° 121	' 11	" E 12	12:20	12:50
Recorded by			Sampled by			
In situ Measurement of Porewater quality						
Color/odor						
YSI data	pH	Temp (°C)	DO (mg/L)	Salinity		
	8.95	28.1	8.60	37.5 ‰		
In situ Measurement of Seawater quality						
Color/odor						
Width/depth/velocity						
YSI data	pH	Temp (°C)	DO (mg/L)	Salinity		

Checklists of Collected Samples			
Seawater			
POCs		HMs	
Ch		Ch	
Sediment			
General property	POCs	HMs	
✓	✓	✓	
Biota			
MPB assemblage	Chl-a	Meiofauna & Microbiome	Macrofauna
✓	✓	✓	
Graphical Description & Remark			

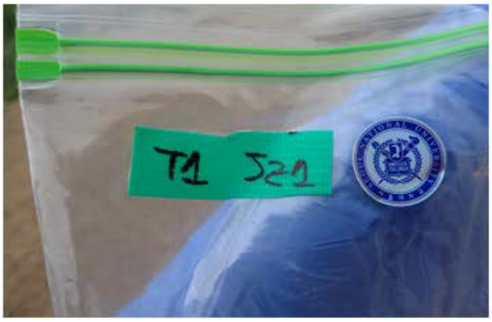
JZ1 (40.9111000, 121.1871000)

샘플링 도중 비가 내림

해구 끝이 댐?으로 막혀있어 해수유통이 안 되고 물이 고여 있음

펌핑 및 캔코어 불가능

사질 지역으로 약 20cm 정도 코어 채집

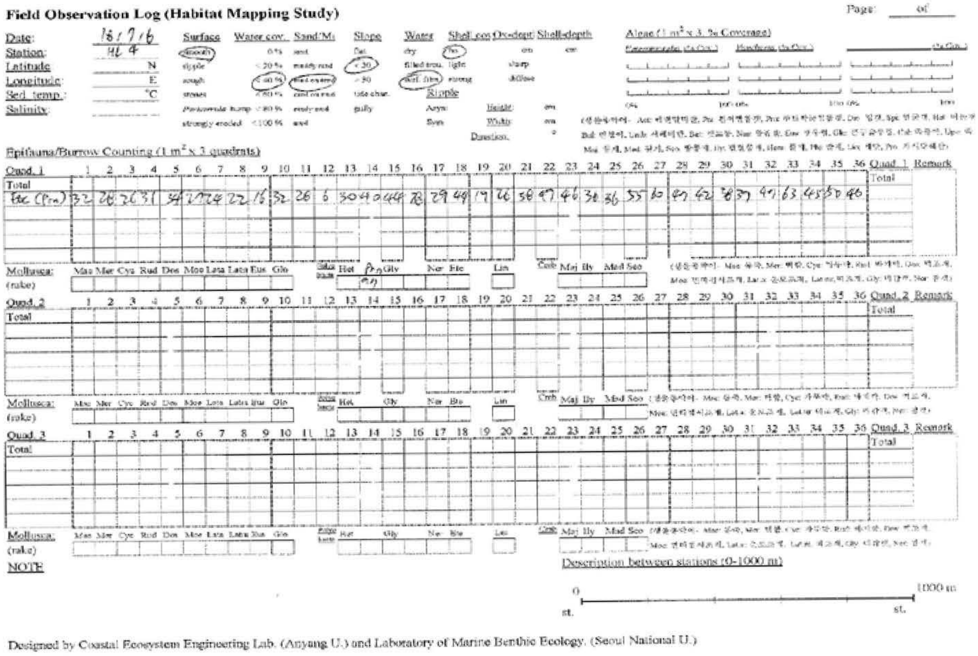








Yellow Sea Ecosystem Study					
Site-ID	HL4	Date	07/06/2018	Weather	Sunny
Location (GPS)	Latitude	40.74694 ° N		Arrival time	Departure time
	Longitude	120.93472 ° E		14:45 pm	15:55 pm
Recorded by	Yunqiao Zhou Bo He	Sampled by		Yunqiao Zhou Bo He Taewoo Kim Beomgi Kim	
In situ Measurement of Riverwater or Seawater quality (Mixed water)					
Color/odor	Bad smelling, many small dead fish				
Width/depth/velocity	Lianshan River (Wuli River and Cishan River also join nearby)				
HACH 40d data	pH	Temp (°C)	DO (mg/L)	Salinity (mS/cm)	
	7.14	30.6	11.12	17.27	
Corresponding soil information					
Site location	Latitude	° N	Landuse	Industrial	



Field Observation Log (Habitat Mapping Study)

Date: 18/7/6
Station: HL 4

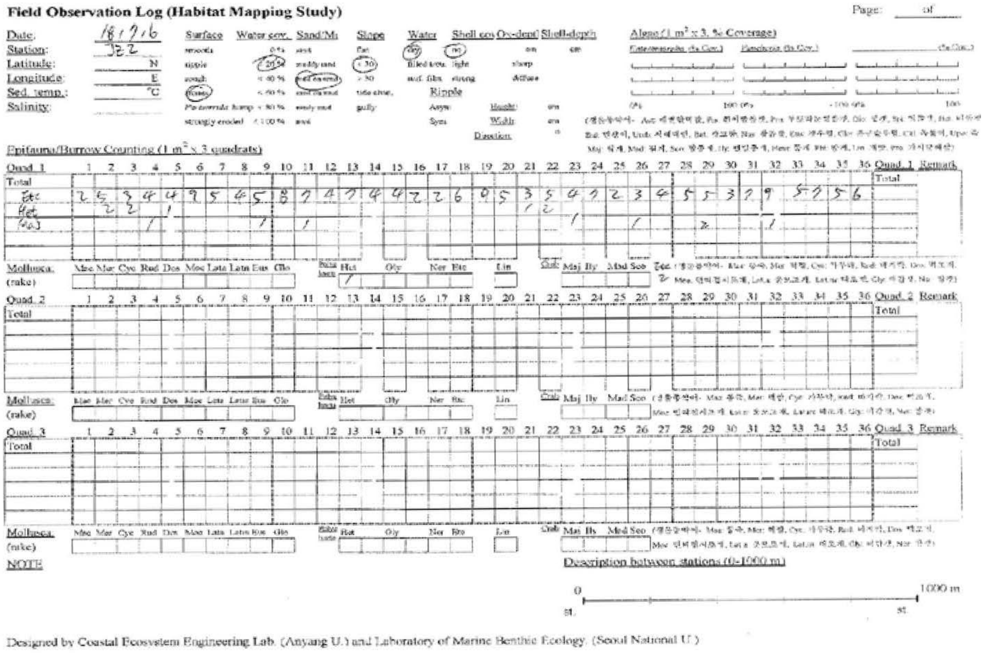
Epifauna/Burrow Counting (1 m² x 3 quadrats)

Quad. 1: Bc (Pra) 32 28 26 31 34 27 24 22 16 32 26 6 30 40 44 28 29 49 19 26 56 47 46 30 36 35 60 47 42 38 37 47 63 45 50 46

Designed by Coastal Ecosystem Engineering Lab. (Anyang U.) and Laboratory of Marine Benthic Ecology. (Seoul National U.)


HL-4

Yellow Sea Ecosystem Study					
Site-ID	YK3	Date	07/04/2018	Weather	Sunny
Location (GPS)	Latitude	40.42500 ° N		Arrival time	Departure time
	Longitude	122.28444 ° E		8:25 am	9:26 am
Recorded by	Yunqiao Zhou Bo He	Sampled by		Yunqiao Zhou Bo He Taewoo Kim Beomgi Kim	
In situ Measurement of Riverwater or Seawater quality (Seawater)					
Color/odor					
Width/depth/velocity	Daqing River, width ~10m				
HACH 40d data	pH	Temp (°C)		DO (mg/L)	Salinity (mS/cm)
	7.82	27.9		4.81	61.0
Corresponding soil information					
Site location	Latitude	° N		Landuse	Agricultural


Field Observation Log (Habitat Mapping Study)

Page: of

Date: 18/7/6
Station: J22
Latitude: N
Longitude: E
Sed. temp.: °C
Salinity:

Surface / Water cov. / Sand/Mud / Slope / Water / Shell cov. / Ox-dept / Shell-depth

Algae (1 m² x 3, % Coverage)

Ripple

Epifauna/Burrow Counting (1 m² x 3 quadrats)

Quad. 1	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	Quad. 1 Total	Remark
Etc	2	5	3	4	4	9	5	4	5	8	7	4	7	4	4	2	2	6	9	5	3	5	4	7	2	3	4	5	5	3	7	9		5	7	5	6	
Het		2	2		1																1	2																
Maj				1					1		1												1			1			2			1						

Mollusca (rake)

Quad. 2

Quad. 3

NOTE

Description between stations (0-1000 m)

Designed by Coastal Ecosystem Engineering Lab. (Anyang U.) and Laboratory of Marine Benthic Ecology. (Seoul National U.)

Field Log and Sample Checklist

Yellow Sea Ecosystem Study						
Site-ID	JZ2	Date	18.9.6		Weather	Sunny
Location (GPS)	Latitude	° 40	' 55	" N 05	Arrival time	Departure time
	Longitude	° 121	' 14	" E 37	9:20	10:20
Recorded by	KBG		Sampled by		KTW, KBG	

In situ Measurement of Porewater quality				
Color/odor				
YSI data	pH	Temp (°C)	DO (mg/L)	Salinity

In situ Measurement of Seawater quality				
Color/odor				
Width/depth/velocity				
YSI data	pH	Temp (°C)	DO (mg/L)	Salinity
	7.86	27.6	7.57	34.2‰

Checklists of Collected Samples

Seawater

POCs	HMs
Ch	Ch

Sediment

General property	POCs	HMs
✓	✓	✓

Biota

MPB assemblage	Chl-a	Meiofauna & Microbiome	Macrofauna
✓	✓	✓	✓

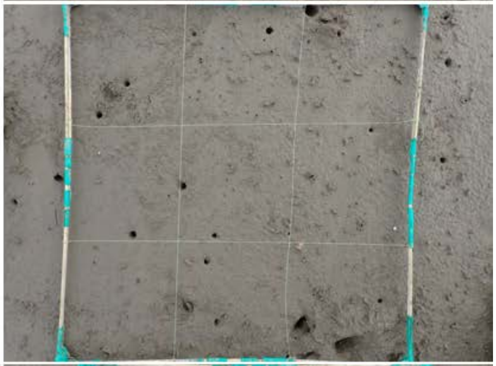
Graphical Description & Remark

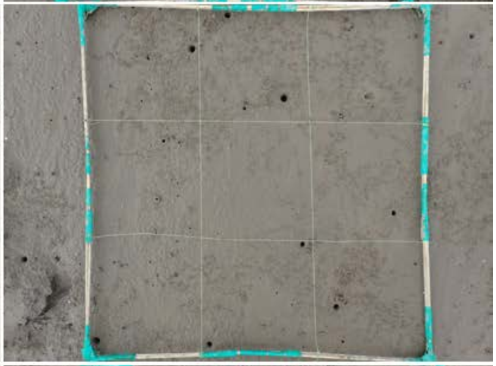
JZ2 (40.9139000, 121.2524000)

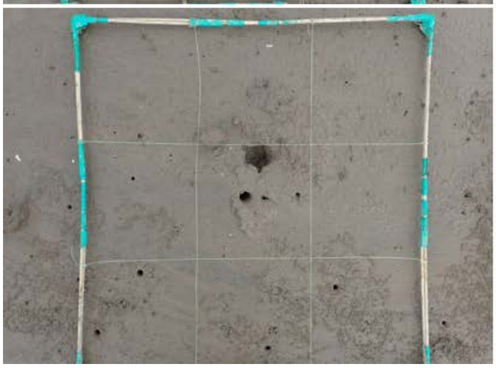
엽록3, 큰코어1 - 사질에 자갈이 많아 1번만 시행

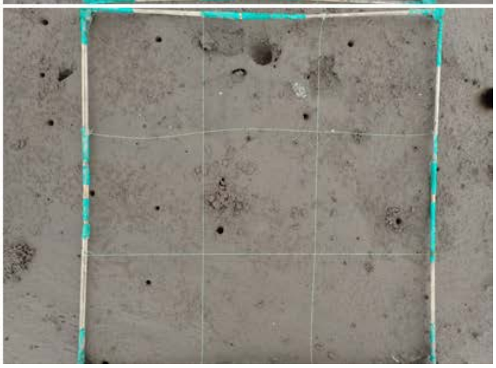
하구 정점으로 서식굴이 많았고 게류, Pm, Het이 관찰됨

준설의 흔적이 많이 보였음

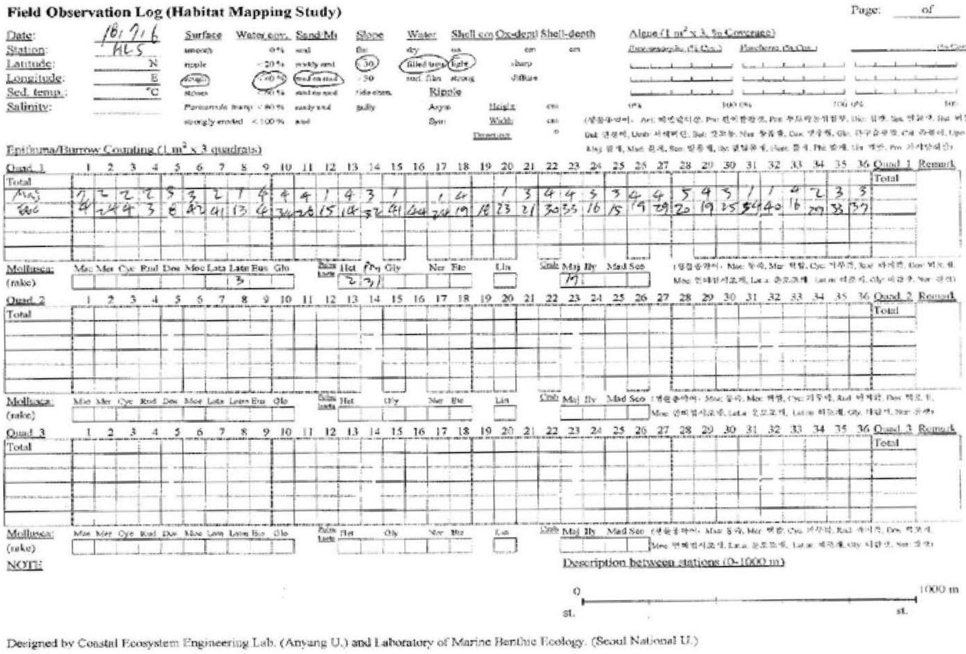








Yellow Sea Ecosystem Study					
Site-ID	HL5	Date	07/06/2018	Weather	Sunny
Location (GPS)	Latitude	40.59194 ° N		Arrival time	Departure time
	Longitude	120.76944 ° E		17:05 pm	18:10 pm
Recorded by	Yunqiao Zhou Bo He	Sampled by		Yunqiao Zhou Bo He Taewoo Kim Beomgi Kim	
In situ Measurement of Riverwater or Seawater quality (Mixed water)					
Color/odor					
Width/depth/velocity	Xingcheng River, estuary, width ~500m				
HACH 40d data	pH	Temp (°C)	DO (mg/L)	Salinity (mS/cm)	
	8.94	28.3	7.44	13.84	
Corresponding soil information					
Site location	Latitude	° N	Landuse	Municipal	


Field Observation Log (Habitat Mapping Study)

Page: of

Date: 18. 7. 6
Station: HL5
Latitude: N
Longitude: E
Sed. temp.: °C
Salinity:

Epifauna/Burrow Counting (1 m² x 3 quadrats)

Quad. 1 ... Quad. 1 Total Remark

Mollusca: (rake)

Quad. 2 ... Quad. 2 Total Remark

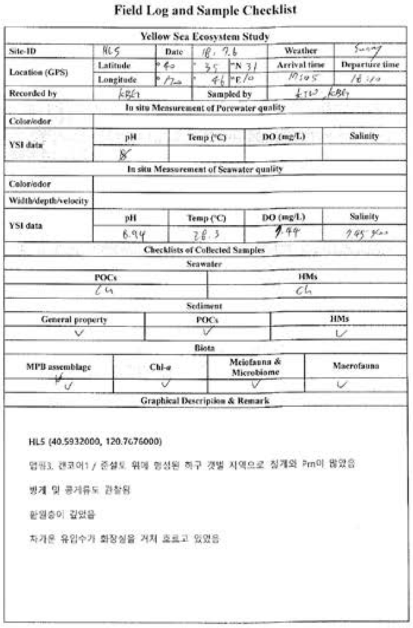
Quad. 3 ... Quad. 3 Total Remark

NOTE:

Description between stations (0-1000 m)

0 st. 1000 m st.

Designed by Coastal Ecosystem Engineering Lab. (Anyang U.) and Laboratory of Marine Benthic Ecology. (Seoul National U.)



Field Log and Sample Checklist

Yellow Sea Ecosystem Study							
Site-ID	HL5	Date	18. 7.6			Weather	Sunny
Location (GPS)	Latitude	° 40	' 35	"N 31		Arrival time	[illegible]
	Longitude	° 120	' 46	"E 10		Departure time	[illegible]
Recorded by	KBG		Sampled by	[illegible], KBG			

In situ Measurement of Porewater quality				
Color/odor				
YSI data	pH	Temp (°C)	DO (mg/L)	Salinity
	8			

In situ Measurement of Seawater quality				
Color/odor				
Width/depth/velocity				
YSI data	pH	Temp (°C)	DO (mg/L)	Salinity
	6.94	28.3	9.44	9.45 [illegible]

Checklists of Collected Samples

Seawater	
POCs	HMs
Ch	Ch

Sediment		
General property	POCs	HMs
✓	✓	✓

Biota			
MPB assemblage	Chl-a	Meiofauna & Microbiome	Macrofauna
✓	✓	✓	✓

Graphical Description & Remark

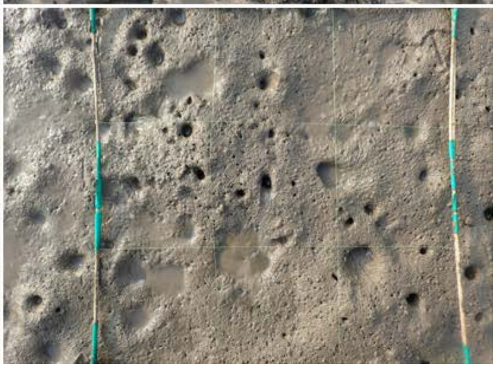
HL5 (40.5932000, 120.7676000)

염원3, 랜코어1 / 준설토 위에 형성된 하구 갯벌 지역으로 칠게와 Prn이 많았음

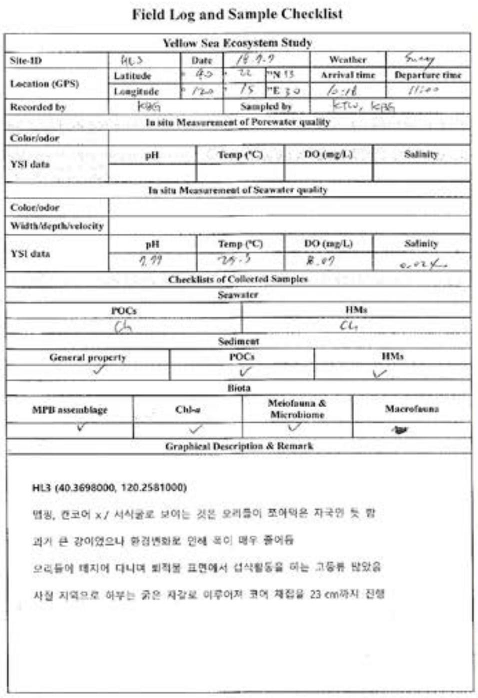
방게 및 풀게류도 관찰됨

환원층이 깊었음

차가운 유입수가 화장실을 거쳐 흐르고 있었음



Yellow Sea Ecosystem Study					
Site-ID	HL3	Date	07/07/2018	Weather	Cloudy
Location (GPS)	Latitude	40.37028 ° N		Arrival time	Departure time
	Longitude	120.25833 ° E		10:18 am	11:00 am
Recorded by	Yunqiao Zhou Bo He	Sampled by		Yunqiao Zhou Bo He Taewoo Kim Beomgi Kim	
In situ Measurement of Riverwater or Seawater quality (Freshwater)					
Color/odor					
Width/depth/velocity	Wangbao River, upstream of the Liugu River, width ~10m				
HACH 40d data	pH	Temp (°C)	DO (mg/L)	Salinity (mS/cm)	
	7.77	25.3	8.07	0.43	
Corresponding soil information					
Site location	Latitude	° N	Landuse	Agricultural	



Field Log and Sample Checklist

Yellow Sea Ecosystem Study						
Site-ID	HL3	Date	18.7.7		Weather	Sunny
Location (GPS)	Latitude	° 40	' 22	"N 13	Arrival time	Departure time
	Longitude	° 120	' 15	"E 30	10:18	11:00
Recorded by	KBG		Sampled by		KTW, KBG	
In situ Measurement of Porewater quality						
Color/odor						
YSI data	pH	Temp (°C)	DO (mg/L)	Salinity		
In situ Measurement of Seawater quality						
Color/odor						
Width/depth/velocity						
YSI data	pH	Temp (°C)	DO (mg/L)	Salinity		
	7.77	25.3	8.07	0.02 ‰		

Checklists of Collected Samples			
Seawater			
POCs		HMs	
Ch		CL	
Sediment			
General property	POCs	HMs	
✓	✓	✓	
Biota			
MPB assemblage	Chl-a	Meiofauna & Microbiome	Macrofauna
✓	✓	✓	
Graphical Description & Remark			

HL3 (40.3698000, 120.2581000)

펄질, 캔코어 x / 서식굴로 보이는 것은 오리들이 쪼아먹은 자국인 듯 함

과거 큰 강이었으나 환경변화로 인해 폭이 매우 줄어듬

오리들이 떼지어 다니며 퇴적물 표면에서 섭식활동을 하는 고등류 많았음

사질 지역으로 하부는 굵은 자갈로 이루어져 코어 채집을 23 cm까지 진행

Yellow Sea Ecosystem Study					
Site-ID	HL6	Date	07/07/2018	Weather	Cloudy
Location (GPS)	Latitude	40.41917 ° N		Arrival time	Departure time
	Longitude	120.29556 ° E		11:35 am	12:20 pm
Recorded by	Yunqiao Zhou Bo He	Sampled by		Yunqiao Zhou Bo He Taewoo Kim Beomgi Kim	
In situ Measurement of Riverwater or Seawater quality (Freshwater)					
Color/odor					
Width/depth/velocity	Liugu River, upstream, width ~15m				
HACH 40d data	pH	Temp (°C)	DO (mg/L)	Salinity (mS/cm)	
	7.20	26.7	2.99	0.54	
Corresponding soil information					
Site location	Latitude	° N	Landuse	Agricultural	

Field Log and Sample Checklist

Yellow Sea Ecosystem Study						
Site-ID	HL6	Date	18.7.7		Weather	Grey
Location (GPS)	Latitude	° 40	' 25	" N 09	Arrival time	Departure time
	Longitude	° 120	' 17	" E 44	11:35	12:20
Recorded by	KBG		Sampled by		KTW, KBG	
In situ Measurement of Porewater quality						
Color/odor						
YSI data	pH	Temp (°C)	DO (mg/L)	Salinity		
In situ Measurement of Seawater quality						
Color/odor						
Width/depth/velocity						
YSI data	pH	Temp (°C)	DO (mg/L)	Salinity		
	7.20	26.7	2.99	0.35‰		

Checklists of Collected Samples	
Seawater	
POCs	HMs
Ch	Ch

Sediment		
General property	POCs	HMs
✓	✓	✓

Biota			
MPB assemblage	Chl-a	Meiofauna & Microbiome	Macrofauna
✓	✓	✓	

Graphical Description & Remark

HL6 (40.4180950, 120.2992270)

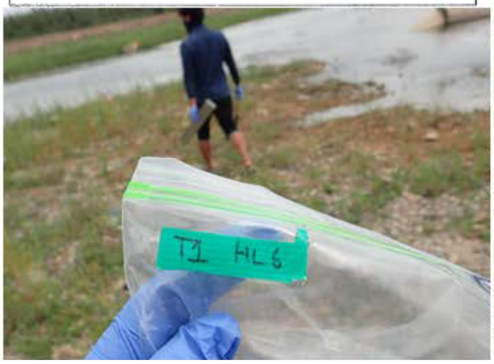
오염된 강 정점으로 표층 퇴적물 바로 하부부터 환원층이 나타났고 주변에서 썩은 냄새가 남

서식굴은 없었고 HL3과 동일한 고둥류 관찰

퇴적물 하부에서 작은 이매패류도 관찰됨

오리들 있었음

사질 지역에 자갈이 매우 많아 코어 불가능









Yellow Sea Ecosystem Study						
Site-ID	HL1	Date	07/07/2018		Weather	Cloudy
Location (GPS)	Latitude	40.26972 ° N			Arrival time	Departure time
	Longitude	120.46222 ° E			13:55 pm	15:00 pm
Recorded by	Yunqiao Zhou Bo He		Sampled by		Yunqiao Zhou Bo He Taewoo Kim Beomgi Kim	
In situ Measurement of Riverwater or Seawater quality (Seawater)						
Color/odor						
Width/depth/velocity	Liugu River, estuary, width ~400m					
HACH 40d data	pH		Temp (°C)	DO (mg/L)	Salinity (mS/cm)	
	8.00		26.2	8.73	52.5	
Corresponding soil information						
Site location	Latitude		° N	Landuse	Agricultural	

Field Log and Sample Checklist

Yellow Sea Ecosystem Study						
Site-ID	HL1	Date	18.7.7		Weather	Cloudy
Location (GPS)	Latitude	° 40	′ 16	″N 11	Arrival time	Departure time
	Longitude	° 120	′ 27	″E 44	13:55	15:00
Recorded by	KBG		Sampled by		KTW, KBG	
In situ Measurement of Porewater quality						
Color/odor						
YSI data	pH		Temp (°C)	DO (mg/L)	Salinity	
In situ Measurement of Seawater quality						
Color/odor						
Width/depth/velocity						
YSI data	pH		Temp (°C)	DO (mg/L)	Salinity	
	8.00		26.2	8.73	33.96	

Checklists of Collected Samples			
Seawater			
POCs		HMs	
Ch		Ch	
Sediment			
General property	POCs	HMs	
✓	✓	✓	
Biota			
MPB assemblage	Chl-a	Meiofauna & Microbiome	Macrofauna
✓	✓	✓	
Graphical Description & Remark			

HL1 (40.2650000, 120.4765000)

강 정점으로 조금 떨어진 곳에 풍력발전소 있음

시들어 심해 나질이 포함된 퇴적물을 찾아 채집함

서식굴을 찾기 힘들어 발굴, 캡고어 못함

해부 지질 때문에 코어 20 cm 채집

퇴적물 내부에서 Pm을 발견하였고 작은 게류와 복족류 등도 관찰됨


HL-1
HL-1
HL-1
HL-1
HL-1
HL-1

Yellow Sea Ecosystem Study						
Site-ID	HL2	Date	07/07/2018		Weather	Sunny
Location (GPS)	Latitude	40.17472 ° N			Arrival time	Departure time
	Longitude	120.26139 ° E			15:40 pm	16:35 pm
Recorded by	Yunqiao Zhou Bo He		Sampled by		Yunqiao Zhou Bo He Taewoo Kim Beomgi Kim	
In situ Measurement of Riverwater or Seawater quality (Freshwater)						
Color/odor						
Width/depth/velocity	Gou River, estuary, width~200m; Inside of a sea dike					
HACH 40d data	pH		Temp (°C)	DO (mg/L)		Salinity (mS/cm)
	9.51		28.7	10.80		0.52
Corresponding soil information						
Site location	Latitude	° N		Landuse		Agricultural

Field Log and Sample Checklist

Yellow Sea Ecosystem Study						
Site-ID	HL2	Date	18.7.7		Weather	Sunny
Location (GPS)	Latitude	° 40	' 10	"N 29	Arrival time	Departure time
	Longitude	° 120	' 15	"E 41	15:40	16:35
Recorded by	KBG		Sampled by		[illegible], EBG	
In situ Measurement of Porewater quality						
Color/odor						
YSI data	pH		Temp (°C)	DO (mg/L)		Salinity
In situ Measurement of Seawater quality						
Color/odor						
Width/depth/velocity						
YSI data	pH		Temp (°C)	DO (mg/L)		Salinity
	9.51		28.7	10.80		[illegible]

Checklists of Collected Samples			
Seawater			
POCs		HMs	
Ch		Ch	
Sediment			
General property	POCs	HMs	
✓	✓	✓	
Biota			
MPB assemblage	Chl-a	Meiofauna & Microbiome	Macrofauna
✓	✓	✓	
Graphical Description & Remark			

HL2 (40.1692000, 120.2629000)

바다와 다리로 분리되어 막혀 있는 강 정점

사질 위에 니질 퇴적물이 쌓여 있음

서식굴이 없고 생물도 거의 발견하지 못함

완전한 코어 채집







Yellow Sea Ecosystem Study					
Site-ID	QH7	Date	07/08/2018	Weather	Cloudy
Location (GPS)	Latitude	39.96528 ° N		Arrival time	Departure time
	Longitude	119.76944 ° E		10:30 am	10:59 am
Recorded by	Yunqiao Zhou Bo He		Sampled by	Yunqiao Zhou Bo He Taewoo Kim Beomgi Kim	
In situ Measurement of Riverwater or Seawater quality (Mixed water)					
Color/odor					
Width/depth/velocity	Shi River, estuary, width~400m; Outside of a sea dike				
HACH 40d data	pH	Temp (°C)	DO (mg/L)	Salinity (mS/cm)	
	8.63	23.8	9.18	34.9	
Corresponding soil information					
Site location	Latitude	° N	Landuse	Municipal	

Field Log and Sample Checklist

Yellow Sea Ecosystem Study						
Site-ID	QH7	Date	18.7.8		Weather	[illegible] Cloudy
Location (GPS)	Latitude	° 39	' 57	"N 55	Arrival time	Departure time
	Longitude	° 119	' 46	"E 10	10:30	10:59
Recorded by	KBG		Sampled by		KTW, KBG	
In situ Measurement of Porewater quality						
Color/odor						
YSI data	pH	Temp (°C)	DO (mg/L)	Salinity		
In situ Measurement of Seawater quality						
Color/odor						
Width/depth/velocity						
YSI data	pH	Temp (°C)	DO (mg/L)	Salinity		
	8.63	23.8	9.18	22.5‰		
Checklists of Collected Samples						
Seawater						
POCs	Ch	HMs	Ch			
Sediment						
General property	✓	POCs	✓	HMs	✓	
Biota						
MPB assemblage	✓	Chl-a	✓	Meiofauna & Microbiome	✓	Macrofauna
Graphical Description & Remark						

QH7 (39.9629280, 119.7689360)

비가 많이 온 뒤 조금 그쳤을 때 다리 밑 강에서 샘플링 진행

준설이 진행 중인 오염지역으로 강 끝이 둑으로 막혀 있음

사질과 굵은 자갈이 많은 지역으로 코어 22.5 cm 채집

퇴적물 하부가 매우 환원되어 검은색을 띠고 냄새가 심함

서식굴이 보이지 않아 햄핑 및 캔코어 진행 못함

Yellow Sea Ecosystem Study						
Site-ID	QH6	Date	07/08/2018		Weather	Cloudy
Location (GPS)	Latitude	39.92028 ° N			Arrival time	Departure time
	Longitude	119.56667 ° E			12:50 pm	13:30 pm
Recorded by	Yunqiao Zhou Bo He		Sampled by		Yunqiao Zhou Bo He Taewoo Kim Beomgi Kim	
In situ Measurement of Riverwater or Seawater quality (Freshwater)						
Color/odor						
Width/depth/velocity	Tang River, estuary, width~200m; Inside of a sea dike					
HACH 40d data	pH		Temp (°C)	DO (mg/L)	Salinity (mS/cm)	
	8.47		24.8	6.28	0.81	
Corresponding soil information						
Site location	Latitude		° N	Landuse	Municipal	

Field Log and Sample Checklist

Yellow Sea Ecosystem Study							
Site-ID	QH6	Date	18.7.6			Weather	Cloudy
Location (GPS)	Latitude	° 39	' 55	"N 13		Arrival time	Departure time
	Longitude	° 119	' 34	"E 00		12:50	13:30
Recorded by	KBG			Sampled by		KTW, KBG	
In situ Measurement of Porewater quality							
Color/odor							
YSI data	pH		Temp (°C)		DO (mg/L)		Salinity
In situ Measurement of Seawater quality							
Color/odor							
Width/depth/velocity							
YSI data	pH		Temp (°C)		DO (mg/L)		Salinity
	8.47		24.8		6.28		0.80 ‰

Checklists of Collected Samples			
Seawater			
POCs		HMs	
Ch		Ch	
Sediment			
General property	POCs	HMs	
✓	✓	✓	
Biota			
MPB assemblage	Chl-a	Meiofauna & Microbiome	Macrofauna
✓	✓	✓	
Graphical Description & Remark			

QH6 (39.9210000, 119.5668000)

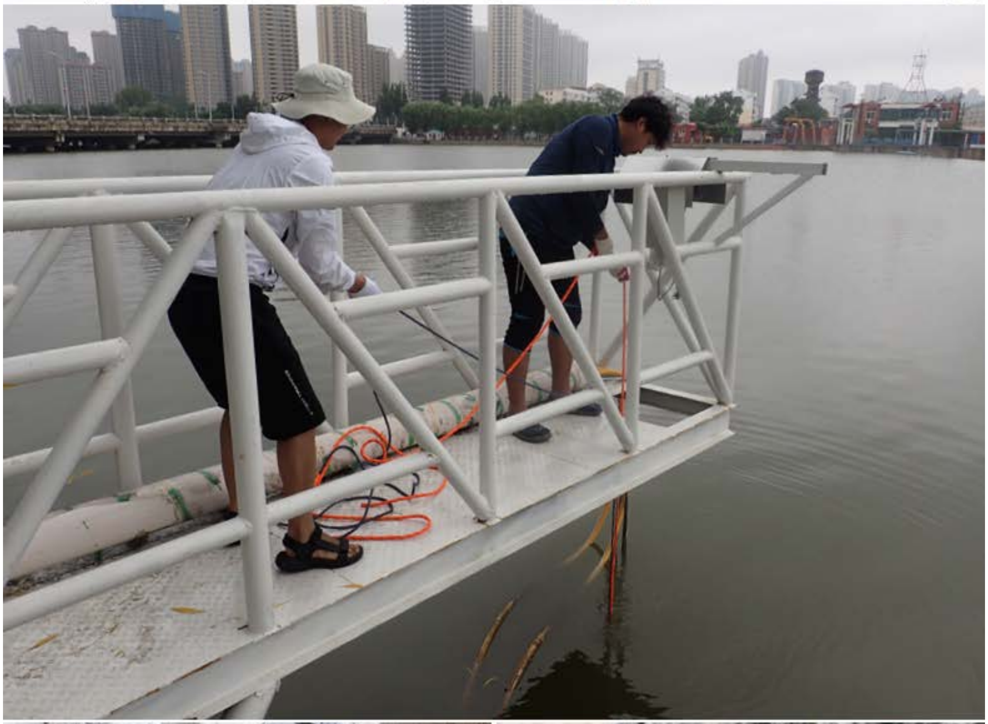
강 끝이 둑으로 막혀 있지만 강우로 인한 것인지 바다 쪽으로 넘쳐 흐르고 있었음

드러난 퇴적 지형이 보이지 않아 핸드그랩 샘플링 진행 - 코어 및 맵핑, 펜코어 진행 못함

매우 오염된 퇴적물로 보이며 검은색을 띠고 냄새가 심함

근처에 낚시를 하는 사람들 있었음





Yellow Sea Ecosystem Study						
Site-ID	QH5	Date	07/08/2018		Weather	Cloudy
Location (GPS)	Latitude	39.98000 ° N			Arrival time	Departure time
	Longitude	119.21083 ° E			15:40 pm	16:10 pm
Recorded by	Yunqiao Zhou Bo He		Sampled by		Yunqiao Zhou Bo He Taewoo Kim Beomgi Kim	
In situ Measurement of Riverwater or Seawater quality (Freshwater)						
Color/odor						
Width/depth/velocity	Inside the Yanghe reservoir					
HACH 40d data	pH	Temp (°C)		DO (mg/L)	Salinity (mS/cm)	
	8.81	25.8		9.88	0.40	
Corresponding soil information						
Site location	Latitude	° N		Landuse	Unused land	

Field Log and Sample Checklist

Yellow Sea Ecosystem Study						
Site-ID	QH 5	Date	18.7.8		Weather	Cloudy
Location (GPS)	Latitude	° 39	' 58	"N 48	Arrival time	Departure time
	Longitude	° 119	' 12	"E 39	15:40	16:10
Recorded by	KBG		Sampled by		KTW, KBG	
In situ Measurement of Porewater quality						
Color/odor						
YSI data	pH	Temp (°C)		DO (mg/L)	Salinity	
In situ Measurement of Seawater quality						
Color/odor						
Width/depth/velocity						
YSI data	pH	Temp (°C)		DO (mg/L)	Salinity	
	8.81	25.8		9.88	0.19 ‰	

Checklists of Collected Samples	
Seawater	
POCs	HMs
Ch	Ch

Sediment		
General property	POCs	HMs
✓	✓	✓

Biota			
MPB assemblage	Chl-a	Meiofauna & Microbiome	Macrofauna
✓	✓	✓	

Graphical Description & Remarks

QH5 (39.9801660, 119.2126080)

2008년 정점과 동일하나 접근이 어려워 조금 옆으로 들어가서 진행

하천들에 유입되는 저수지 정점

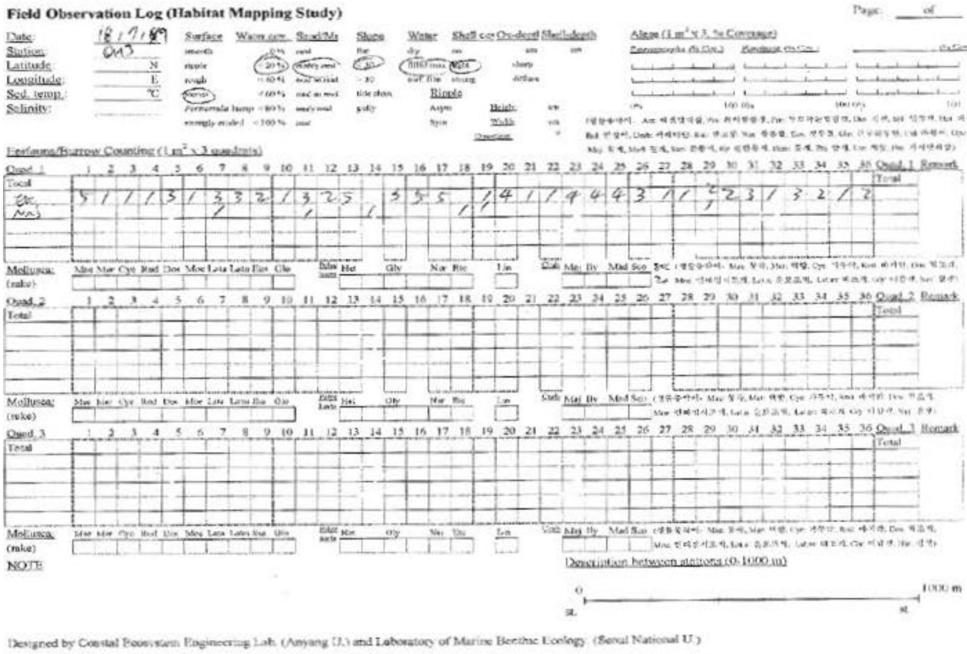
퇴적물 표면에 그물류가 많았고 서식굴은 확인이 안 되어 [illegible]

표층 아래부터 환원이 되어 검은색을 나타냈고 하부는 자갈로 이루어져 코어 25 cm 채집





Yellow Sea Ecosystem Study					
Site-ID	QH3	Date	07/09/2018	Weather	Cloudy
Location (GPS)	Latitude	39.83944 ° N		Arrival time	Departure time
	Longitude	119.51333 ° E		10:30 am	11:10 am
Recorded by	Yunqiao Zhou Bo He	Sampled by		Yunqiao Zhou Bo He Taewoo Kim Beomgi Kim	
In situ Measurement of Riverwater or Seawater quality (Freshwater)					
Color/odor					
Width/depth/velocity	Xin River, estuary, width~50m				
HACH 40d data	pH	Temp (°C)	DO (mg/L)	Salinity (mS/cm)	
	7.23	25.0	5.36	0.93	
Corresponding soil information					
Site location	Latitude	° N	Landuse	Municipal	


Field Observation Log (Habitat Mapping Study)

Date: 18/7/9
Station: QH3

Designed by Coastal Ecosystem Engineering Lab. (Anyang U.) and Laboratory of Marine Benthic Ecology (Seoul National U.)

Field Log and Sample Checklist

Yellow Sea Ecosystem Study						
Site-ID	QH 3	Date	18.7.7		Weather	Cloudy
Location (GPS)	Latitude	° 39	' 50	"N 22	Arrival time	Departure time
	Longitude	° 119	' 30	"E 48	10:30	11:40
Recorded by	KBG		Sampled by		KTW, KBG	

In situ Measurement of Porewater quality				
Color/odor				
YSI data	pH	Temp (°C)	DO (mg/L)	Salinity

In situ Measurement of Seawater quality				
Color/odor				
Width/depth/velocity				
YSI data	pH	Temp (°C)	DO (mg/L)	Salinity
	7.23	25.0	5.36	0.46 ‰

Checklists of Collected Samples	
Seawater	
POCs	HMs
C4	C4

Sediment		
General property	POCs	HMs
✓	✓	✓

Biota			
MPB assemblage	Chl-a	Meiofauna & Microbiome	Macrofauna
✓	✓	✓	✓

Graphical Description & Remark

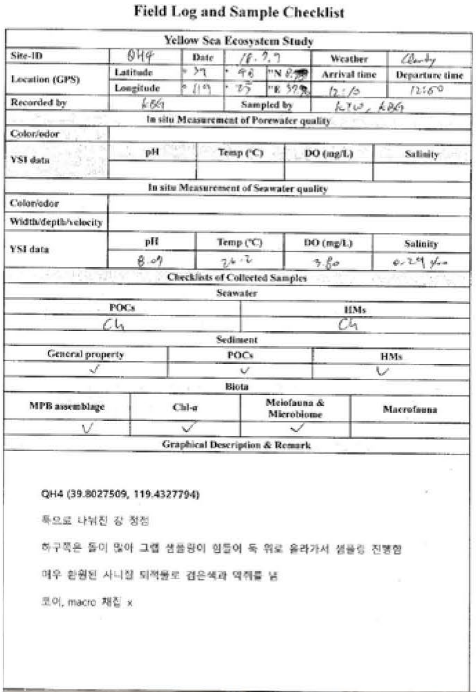
QH3 (39.8396000, 119.5154000)

사질에 굵은 자갈이 많아 캔코어 1번 진행 / 서식굴 많았고 게류와 Pm이 관찰됨

보호지역 공원이라 접근이 힘들었음

다리 밑 하구에서 샘플링

Yellow Sea Ecosystem Study					
Site-ID	QH4	Date	07/09/2018	Weather	Cloudy
Location (GPS)	Latitude	39.80167 ° N		Arrival time	Departure time
	Longitude	119.44194 ° E		12:10 pm	12:50 pm
Recorded by	Yunqiao Zhou Bo He	Sampled by		Yunqiao Zhou Bo He Taewoo Kim Beomgi Kim	
In situ Measurement of Riverwater or Seawater quality (Freshwater)					
Color/odor					
Width/depth/velocity	Dai River, estuary, width~200m; Inside of a sea dike				
HACH 40d data	pH	Temp (°C)	DO (mg/L)	Salinity (mS/cm)	
	8.07	26.2	3.80	0.62	
Corresponding soil information					
Site location	Latitude	° N	Landuse	Municipal	



Field Log and Sample Checklist

Yellow Sea Ecosystem Study						
Site-ID	QH4	Date	18.7.9		Weather	Cloudy
Location (GPS)	Latitude	° 39	' 48	"N	Arrival time	Departure time
	Longitude	° 119	' 25	"E	12:10	12:50
Recorded by	KBG		Sampled by	KTW, KBG		
In situ Measurement of Porewater quality						
Color/odor						
YSI data	pH	Temp (°C)	DO (mg/L)	Salinity		
In situ Measurement of Seawater quality						
Color/odor						
Width/depth/velocity						
YSI data	pH	Temp (°C)	DO (mg/L)	Salinity		
	8.07	26.2	3.80	0.29 ‰		
Checklists of Collected Samples						
Seawater						
POCs	HMs					
Ch	Ch					
Sediment						
General property	POCs	HMs				
✓	✓	✓				
Biota						
MPB assemblage	Chl-a	Meiofauna & Microbiome	Macrofauna			
✓	✓	✓				
Graphical Description & Remark						

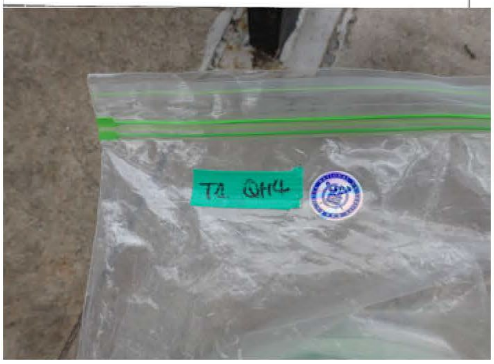
QH4 (39.8027509, 119.4327794)

둑으로 나뉘진 강 정점

하구쪽은 돌이 많아 그랩 샘플링이 힘들어 둑 위로 올라가서 샘플링 진행함

매우 환원된 사니질 퇴적물로 검은색과 악취를 냄

코어, macro 채집 x




QH-4
QH-4
QH-4
QH-4
QH-4

Yellow Sea Ecosystem Study					
Site-ID	QH2	Date	07/09/2018	Weather	Cloudy
Location (GPS)	Latitude	39.78139 ° N		Arrival time	Departure time
	Longitude	119.41361 ° E		14:00 pm	14:35 pm
Recorded by	Yunqiao Zhou Bo He	Sampled by		Yunqiao Zhou Bo He Taewoo Kim Beomgi Kim	
In situ Measurement of Riverwater or Seawater quality (Mixed water)					
Color/odor					
Width/depth/velocity	Yang River, estuary, width~300m				
HACH 40d data	pH	Temp (°C)	DO (mg/L)	Salinity (mS/cm)	
	7.95	25.6	7.97	14.20	
Corresponding soil information					
Site location	Latitude	° N	Landuse	Municipal	

Field Log and Sample Checklist

Yellow Sea Ecosystem Study						
Site-ID	QH2	Date	18.7.9		Weather	Cloudy
Location (GPS)	Latitude	° 39	′ 46	″N 53	Arrival time	Departure time
	Longitude	° 119	′ 24	″E 49	14:00	14:35
Recorded by	KBG		Sampled by		KTW, KBG	
In situ Measurement of Porewater quality						
Color/odor						
YSI data	pH	Temp (°C)	DO (mg/L)	Salinity		
In situ Measurement of Seawater quality						
Color/odor						
Width/depth/velocity						
YSI data	pH	Temp (°C)	DO (mg/L)	Salinity		
	7.95	25.6	7.97	[illegible]		

Checklists of Collected Samples	
Seawater	
POCs	HMs
Ch	Ch

Sediment		
General property	POCs	HMs
✓	✓	✓

Biota			
MPB assemblage	Chl-a	Meiofauna & Microbiome	Macrofauna
✓	✓	✓	

Graphical Description & Remark

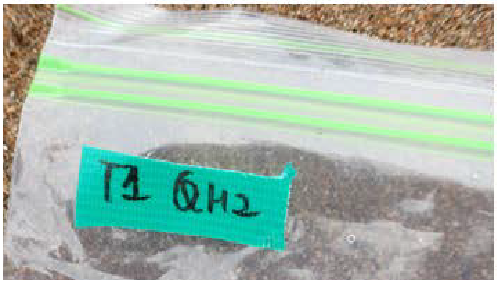
QH2 (39.7781700, 119.4119896)

하구 정점으로 모래사장처럼 완전한 사질로 이루어짐

코어 20 cm 채집

저서동물 및 서식굴 확인 못함

낚시하는 사람들과 주변에 배가 많이 정박되어 있었고 어업 활동이 활발한 곳으로 보임

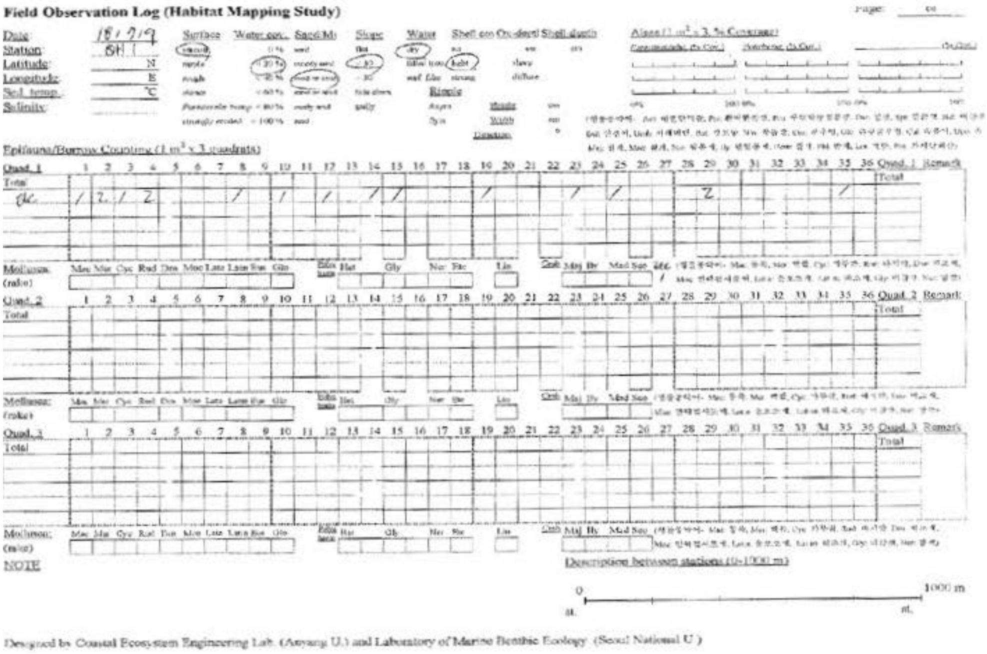








Yellow Sea Ecosystem Study					
Site-ID	QH1	Date	07/09/2018	Weather	Cloudy
Location (GPS)	Latitude	39.67889 ° N		Arrival time	Departure time
	Longitude	119.29111 ° E		15:56 pm	16:50 pm
Recorded by	Yunqiao Zhou Bo He	Sampled by		Yunqiao Zhou Bo He Taewoo Kim Beomgi Kim	
In situ Measurement of Riverwater or Seawater quality (Seawater)					
Color/odor					
Width/depth/velocity	Yinma River estuary, width~100m				
HACH 40d data	pH	Temp (°C)	DO (mg/L)	Salinity (mS/cm)	
	7.93	25.2	6.79	38.3	
Corresponding soil information					
Site location	Latitude	° N	Landuse	Municipal	


Field Observation Log (Habitat Mapping Study)

Date: 18/7/9

Station: QH1

Latitude: N

Longitude: E

Soil temp.: ℃

Salinity:

Epifauna/Burrow Counting (1 m² x 3 quadrats)

Quad. 1 Total

Quad. 2 Total

Quad. 3 Total

Mollusca (rake)

NOTE

Description between stations (0~1000 m)

Designed by Coastal Ecosystem Engineering Lab. (Anyang U.) and Laboratory of Marine Benthic Ecology (Seoul National U.)


Field Log and Sample Checklist

Yellow Sea Ecosystem Study							
Site-ID	HL4	Date	18.9.6			Weather	Sunny
Location (GPS)	Latitude	° 40	' 44	"N 49		Arrival time	Departure time
	Longitude	° 120	' 56	"E 05		14:45	15:55
Recorded by	KBG		Sampled by		KTW, KBG		

In situ Measurement of Porewater quality				
Color/odor				
YSI data	pH	Temp (°C)	DO (mg/L)	Salinity

In situ Measurement of Seawater quality				
Color/odor				
Width/depth/velocity				
YSI data	pH	Temp (°C)	DO (mg/L)	Salinity
	7.84	30.6	11.12	9.05‰

Checklists of Collected Samples

Seawater

POCs	HMs
C4	C4

Sediment

General property	POCs	HMs
✓	✓	✓

Biota

MPB assemblage	Chl-a	Meiofauna & Microbiome	Macrofauna
✓	✓	✓	✓

Graphical Description & Remark

HL4 (40.7415000, 120.9454000)

캡틴3, 랜코어1 / 서식굴이 상당히 많았고 배설물은 없었지만 대부분 Pm인 것으로 보임

칠면초 군락이 넓게 형성되어있음

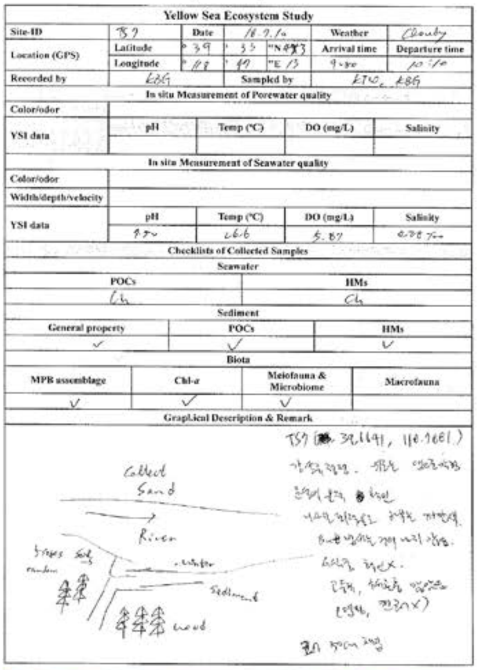
밀집된 공장 인근 정점으로 퇴적물 및 흐르는 강물에서 냄새가 심했고 환원층이 깊었음

퇴적물이 교란되었을 때 수면위로 기름이 뜨고 재어, 갯지렁이 등 죽은 생물이 상당히 많았음

저서미세조류와 조류의 퇴적도 많이 관찰됨

Yellow Sea Ecosystem Study					
Site-ID	TS7	Date	07/10/2018	Weather	Cloudy
Location (GPS)	Latitude	39.66194 ° N		Arrival time	Departure time
	Longitude	118.78694 ° E		9:50 am	10:10 am
Recorded by	Yunqiao Zhou Bo He	Sampled by		Yunqiao Zhou Bo He Taewoo Kim Beomgi Kim	
In situ Measurement of Riverwater or Seawater quality (Freshwater)					
Color/odor					
Width/depth/velocity	Luan River, upstream, width~50m				
HACH 40d data	pH	Temp (°C)	DO (mg/L)	Salinity (mS/cm)	
	7.50	26.6	5.87	0.59	
Corresponding soil information					
Site location	Latitude	° N	Landuse	Agricultural	

Field Log and Sample Checklist



Yellow Sea Ecosystem Study							
Site-ID	TS7	Date	18.7.10		Weather	Cloudy	
Location (GPS)	Latitude	° 39	' 35	" N 43	Arrival time	Departure time	
	Longitude	° 118	' 47	" E 13	9:50	10:10	
Recorded by	KBG	Sampled by			KTW, KBG		
In situ Measurement of Porewater quality							
Color/odor							
YSI data	pH	Temp (°C)	DO (mg/L)	Salinity			
In situ Measurement of Seawater quality							
Color/odor							
Width/depth/velocity							
YSI data	pH	Temp (°C)	DO (mg/L)	Salinity			
	7.50	26.6	5.87	0.59			

Checklists of Collected Samples	
Seawater	
POCs	HMs
Ch	Ch

Sediment		
General property	POCs	HMs
✓	✓	✓

Biota			
MPB assemblage	Chl-a	Meiofauna & Microbiome	Macrofauna
✓	✓	✓	

Graphical Description & Remark

TS7 (39.6691, 118.7661)

Collect Sand

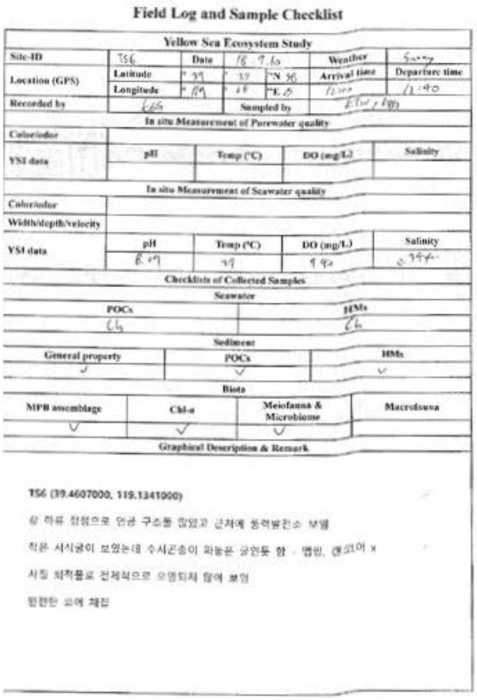
River

Water

Sediment

wood

Yellow Sea Ecosystem Study					
Site-ID	TS6	Date	07/10/2018	Weather	Sunny
Location (GPS)	Latitude	39.46056 ° N		Arrival time	Departure time
	Longitude	119.13472 ° E		12:00 am	12:40 pm
Recorded by	Yunqiao Zhou Bo He	Sampled by		Yunqiao Zhou Bo He Taewoo Kim Beomgi Kim	
In situ Measurement of Riverwater or Seawater quality (Freshwater)					
Color/odor					
Width/depth/velocity	Luan River, upstream, width~100m				
HACH 40d data	pH	Temp (°C)	DO (mg/L)	Salinity (mS/cm)	
	8.09	27.0	9.40	0.73	
Corresponding soil information					
Site location	Latitude	° N	Landuse	Agricultural	



Field Log and Sample Checklist

Yellow Sea Ecosystem Study					
Site-ID	TS6	Date	18.7.10	Weather	Sunny
Location (GPS)	Latitude	° 39	′ 27 ″N 38	Arrival time	Departure time
	Longitude	° 119	′ 08 ″E 8	12:00	12:40
Recorded by	[illegible]	Sampled by	[illegible]		
In situ Measurement of Porewater quality					
Color/odor					
YSI data	pH	Temp (°C)	DO (mg/L)	Salinity	
In situ Measurement of Seawater quality					
Color/odor					
Width/depth/velocity					
YSI data	pH	Temp (°C)	DO (mg/L)	Salinity	
	8.09	27	9.40	0.734	
Checklists of Collected Samples					
Seawater					
POCs			HMs		
Ch			Ch		
Sediment					
General property		POCs		HMs	
✓		✓		✓	
Biota					
MPB assemblage	Chl-a	Meiofauna & Microbiome	Macrofauna		
✓	✓	✓			
Graphical Description & Remark					

TS6 (39.4607000, 119.1341000)

강 하류 정점으로 인공 구조물 많았고 근처에 풍력발전소 보임

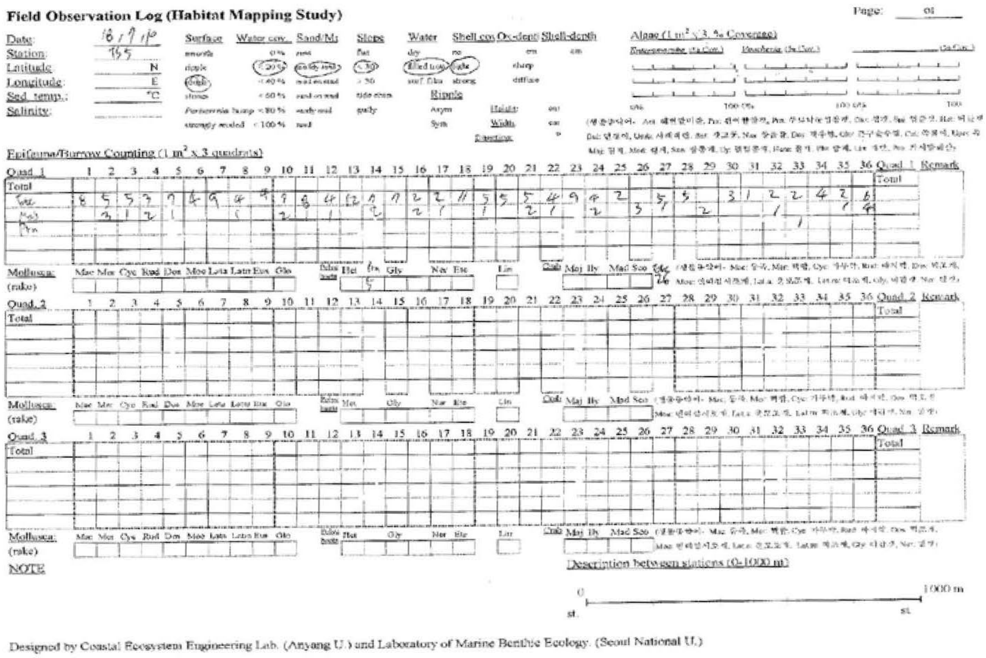
작은 서식굴이 보였는데 수서곤충이 파놓은 굴인듯 함 - [illegible] x

사질 퇴적물로 전체적으로 오염되지 않아 보임

평탄한 곳에 채집




Yellow Sea Ecosystem Study					
Site-ID	TS5	Date	07/10/2018	Weather	Sunny
Location (GPS)	Latitude	39.43083 ° N		Arrival time	Departure time
	Longitude	119.28000 ° E		13:40 pm	14:30 pm
Recorded by	Yunqiao Zhou Bo He	Sampled by		Yunqiao Zhou Bo He Taewoo Kim Beomgi Kim	
In situ Measurement of Riverwater or Seawater quality (Seawater)					
Color/odor					
Width/depth/velocity	Luan River, estuary, width~800m				
HACH 40d data	pH	Temp (°C)		DO (mg/L)	Salinity (mS/cm)
	7.75	28.4		8.37	57.4
Corresponding soil information					
Site location	Latitude	° N		Landuse	Agricultural



Field Observation Log (Habitat Mapping Study) Page: 01

Date: 18/7/10
Station: TS5
Latitude: N
Longitude: E
Sed. temp.: °C
Salinity:

Epifauna/Burrow Counting (1 m² x 3 quadrats)

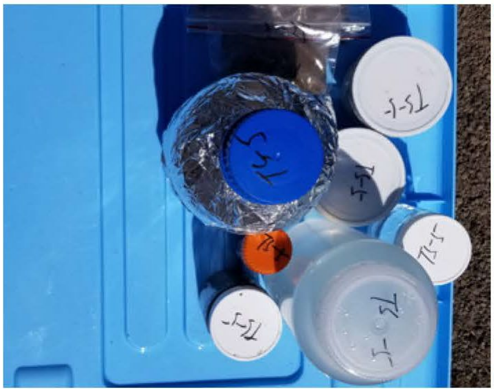
Quad. 1 / Quad. 2 / Quad. 3 — 1 – 36, Total, Remark

Mollusca: (rake)

NOTE

Description between stations (0-1000 m)

Designed by Coastal Ecosystem Engineering Lab. (Anyang U.) and Laboratory of Marine Benthic Ecology. (Seoul National U.)



Field Log and Sample Checklist

Yellow Sea Ecosystem Study							
Site-ID	TS5	Date	18.9.10			Weather	Sunny
Location (GPS)	Latitude	° 39	' 25	" N 51		Arrival time	Departure time
	Longitude	° 119	' 16	" E 48		13:40	14:30
Recorded by	KBG		Sampled by		LTW, KBG		

In situ Measurement of Porewater quality				
Color/odor				
YSI data	pH	Temp (°C)	DO (mg/L)	Salinity

In situ Measurement of Seawater quality				
Color/odor				
Width/depth/velocity				
YSI data	pH	Temp (°C)	DO (mg/L)	Salinity
	8.75	26.4	6.37	35.3‰

Checklists of Collected Samples

Seawater	
POCs	HMs
Ch	Ch

Sediment		
General property	POCs	HMs
✓	✓	✓

Biota			
MPB assemblage	Chl-a	Meiofauna & Microbiome	Macrofauna
✓	✓	✓	✓

Graphical Description & Remark

TS5 (39.4179000, 119.2758000)

하구 정점으로 서식굴 매우 많았음 - 캔코어 3회 시행

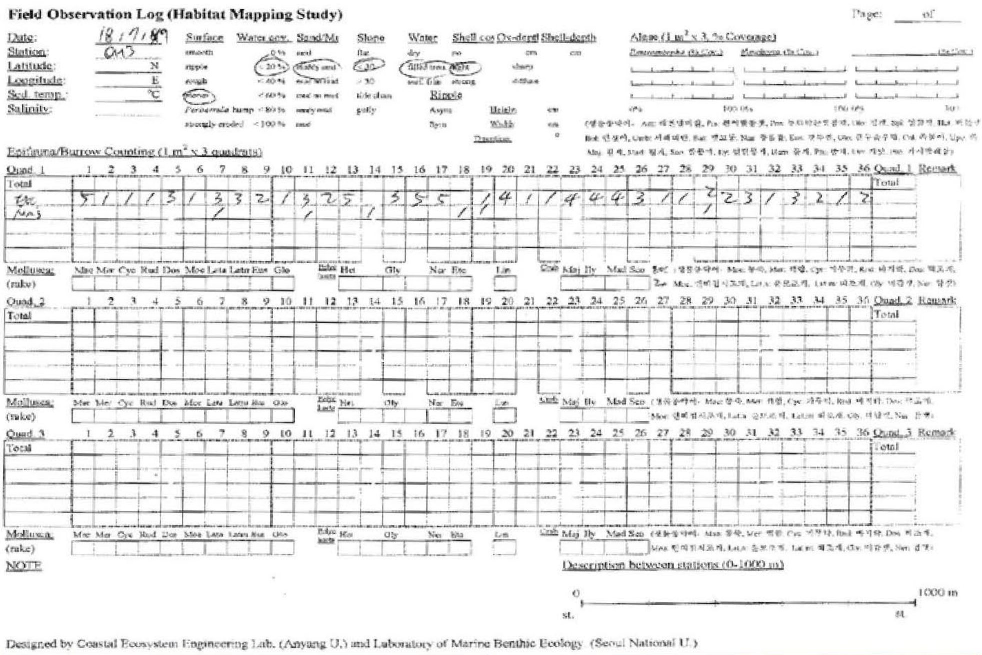
물이 거의 차지 않는 최상부는 달랑게 등이, 하부 쪽으로 갈수록 칠게의 서식굴이 우점함

Pm 또한 레이킹과 배설물로 확인됨

니사질 퇴적물에 입자가 크지 않아 시빙 수월하였고 완전한 코어를 채집함

따놓은 서식굴에서 군데군데 검은색 환원층과 수층 표면에서 기름기?도 확인됨

Yellow Sea Ecosystem Study					
Site-ID	TS2	Date	07/10/2018	Weather	Sunny
Location (GPS)	Latitude	39.15222 ° N		Arrival time	Departure time
	Longitude	118.53417 ° E		16:15 pm	17:15 pm
Recorded by	Yunqiao Zhou Bo He	Sampled by		Yunqiao Zhou Bo He Taewoo Kim Beomgi Kim	
In situ Measurement of Riverwater or Seawater quality (Seawater)					
Color/odor					
Width/depth/velocity	Qinglong River, estuary, width~150m				
HACH 40d data	pH	Temp (°C)	DO (mg/L)	Salinity (mS/cm)	
	7.82	27.7	6.35	59.2	
Corresponding soil information					
Site location	Latitude	° N	Landuse	Agricultural	


Field Observation Log (Habitat Mapping Study)
Date: 18.7.10
Station: QH3
Epifauna/Burrow Counting (1 m² x 3 quadrats)
Quad. 1
Quad. 2
Quad. 3
NOTE
Description between stations (0-1000 m)
Designed by Coastal Ecosystem Engineering Lab. (Anyang U.) and Laboratory of Marine Benthic Ecology (Seoul National U.)

Field Log and Sample Checklist

Yellow Sea Ecosystem Study						
Site-ID	TS 2	Date	18.9.10		Weather	Sunny
Location (GPS)	Latitude	° 39	′ 09	″N 08	Arrival time	Departure time
	Longitude	° 118	′ 32	″E 03	16:15	17:15
Recorded by			Sampled by			

In situ Measurement of Porewater quality				
Color/odor				
YSI data	pH	Temp (°C)	DO (mg/L)	Salinity

In situ Measurement of Seawater quality				
Color/odor				
Width/depth/velocity				
YSI data	pH	Temp (°C)	DO (mg/L)	Salinity
	7.82	28.7	1.37	37.3‰

Checklists of Collected Samples

Seawater	
POCs	HMs
Ch	Ch

Sediment		
General property	POCs	HMs
✓	✓	✓

Biota			
MPB assemblage	Chl-a	Meiofauna & Microbiome	Macrofauna
✓	✓	✓	✓

Graphical Description & Remark

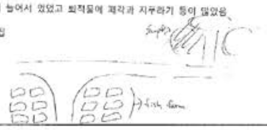
TS2 (39.1515000, 118.5339000)

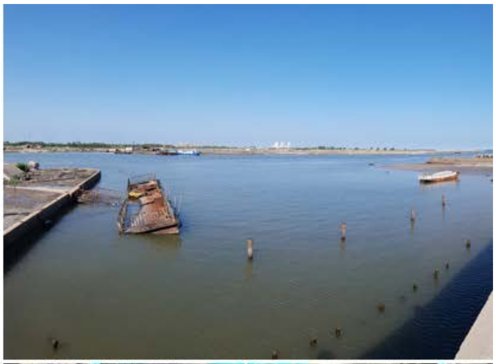
하구 갯벌 정점으로 니질, 사니질, 혼합 갯벌 등 환경이 매우 다양했음

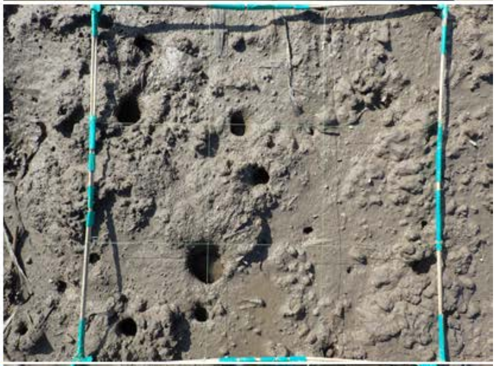
니질 최상부는 큰 방게, 사니질 최상부는 달랑게류가 관찰됨 - 햄뮴 3, 캔코어 1회 시행

주변에 양식장이 늘어서 있었고 퇴적물에 패각과 지푸라기 등이 많았음

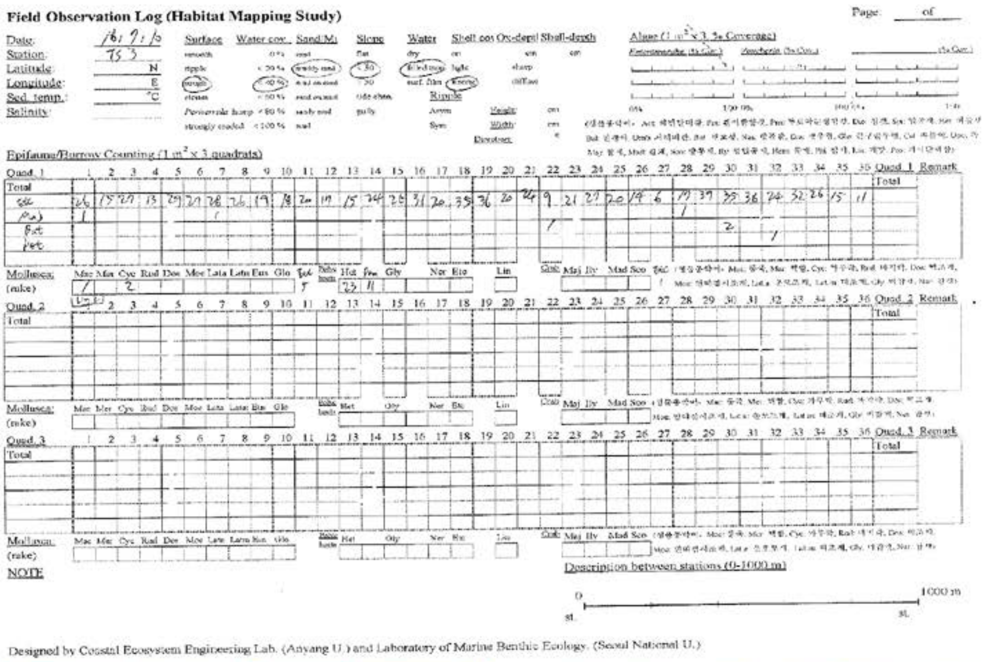
완전한 코어 채집







Yellow Sea Ecosystem Study					
Site-ID	TS3	Date	07/10/2018	Weather	Sunny
Location (GPS)	Latitude	39.04361 ° N		Arrival time	Departure time
	Longitude	118.36417 ° E		18:15 pm	19:10 pm
Recorded by	Yunqiao Zhou Bo He	Sampled by		Yunqiao Zhou Bo He Taewoo Kim Beomgi Kim	
In situ Measurement of Riverwater or Seawater quality (Seawater)					
Color/odor					
Width/depth/velocity	Shuanglong River, estuary, width~250m				
HACH 40d data	pH	Temp (°C)	DO (mg/L)	Salinity (mS/cm)	
	7.90	25.6	7.54	57.2	
Corresponding soil information					
Site location	Latitude	° N	Landuse	Municipal	



Field Observation Log (Habitat Mapping Study)

Page: of

Date: 18. 7. 10

Station: TS3

Latitude: N

Longitude: E

Sed. temp.: °C

Salinity:

Epifauna/Burrow Counting (1 m² x 3 quadrats)

Quad. 1

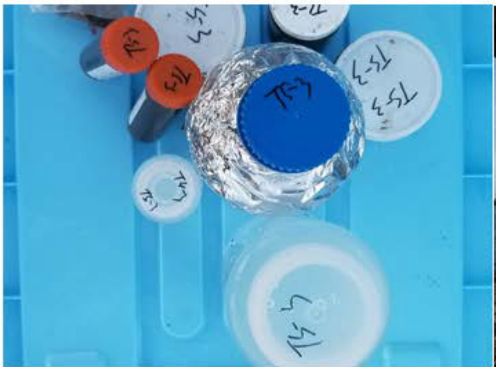
Quad. 2

Quad. 3

NOTE

Description between stations (0-1000 m)

Designed by Coastal Ecosystem Engineering Lab. (Anyang U.) and Laboratory of Marine Benthic Ecology. (Seoul National U.)



Field Log and Sample Checklist

Yellow Sea Ecosystem Study							
Site-ID	TS3	Date	18.7.10			Weather	Sunny
Location (GPS)	Latitude	° 39	′ 02	″N 37		Arrival time	Departure time
	Longitude	° 118	′ 21	″E 51		18:45	19:10
Recorded by			Sampled by				

In situ Measurement of Porewater quality				
Color/odor				
YSI data	pH	Temp (℃)	DO (mg/L)	Salinity

In situ Measurement of Seawater quality				
Color/odor				
Width/depth/velocity				
YSI data	pH	Temp (℃)	DO (mg/L)	Salinity
	7.9	25.6	7.54	30 ‰

Checklists of Collected Samples

Seawater	
POCs	HMs
C4	C6

Sediment		
General property	POCs	HMs
✓	✓	✓

Biota			
MPB assemblage	Chl-a	Meiofauna & Microbiome	Macrofauna
✓	✓	✓	✓

Graphical Description & Remark

TS3 (39.0431000, 118.3629000)

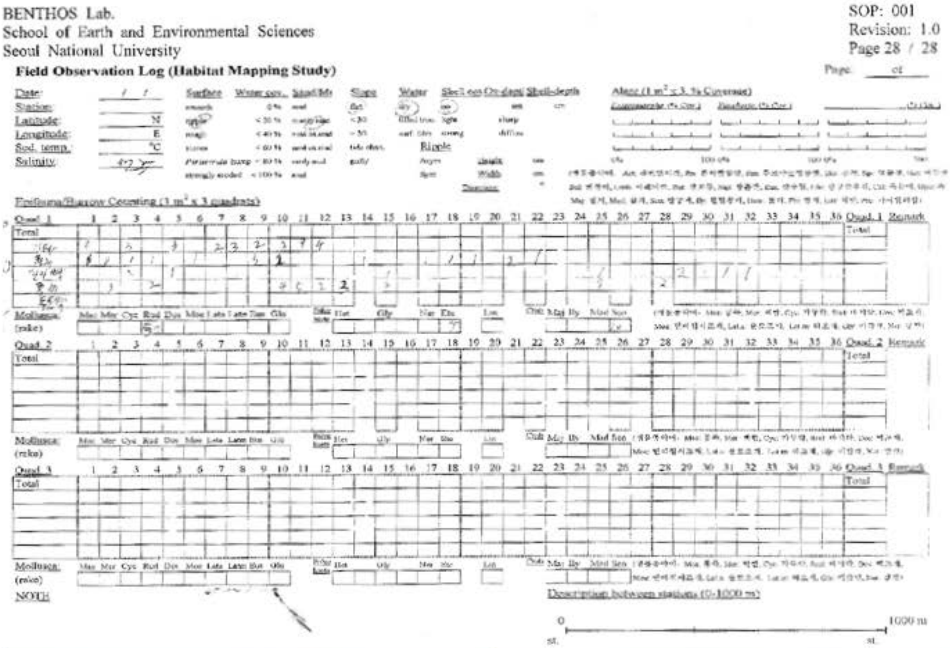
하구 갯벌 정점으로 주변에 큰 선박들이 많이 정박하고 있음

니사질 갯벌로 굴 및 이매패류의 패각이 많았고 많은 사람들이 생물 채집을 하고있었음

배설물은 없었으나 대부분 Het이나 Pm의 서식굴로 보이며, 다양한 생물이 관찰됨

완전한 코어를 채집하였고 렙핑 3, 캔코어 1회 시행함

Yellow Sea Ecosystem Study					
Site-ID	RZ2	Date	06/27/2018	Weather	Cloudy
Location (GPS)	Latitude	35.07815 ° N		Arrival time	Departure time
	Longitude	119.30326 ° E		12:30 pm	13:30 pm
Recorded by	Bin Shi		Sampled by	Yunqiao Zhou Bin Shi Jongmin Lee Seo Joon Yoon Bong-Oh Kwon	
In situ Measurement of Riverwater or Seawater quality (Mixed water)					
Color/odor					
Width/depth/velocity	Xiuzhen River, estuary, width~20m				
HACH 40d data	pH	Temp (°C)	DO (mg/L)	Salinity (mS/cm)	
	7.97	27.2	4.46	41.1	
Corresponding soil information					
Site location	Latitude	° N	Landuse	Unused land	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Field Observation Log (Habitat Mapping Study)

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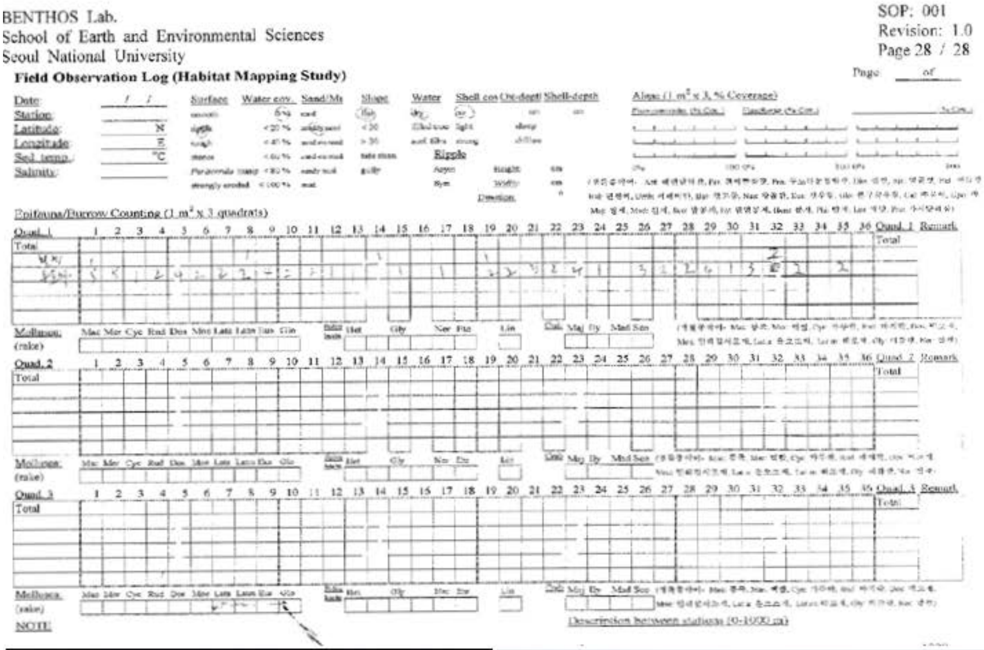
R2-1과 R2-2 [illegible] ([illegible] R2-2)

Yellow Sea Ecosystem Study					
Site-ID	R2-2	Date	[illegible]	Weather	[illegible]
Location (GPS)	Latitude	°	'	"N	Arrival time / Departure time
	Longitude	°	'	"E	13:20 / 13:48
Recorded by	SJ		Sampled by	SJ	
In situ Measurement of Porewater quality					
Color/odor	[illegible] grey				
YSI data	pH	Temp (°C)	DO (mg/L)	Salinity	
				[illegible]	
In situ Measurement of Seawater quality					
Color/odor					
Width/depth/velocity					
YSI data	pH	Temp (°C)	DO (mg/L)	Salinity	
				25	
Checklists of Collected Samples					
Seawater					
POCs			HMs		
✓ [illegible]			✓ [illegible]		
Sediment					
General property		POCs		HMs	
✓		✓		✓	
Biota					
MPB assemblage	Chl-a	Meiofauna & Microbiome	Macrofauna		
	✓	✓	✓		
Graphical Description & Remark					

Yellow Sea Ecosystem Study					
Site-ID	RZ1	Date	06/27/2018	Weather	Sunny
Location (GPS)	Latitude	35.29801 ° N		Arrival time	Departure time
	Longitude	119.44824 ° E		15:00 pm	16:00 pm
Recorded by	Bin Shi	Sampled by		Yunqiao Zhou Bin Shi Jongmin Lee Seo Joon Yoon Bong-Oh Kwon	
In situ Measurement of Riverwater or Seawater quality (Mixed water)					
Color/odor					
Width/depth/velocity	Futong River, estuary, width~200m				
HACH 40d data	pH	Temp (°C)	DO (mg/L)	Salinity (mS/cm)	
	7.73	31.3	4.88	26.4	
Corresponding soil information					
Site location	Latitude	° N	Landuse	Municipal	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Field Observation Log (Habitat Mapping Study)

Page ___ of ___

Date: / /
Station:
Latitude: N
Longitude: E
Sed temp.: °C
Salinity:

Epifauna/Burrow Counting (1 m² x 3 quadrats)

Quad. 1 — 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 Quad. 1 Remark
Total

Mollusca (rake)

Quad. 2 — 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 Quad. 2 Remark
Total

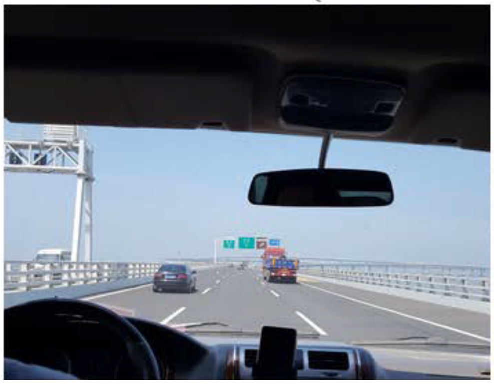
Mollusca (rake)

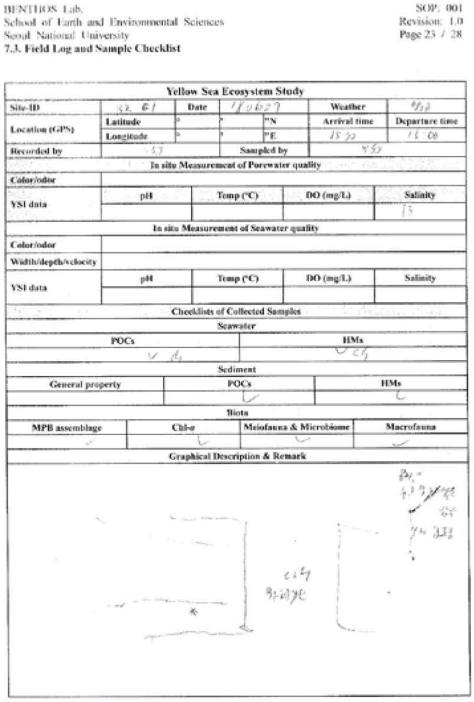
Quad. 3 — 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 Quad. 3 Remark
Total

Mollusca (rake)

NOTE:

Description between stations (0-1000 m)





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Yellow Sea Ecosystem Study						
Site-ID		Date	180627		Weather	
Location (GPS)	Latitude	°	'	"N	Arrival time	Departure time
	Longitude	°	'	"E	15:30	16:00
Recorded by			Sampled by			

In situ Measurement of Porewater quality				
Color/odor				
YSI data	pH	Temp (°C)	DO (mg/L)	Salinity
				13

In situ Measurement of Seawater quality				
Color/odor				
Width/depth/velocity				
YSI data	pH	Temp (°C)	DO (mg/L)	Salinity

Checklists of Collected Samples

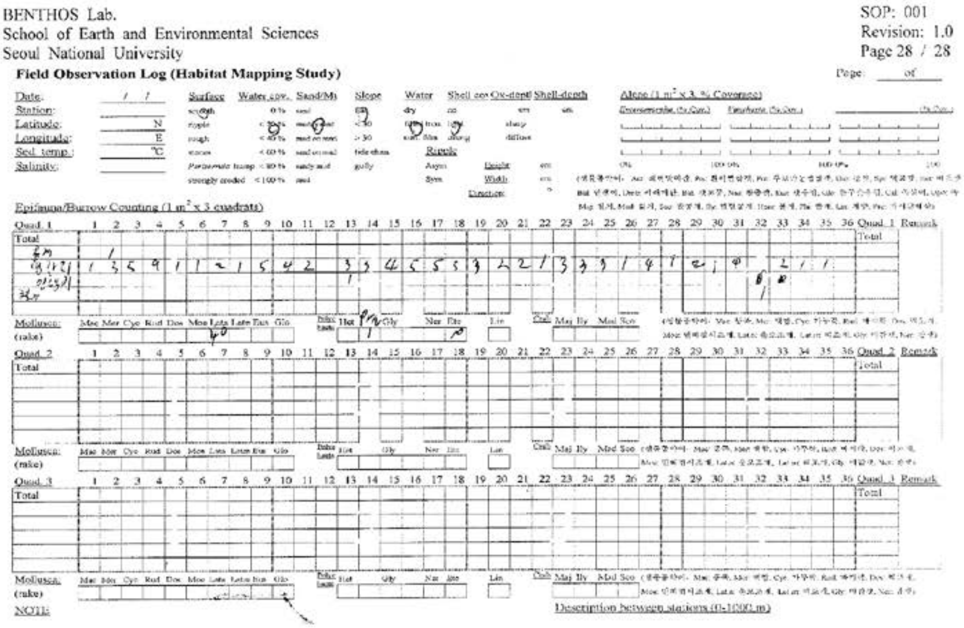
Seawater	
POCs	HMs
✓	✓

Sediment		
General property	POCs	HMs
	✓	✓

Biota			
MPB assemblage	Chl-a	Meiofauna & Microbiome	Macrofauna
✓	✓	✓	✓

Graphical Description & Remark

Yellow Sea Ecosystem Study					
Site-ID	QD7	Date	06/28/2018	Weather	Sunny
Location (GPS)	Latitude	35.74050 ° N		Arrival time	Departure time
	Longitude	119.91108 ° E		10:40 am	11:20 am
Recorded by	Bin Shi	Sampled by		Yunqiao Zhou Bin Shi Jongmin Lee Seo Joon Yoon Bong-Oh Kwon	
In situ Measurement of Riverwater or Seawater quality (Mixed water)					
Color/odor					
Width/depth/velocity	Xiacun River, estuary, width~5m				
HACH 40d data	pH	Temp (°C)	DO (mg/L)	Salinity (mS/cm)	
	7.73	29.0	3.77	25.9	
Corresponding soil information					
Site location	Latitude	° N	Landuse	Unused land	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Field Observation Log (Habitat Mapping Study)

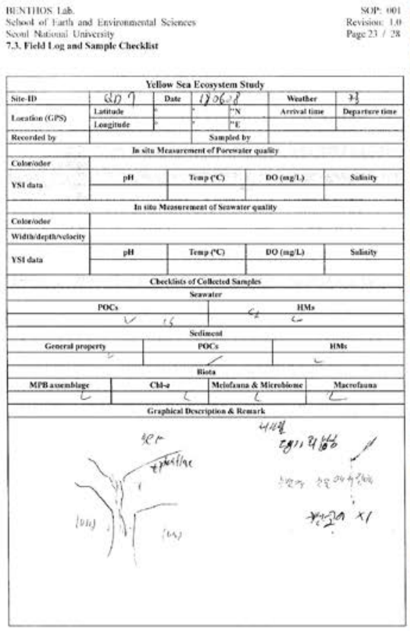
Epifauna/Burrow Counting (1 m² x 3 quadrats)

Quad. 1 · Quad. 2 · Quad. 3

Mollusca: (rake)

NOTE:

Description between stations (0~1000 m)



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Yellow Sea Ecosystem Study							
Site-ID	GD 7	Date	190608			Weather	
Location (GPS)	Latitude	°	'	"N		Arrival time	Departure time
	Longitude	°	'	"E			
Recorded by				Sampled by			

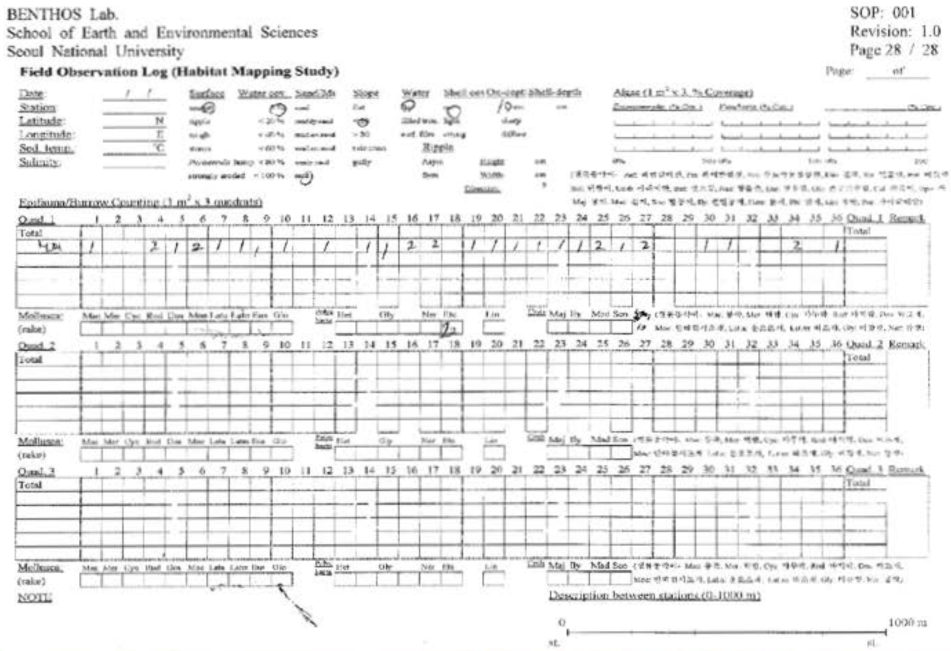
In situ Measurement of Porewater quality				
Color/odor				
YSI data	pH	Temp (°C)	DO (mg/L)	Salinity

In situ Measurement of Seawater quality				
Color/odor				
Width/depth/velocity				
YSI data	pH	Temp (°C)	DO (mg/L)	Salinity

Checklists of Collected Samples			
Seawater			
POCs		HMs	
Sediment			
General property	POCs	HMs	
Biota			
MPB assemblage	Chl-a	Meiofauna & Microbiome	Macrofauna

Graphical Description & Remark

Yellow Sea Ecosystem Study					
Site-ID	QD6	Date	06/28/2018	Weather	Sunny
Location (GPS)	Latitude	35.76765 ° N		Arrival time	Departure time
	Longitude	119.93114 ° E		11:40 am	12:30 pm
Recorded by	Bin Shi	Sampled by		Yunqiao Zhou Bin Shi Jongmin Lee Seo Joon Yoon Bong-Oh Kwon	
In situ Measurement of Riverwater or Seawater quality (Mixed water)					
Color/odor					
Width/depth/velocity	Hailong, estuary, width~20m				
HACH 40d data	pH	Temp (°C)	DO (mg/L)	Salinity (mS/cm)	
	8.11	30.1	7.13	8.89	
Corresponding soil information					
Site location	Latitude	° N	Landuse	Agricultural	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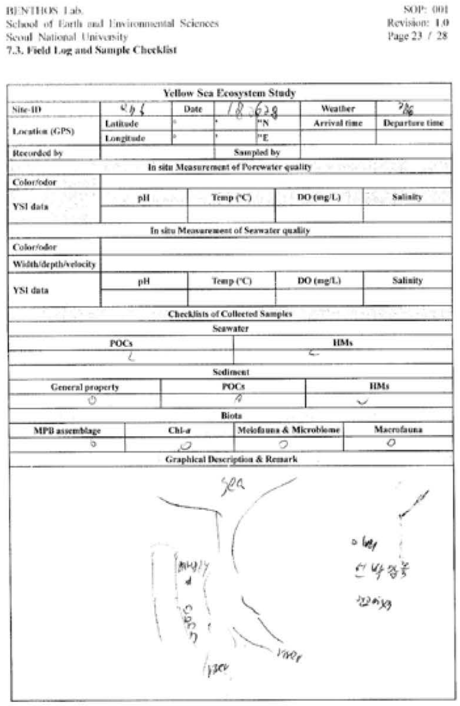
Field Observation Log (Habitat Mapping Study)



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Yellow Sea Ecosystem Study					
Site-ID		Date		Weather	
Location (GPS)	Latitude	°	'	"N	Arrival time / Departure time
	Longitude	°	'	"E	
Recorded by			Sampled by		

In situ Measurement of Porewater quality				
Color/odor				
YSI data	pH	Temp (℃)	DO (mg/L)	Salinity

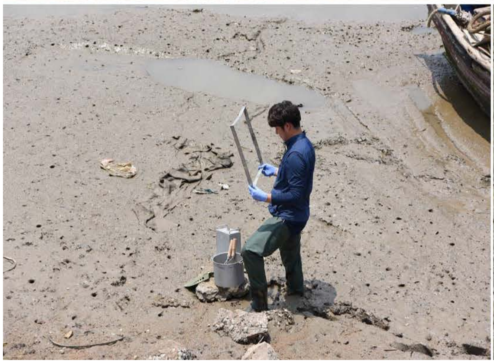
In situ Measurement of Seawater quality				
Color/odor				
Width/depth/velocity				
YSI data	pH	Temp (℃)	DO (mg/L)	Salinity

Checklists of Collected Samples	
Seawater	
POCs	HMs

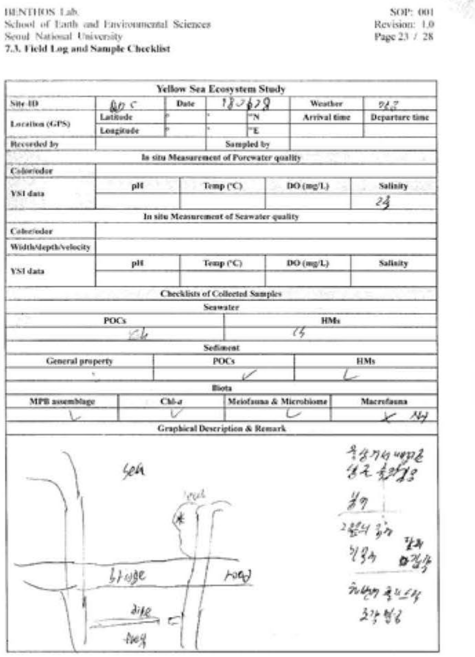
Sediment		
General property	POCs	HMs
O		

Biota			
MPB assemblage	Chl-a	Meiofauna & Microbiome	Macrofauna
O	O	O	O

Graphical Description & Remark



Yellow Sea Ecosystem Study					
Site-ID	QD5	Date	06/28/2018	Weather	Sunny
Location (GPS)	Latitude	35.85684 ° N		Arrival time	Departure time
	Longitude	120.04766 ° E		14:50 pm	15:30 pm
Recorded by	Bin Shi		Sampled by	Yunqiao Zhou Bin Shi Jongmin Lee Seo Joon Yoon Bong-Oh Kwon	
In situ Measurement of Riverwater or Seawater quality (Mixed water)					
Color/odor					
Width/depth/velocity	Feng River, estuary, width~200m				
HACH 40d data	pH	Temp (°C)		DO (mg/L)	Salinity (mS/cm)
	8.54	27.4		13.61	36.6
Corresponding soil information					
Site location	Latitude	° N		Landuse	Municipal



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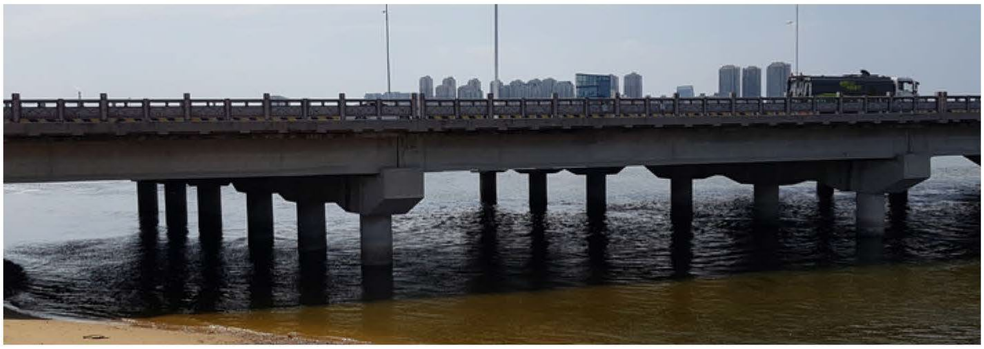
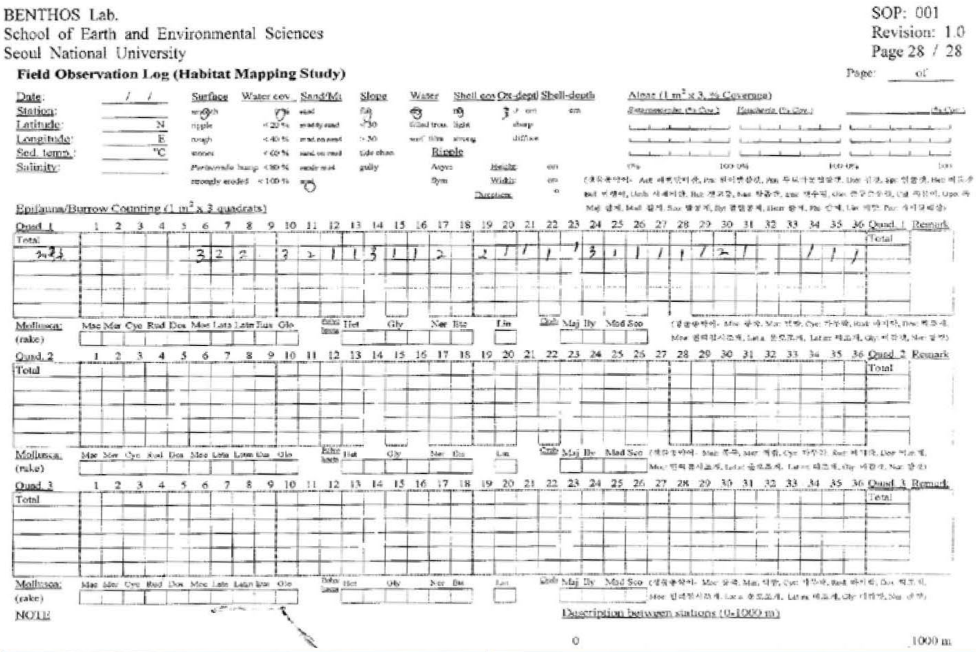
Yellow Sea Ecosystem Study						
Site-ID	QD5	Date	180628		Weather	
Location (GPS)	Latitude	°	'	"N	Arrival time	Departure time
	Longitude	°	'	"E		
Recorded by			Sampled by			
In situ Measurement of Porewater quality						
Color/odor						
YSI data	pH	Temp (°C)	DO (mg/L)	Salinity		
				23		
In situ Measurement of Seawater quality						
Color/odor						
Width/depth/velocity						
YSI data	pH	Temp (°C)	DO (mg/L)	Salinity		
Checklists of Collected Samples						
Seawater						
POCs	HMs					
Sediment						
General property	POCs	HMs				
	✓	✓				
Biota						
MPB assemblage	Chl-a	Meiofauna & Microbiome	Macrofauna			
✓	✓	✓	✗			
Graphical Description & Remark						







Yellow Sea Ecosystem Study					
Site-ID	QD4	Date	06/28/2018	Weather	Sunny
Location (GPS)	Latitude	36.23533 ° N		Arrival time	Departure time
	Longitude	120.12064 ° E		17:30 pm	18:30 pm
Recorded by	Bin Shi	Sampled by	Yunqiao Zhou Bin Shi Jongmin Lee Seo Joon Yoon Bong-Oh Kwon		
In situ Measurement of Riverwater or Seawater quality (Mixed water)					
Color/odor					
Width/depth/velocity	Dagu River, estuary, width~50m				
HACH 40d data	pH	Temp (°C)	DO (mg/L)	Salinity (mS/cm)	
	8.00	27.4	7.09	32.4	
Corresponding soil information					
Site location	Latitude	° N	Landuse	Municipal	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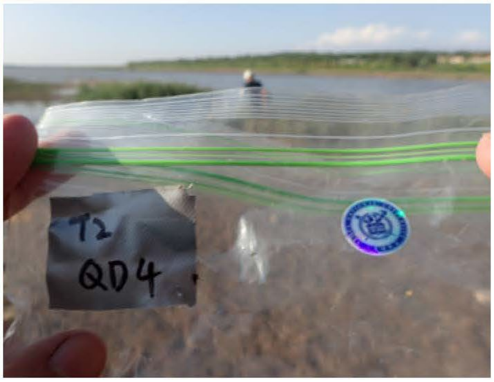
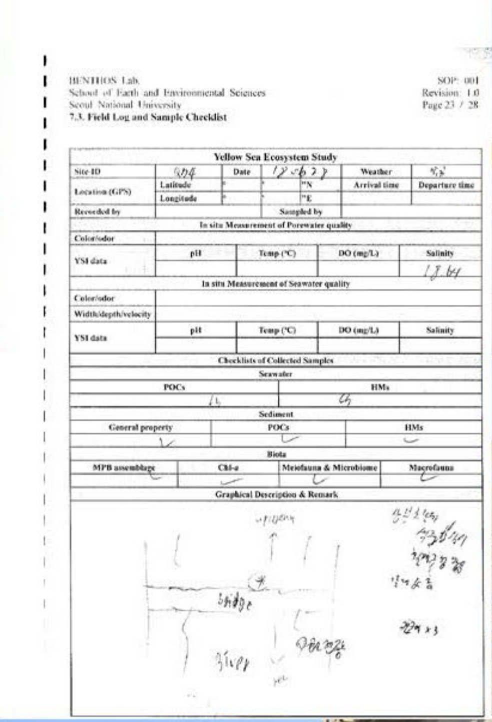
Field Observation Log (Habitat Mapping Study)





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Yellow Sea Ecosystem Study							
Site ID	[illegible]	Date	[illegible]			Weather	[illegible]
Location (GPS)	Latitude	°	'	"N		Arrival time	Departure time
	Longitude	°	'	"E			
Recorded by			Sampled by				

In situ Measurement of Porewater quality				
Color/odor				
YSI data	pH	Temp (°C)	DO (mg/L)	Salinity
				18.64

In situ Measurement of Seawater quality				
Color/odor				
Width/depth/velocity				
YSI data	pH	Temp (°C)	DO (mg/L)	Salinity

Checklists of Collected Samples	
Seawater	
POCs	HMs
✓	✓

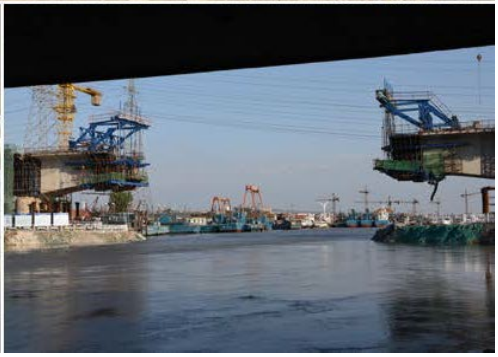
Sediment		
General property	POCs	HMs
✓	✓	✓

Biota			
MPB assemblage	Chl-a	Meiofauna & Microbiome	Macrofauna
✓	✓	✓	✓

Graphical Description & Remark

bridge

river



Yellow Sea Ecosystem Study					
Site-ID	QD3	Date	06/29/2018	Weather	Sunny
Location (GPS)	Latitude	36.66374 ° N		Arrival time	Departure time
	Longitude	120.29503 ° E		12:30 pm	13:00 pm
Recorded by	Bin Shi	Sampled by		Yunqiao Zhou Bin Shi Jongmin Lee Seo Joon Yoon Bong-Oh Kwon	
In situ Measurement of Riverwater or Seawater quality (Freshwater)					
Color/odor					
Width/depth/velocity	Dagu River, upstream, width~100m				
HACH 40d data	pH	Temp (°C)	DO (mg/L)	Salinity (mS/cm)	
	9.30	30.0	11.97	0.70	
Corresponding soil information					
Site location	Latitude	° N	Landuse	Unused land	

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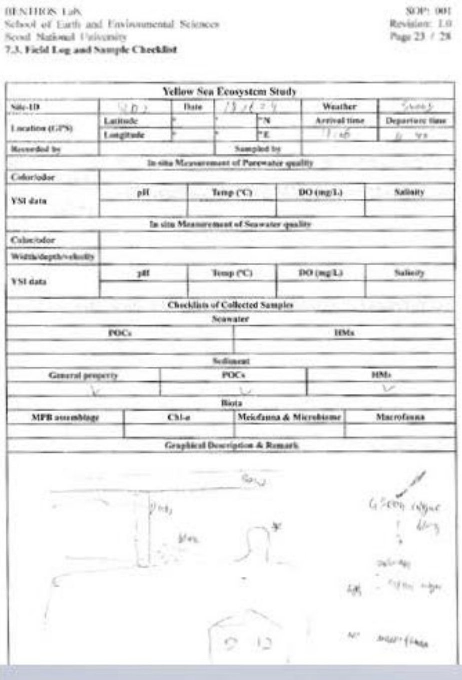
Yellow Sea Ecosystem Study					
Site-ID		Date	180629	Weather	
Location (GPS)	Latitude	°	' "N	Arrival time	Departure time
	Longitude	°	' "E		
Recorded by		Sampled by			
In situ Measurement of Porewater quality					
Color/odor					
YSI data	pH	Temp (°C)	DO (mg/L)	Salinity	
In situ Measurement of Seawater quality					
Color/odor					
Width/depth/velocity					
YSI data	pH	Temp (°C)	DO (mg/L)	Salinity	
Checklists of Collected Samples					
Seawater					
POCs		HMs			
Sediment					
General property	POCs	HMs			
✓	✓	✓			
Biota					
MPB assemblage	Chl-a	Meiofauna & Microbiome	Macrofauna		
Graphical Description & Remark					








Yellow Sea Ecosystem Study					
Site-ID	QD2	Date	06/29/2018	Weather	Sunny
Location (GPS)	Latitude	36.78020 ° N		Arrival time	Departure time
	Longitude	120.40990 ° E		11:00 am	11:30 am
Recorded by	Bin Shi	Sampled by		Yunqiao Zhou Bin Shi Jongmin Lee Seo Joon Yoon Bong-Oh Kwon	
In situ Measurement of Riverwater or Seawater quality (Freshwater)					
Color/odor					
Width/depth/velocity	Dagu River, upstream, width~200m				
HACH 40d data	pH	Temp (°C)	DO (mg/L)	Salinity (mS/cm)	
	10.37	29.9	16.73	1.09	
Corresponding soil information					
Site location	Latitude	° N	Landuse	Unused land	



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7.3. Field Log and Sample Checklist

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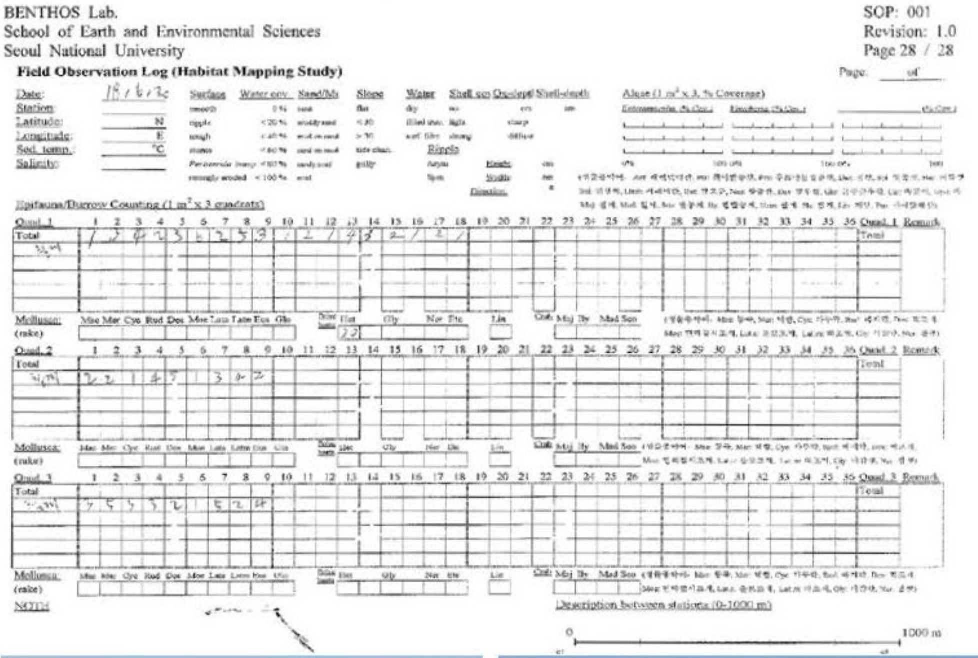
Yellow Sea Ecosystem Study						
Site-ID		Date			Weather	
Location (GPS)	Latitude	°	°	°N	Arrival time	Departure time
	Longitude	°	°	°E		
Recorded by			Sampled by			
In situ Measurement of Porewater quality						
Color/odor						
YSI data	pH	Temp (°C)	DO (mg/L)	Salinity		
In situ Measurement of Seawater quality						
Color/odor						
Width/depth/velocity						
YSI data	pH	Temp (°C)	DO (mg/L)	Salinity		
Checklists of Collected Samples						
Seawater						
POCs	HMs					
Sediment						
General property	POCs	HMs				
Biota						
MPB assemblage	Chl-a	Meiofauna & Microbiome	Macrofauna			
Graphical Description & Remark						


爱镇连心大桥

Yellow Sea Ecosystem Study					
Site-ID	QD1	Date	06/30/2018	Weather	Suuny
Location (GPS)	Latitude	36.26093 ° N		Arrival time	Departure time
	Longitude	120.32588 ° E		9:00 am	11:30 am
Recorded by	Bin Shi	Sampled by		Yunqiao Zhou Bin Shi Jongmin Lee Seo Joon Yoon Bong-Oh Kwon	
In situ Measurement of Riverwater or Seawater quality (Mixed water)					
Color/odor					
Width/depth/velocity	Moshui River, estuary, width~500m				
HACH 40d data	pH	Temp (°C)	DO (mg/L)	Salinity (mS/cm)	
	7.76	31.7	3.83	34.9	
Corresponding soil information					
Site location	Latitude	° N	Landuse	Municipal	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Field Observation Log (Habitat Mapping Study)

Date: 18/6/30
Station:
Latitude: N
Longitude: E
Sed. temp. °C
Salinity:

Epifauna/Burrow Counting (1 m² x 3 quadrats)

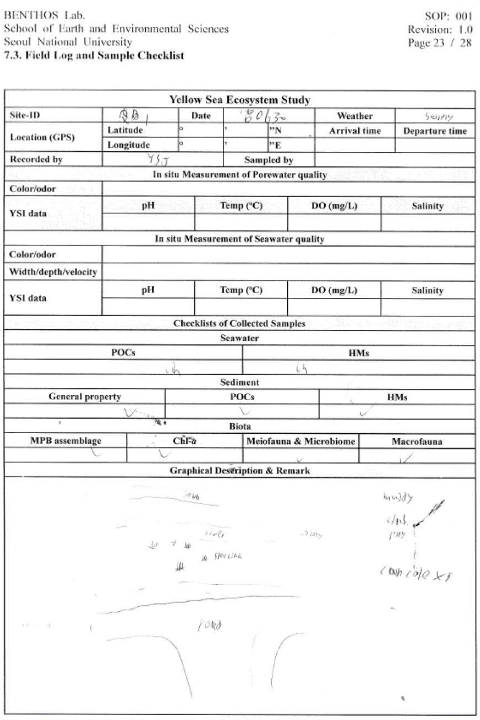
Quad. 1 — Total
Quad. 2 — Total
Quad. 3 — Total

Mollusca: (rake)

NOTE:

Description between stations (0-1000 m)

0 — 1000 m



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Yellow Sea Ecosystem Study						
Site-ID	QD1	Date	180630		Weather	sunny
Location (GPS)	Latitude	°	'	"N	Arrival time	Departure time
	Longitude	°	'	"E		
Recorded by	YSJ		Sampled by			
In situ Measurement of Porewater quality						
Color/odor						
YSI data	pH	Temp (°C)		DO (mg/L)		Salinity
In situ Measurement of Seawater quality						
Color/odor						
Width/depth/velocity						
YSI data	pH	Temp (°C)		DO (mg/L)		Salinity
Checklists of Collected Samples						
Seawater						
POCs			HMs			
Sediment						
General property		POCs		HMs		
✓		✓		✓		
Biota						
MPB assemblage		Chl-a	Meiofauna & Microbiome		Macrofauna	
✓		✓	✓		✓	
Graphical Description & Remark						

muddy

Yellow Sea Ecosystem Study					
Site-ID	YT5	Date	07/01/2018	Weather	Sunny
Location (GPS)	Latitude	36.65427 ° N		Arrival time	Departure time
	Longitude	120.76880 ° E		11:00 am	11:30 am
Recorded by	Bin Shi	Sampled by		Lu Yang Bin Shi Jongmin Lee Seo Joon Yoon	
In situ Measurement of Riverwater or Seawater quality (Mixed water)					
Color/odor					
Width/depth/velocity	Wulong River, width~400m				
HACH 40d data	pH	Temp (°C)	DO (mg/L)	Salinity (mS/cm)	
	8.96	26.3	11.63	3.56	
Corresponding soil information					
Site location	Latitude	° N	Landuse	Agricultural	

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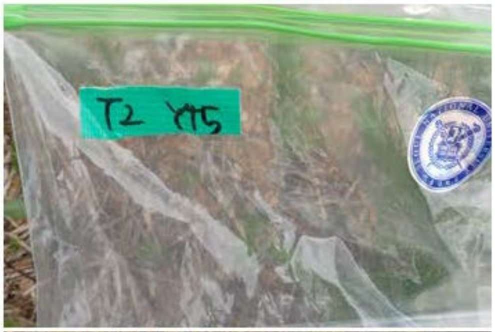
Yellow Sea Ecosystem Study					
Site-ID	YT5	Date		Weather	
Location (GPS)	Latitude		°N	Arrival time	Departure time
	Longitude		°E		
Recorded by		Sampled by			
In situ Measurement of Porewater quality					
Color/odor					
YSI data	pH	Temp (°C)	DO (mg/L)	Salinity	
In situ Measurement of Seawater quality					
Color/odor					
Width/depth/velocity					
YSI data	pH	Temp (°C)	DO (mg/L)	Salinity	
Checklists of Collected Samples					
Seawater					
POCs		HMs			
Sediment					
General property	POCs	HMs			
Biota					
MPB assemblage	Chl-a	Meiofauna & Microbiome	Macrofauna		
Graphical Description & Remark					

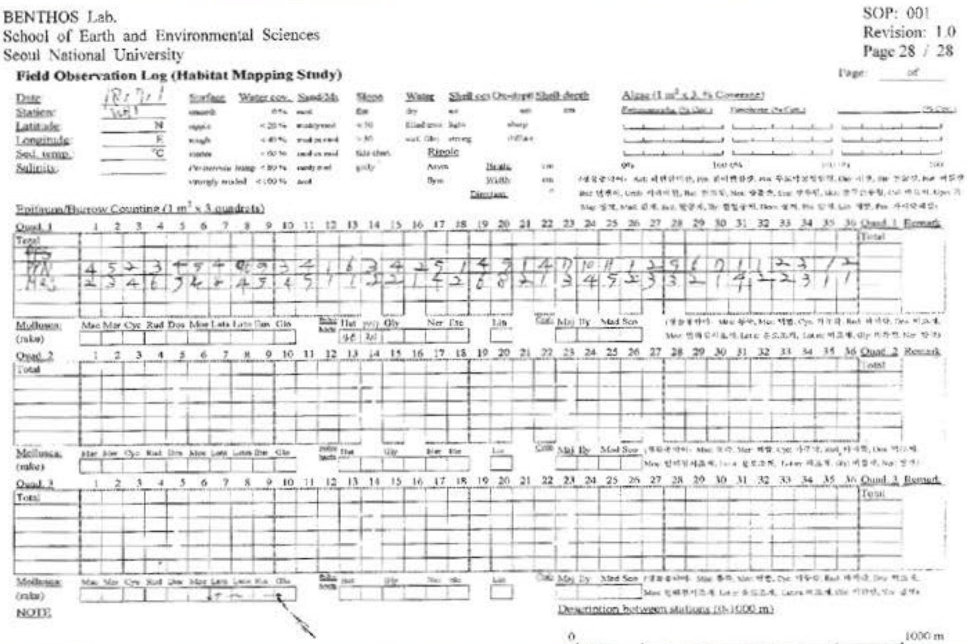








Yellow Sea Ecosystem Study					
Site-ID	WH1	Date	07/01/2018	Weather	Sunny
Location (GPS)	Latitude	36.82660 ° N		Arrival time	Departure time
	Longitude	121.46356 ° E		13:40 pm	14:30 pm
Recorded by	Bin Shi	Sampled by		Lu Yang Bin Shi Jongmin Lee Seo Joon Yoon	
In situ Measurement of Riverwater or Seawater quality (Mixed water)					
Color/odor					
Width/depth/velocity	Rushan River, width~500m				
HACH 40d data	pH	Temp (°C)	DO (mg/L)	Salinity (mS/cm)	
	7.93	28.7	7.95	34.9	
Corresponding soil information					
Site location	Latitude	° N	Landuse	Agricultural	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Field Observation Log (Habitat Mapping Study)

Date:
Station:
Latitude: N
Longitude: E
Sed. temp.: °C
Salinity:

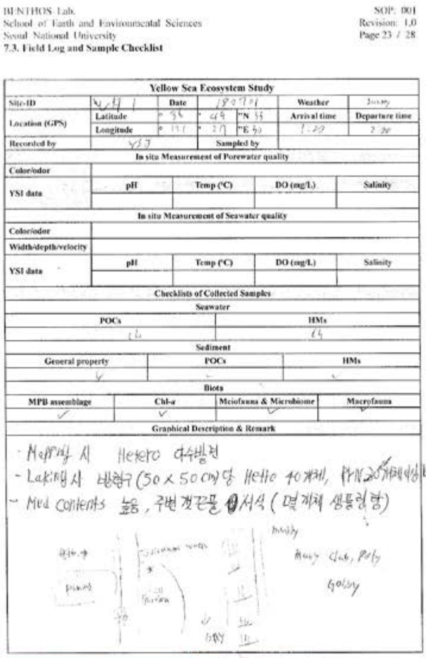
Epifauna/Burrow Counting (1 m² x 3 quadrats)

Quad. 1 Total Remark

Quad. 2 Total Remark

Quad. 3 Total Remark

NOTE:



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Yellow Sea Ecosystem Study							
Site-ID	WH 1	Date	180701			Weather	Sunny
Location (GPS)	Latitude	° 38	' 49	"N 33		Arrival time	Departure time
	Longitude	° 121	' 27	"E 50		1:20	2:30
Recorded by	YSJ		Sampled by				

In situ Measurement of Porewater quality				
Color/odor				
YSI data	pH	Temp (°C)	DO (mg/L)	Salinity

In situ Measurement of Seawater quality				
Color/odor				
Width/depth/velocity				
YSI data	pH	Temp (°C)	DO (mg/L)	Salinity

Checklists of Collected Samples

Seawater	
POCs	HMs
✓	✓

Sediment		
General property	POCs	HMs
✓	✓	✓

Biota			
MPB assemblage	Chl-a	Meiofauna & Microbiome	Macrofauna
✓	✓	✓	✓

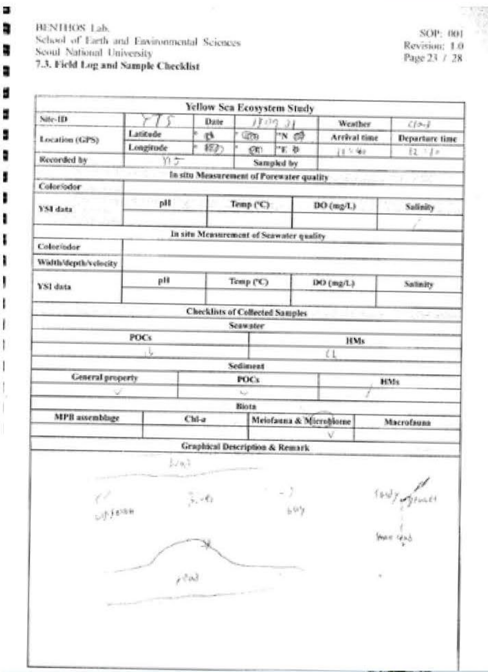
Graphical Description & Remark

- Mapping 시 Hetero 대수발견
- Raking 시 방형구 (50 × 50 cm) 당 Hetero 40개체, PN 20개체 이상 나
- Mud contents 높음, 주변 갯끈풀 서식 (몇 개체 샘플링 함)

Muddy Club, Poly

Goby

Yellow Sea Ecosystem Study					
Site-ID	WH3	Date	07/01/2018	Weather	Sunny
Location (GPS)	Latitude	36.93209 ° N		Arrival time	Departure time
	Longitude	121.86571 ° E		17:00 pm	18:00 pm
Recorded by	Bin Shi		Sampled by	Lu Yang Bin Shi Jongmin Lee Seo Joon Yoon	
In situ Measurement of Riverwater or Seawater quality (Mixed water)					
Color/odor					
Width/depth/velocity	Huanglei River, estuary, width~400m				
HACH 40d data	pH	Temp (°C)	DO (mg/L)	Salinity (mS/cm)	
	8.33	27.6	9.82	35.3	
Corresponding soil information					
Site location	Latitude	° N	Landuse	Agricultural	



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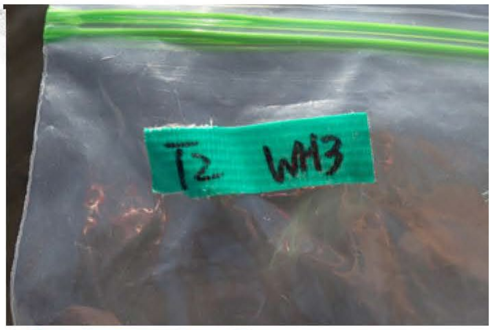
Yellow Sea Ecosystem Study					
Site-ID		Date		Weather	
Location (GPS)	Latitude	°	°N	Arrival time	Departure time
	Longitude	°	°E		
Recorded by		Sampled by			
In situ Measurement of Porewater quality					
Color/odor					
YSI data	pH	Temp (°C)	DO (mg/L)	Salinity	
In situ Measurement of Seawater quality					
Color/odor					
Width/depth/velocity					
YSI data	pH	Temp (°C)	DO (mg/L)	Salinity	
Checklists of Collected Samples					
Seawater					
POCs		HMs			
Sediment					
General property	POCs	HMs			
Biota					
MPB assemblage	Chl-a	Meiofauna & Microbiome	Macrofauna		
Graphical Description & Remark					




Yellow Sea
2018. 6 June ~ 7 July
中韓黃海共同調査
한중황해공동조사
Joint Field Survey

Yellow Sea Ecosystem Study					
Site-ID	WH2	Date	07/02/2018	Weather	Sunny
Location (GPS)	Latitude	37.42958 ° N		Arrival time	Departure time
	Longitude	122.27542 ° E		9:00 am	10:30 am
Recorded by	Bin Shi	Sampled by		Lu Yang Bin Shi Jongmin Lee Seo Joon Yoon	
In situ Measurement of Riverwater or Seawater quality (Mixed water)					
Color/odor					
Width/depth/velocity	Wuzhu River, estuary, width~200m				
HACH 40d data	pH	Temp (°C)	DO (mg/L)	Salinity (mS/cm)	
	8.17	22.4	9.24	42.4	
Corresponding soil information					
Site location	Latitude	° N	Landuse	Municipal	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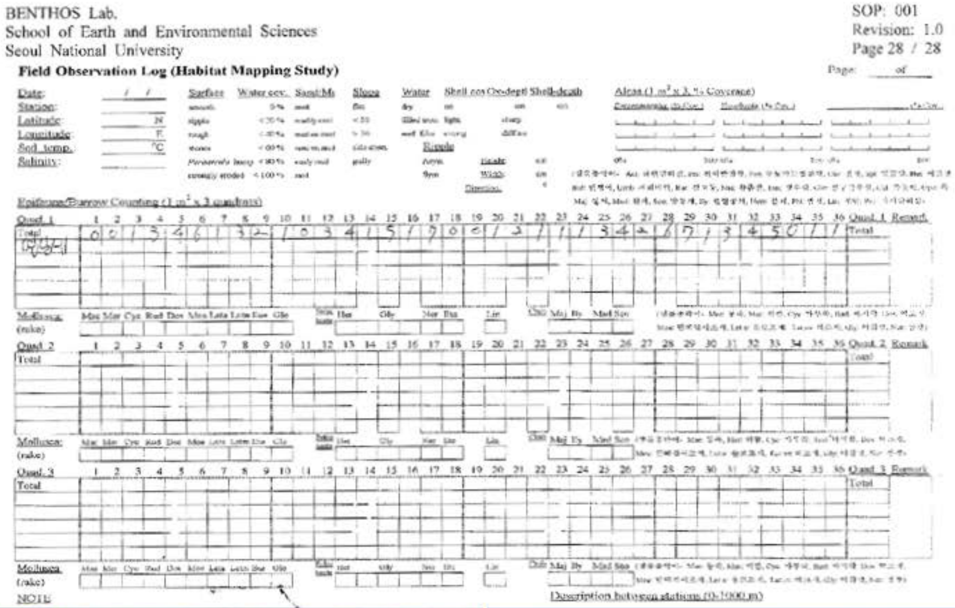
Yellow Sea Ecosystem Study				
Site-ID		Date		Weather
Location (GPS)	Latitude			Arrival time / Departure time
	Longitude			10:30
Recorded by		Sampled by		
In situ Measurement of Porewater quality				
Color/odor				
YSI data	pH	Temp (°C)	DO (mg/L)	Salinity
In situ Measurement of Seawater quality				
Color/odor				
Width/depth/velocity				
YSI data	pH	Temp (°C)	DO (mg/L)	Salinity
Checklists of Collected Samples				
Seawater				
POCs: Ch		HMs: Ch		
Sediment				
General property: ✓		POCs: ✓		HMs: ✓
Biota				
MPB assemblage: ✓	Chl-a: ✓	Meiofauna & Microbiome: ✓	Macrofauna	
Graphical Description & Remark				

Yellow Sea Ecosystem Study					
Site-ID	YT6	Date	07/02/2018	Weather	Sunny
Location (GPS)	Latitude	37.57533 ° N		Arrival time	Departure time
	Longitude	121.29662 ° E		14:30 pm	15:00 pm
Recorded by	Bin Shi	Sampled by		Lu Yang Bin Shi Jongmin Lee Seo Joon Yoon	
In situ Measurement of Riverwater or Seawater quality (Mixed Water)					
Color/odor					
Width/depth/velocity	Jia River, estuary, width~500m				
HACH 40d data	pH	Temp (°C)	DO (mg/L)	Salinity (mS/cm)	
	8.27	25.8	9.8	44.3	
Corresponding soil information					
Site location	Latitude	° N	Landuse	Municipal	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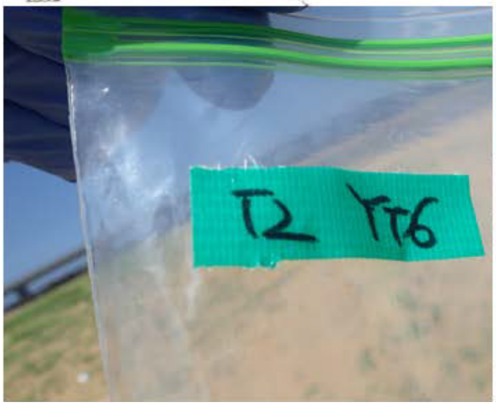
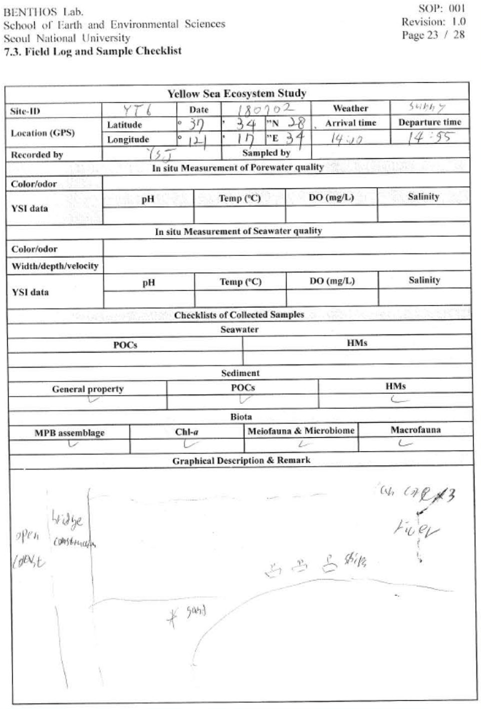
Field Observation Log (Habitat Mapping Study)





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Yellow Sea Ecosystem Study							
Site-ID	YT6	Date	180702			Weather	sunny
Location (GPS)	Latitude	° 37	' 34	"N 28		Arrival time	Departure time
	Longitude	° 121	' 17	"E 34		14:00	14:55
Recorded by	YSJ		Sampled by				

In situ Measurement of Porewater quality				
Color/odor				
YSI data	pH	Temp (°C)	DO (mg/L)	Salinity

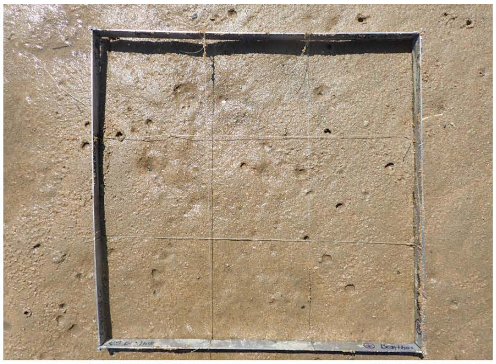
In situ Measurement of Seawater quality				
Color/odor				
Width/depth/velocity				
YSI data	pH	Temp (°C)	DO (mg/L)	Salinity

Checklists of Collected Samples	
Seawater	
POCs	HMs

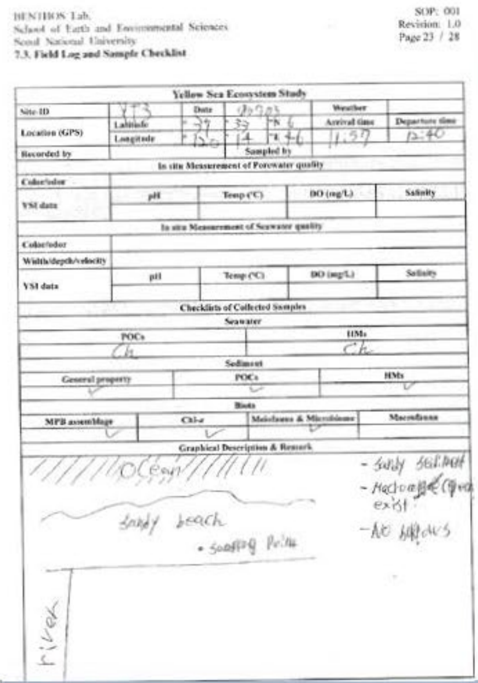
Sediment		
General property	POCs	HMs
✓	✓	✓

Biota			
MPB assemblage	Chl-*a*	Meiofauna & Microbiome	Macrofauna
✓	✓	✓	✓

Graphical Description & Remark



Yellow Sea Ecosystem Study					
Site-ID	YT3	Date	07/03/2018	Weather	Sunny
Location (GPS)	Latitude	37.55176 ° N		Arrival time	Departure time
	Longitude	120.24818 ° E		12:00 am	12:50 pm
Recorded by	Bin Shi		Sampled by	Lu Yang Bin Shi Jongmin Lee Seo Joon Yoon	
In situ Measurement of Riverwater or Seawater quality (Mixed water)					
Color/odor					
Width/depth/velocity	Jie River, estuary, width~100m				
HACH 40d data	pH	Temp (°C)		DO (mg/L)	Salinity (mS/cm)
	8.54	29.5		9.07	31.6
Corresponding soil information					
Site location	Latitude	° N		Land use	Unused land



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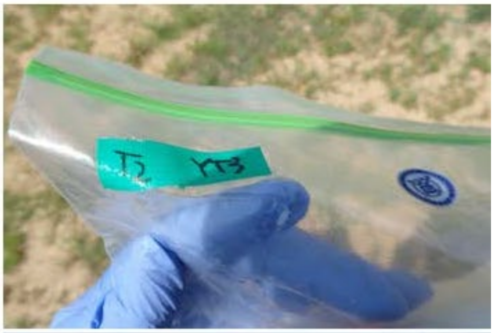
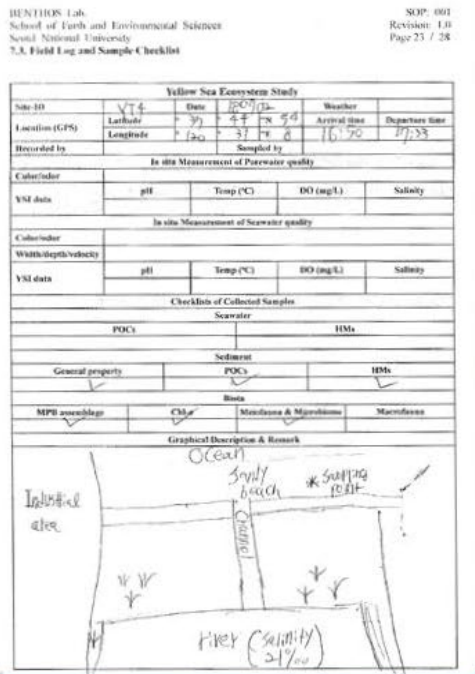
Yellow Sea Ecosystem Study					
Site-ID	YT3	Date	07703	Weather	
Location (GPS)	Latitude	° 37 ° 33 ′ N 6		Arrival time	Departure time
	Longitude	° 120 ° 14 ′ E 46		11:57	12:40
Recorded by		Sampled by			
In situ Measurement of Porewater quality					
Color/odor					
YSI data	pH	Temp (°C)	DO (mg/L)	Salinity	
In situ Measurement of Seawater quality					
Color/odor					
Width/depth/velocity					
YSI data	pH	Temp (°C)	DO (mg/L)	Salinity	
Checklists of Collected Samples					
Seawater					
POCs		HMs			
Ch		Ch			
Sediment					
General property	POCs	HMs			
✓	✓	✓			
Biota					
MPB assemblage	Chl-a	Meiofauna & Microbiome	Macrofauna		
✓	✓	✓			
Graphical Description & Remark					

Ocean
sandy beach
• sampling point
river

- sandy sediment
- Macroalgae exist
- No burrows



Yellow Sea Ecosystem Study					
Site-ID	YT4	Date	07/02/2018	Weather	Sunny
Location (GPS)	Latitude	37.74926 ° N		Arrival time	Departure time
	Longitude	120.52423 ° E		16:40 pm	17:30 pm
Recorded by	Bin Shi		Sampled by	Lu Yang Bin Shi Jongmin Lee Seo Joon Yoon	
In situ Measurement of Riverwater or Seawater quality (Mixed water)					
Color/odor					
Width/depth/velocity	Huangshui River, estuary, width~200m				
HACH 40d data	pH	Temp (°C)	DO (mg/L)	Salinity (mS/cm)	
	8.38	26.1	8.55	44.4	
Corresponding soil information					
Site location	Latitude	° N	Landuse	Industrial	



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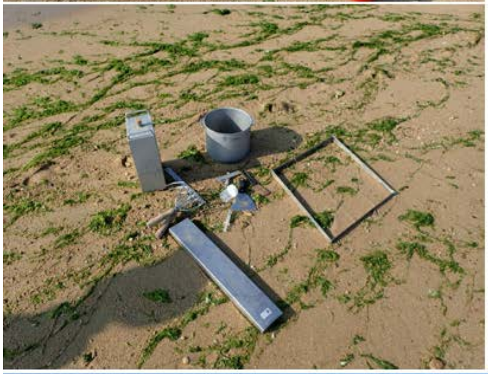
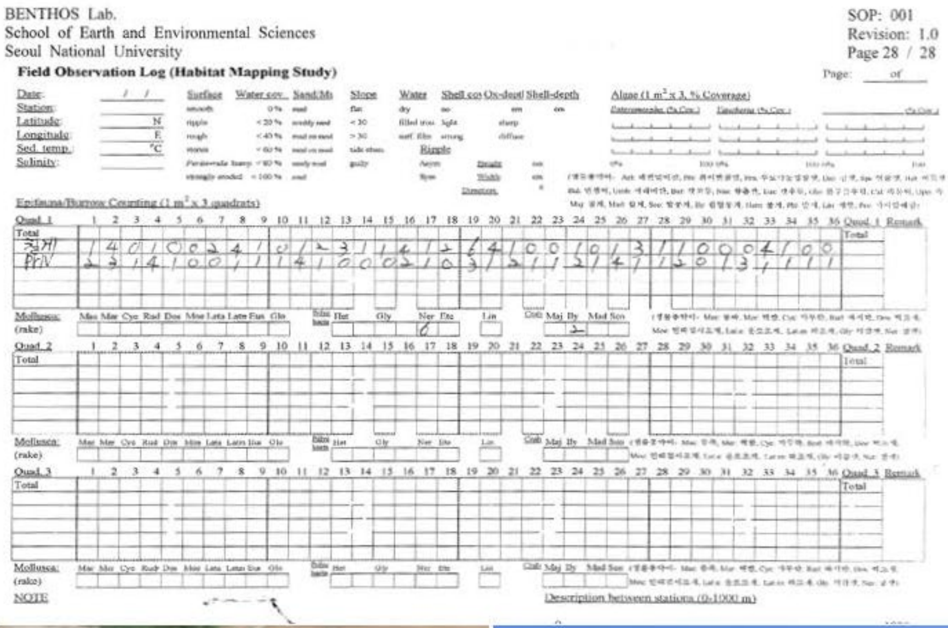
Yellow Sea Ecosystem Study					
Site-ID	YT4	Date		Weather	
Location (GPS)	Latitude	° 37	° 44 ′N 54	Arrival time	Departure time
	Longitude	° 120	° 31 ′E 8	16:50	17:33
Recorded by		Sampled by			
In situ Measurement of Porewater quality					
Color/odor					
YSI data	pH	Temp (°C)	DO (mg/L)	Salinity	
In situ Measurement of Seawater quality					
Color/odor					
Width/depth/velocity					
YSI data	pH	Temp (°C)	DO (mg/L)	Salinity	
Checklists of Collected Samples					
Seawater					
POCs		HMs			
Sediment					
General property	POCs	HMs			
Biota					
MPB assemblage	Chl-a	Meiofauna & Microbiome	Macrofauna		
Graphical Description & Remark					

Ocean
Sandy beach
* Sampling point
Industrial area
Channel
river (Salinity 21‰)



Yellow Sea Ecosystem Study					
Site-ID	YT2	Date	07/03/2018	Weather	Sunny
Location (GPS)	Latitude	37.40168 ° N		Arrival time	Departure time
	Longitude	119.94928 ° E		14:20 pm	15:00 pm
Recorded by	Bin Shi		Sampled by	Lu Yang Bin Shi Jongmin Lee Seo Joon Yoon	
In situ Measurement of Riverwater or Seawater quality (Mixed water)					
Color/odor					
Width/depth/velocity	Wang River, estuary, width~100m				
HACH 40d data	pH	Temp (°C)	DO (mg/L)	Salinity (mS/cm)	
	8.36	29.5	9.35	46.9	
Corresponding soil information					
Site location	Latitude	° N	Landuse	Industrial	



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Field Observation Log (Habitat Mapping Study)

Date: / / Station: Latitude: N Longitude: E Sed. temp.: °C Salinity:

Epifauna/Burrow Counting (1 m² x 3 quadrats)

Quad. 1	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	Quad. 1 Total	Remark
칠게	1	4	0	1	0	0	2	4	1	0	1	2	3	1	1	4	1	2	6	4	1	0	0	1	0	1	3	1	1	0	0	0	4	1	0	0		
PrN	2	3	1	4	1	0	0	1	1	1	4	1	0	0	0	2	1	0	3	1	2	1	1	2	1	4	1	1	2	0	1	3	1	1	1	1		

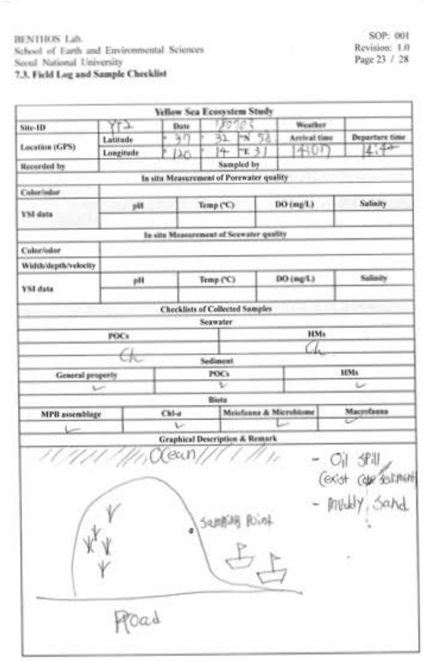
Mollusca: (rake) Ner 6; Maj 2

Quad. 2 — Total

Quad. 3 — Total

NOTE

Description between stations (0-1000 m)



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Yellow Sea Ecosystem Study						
Site-ID	YT-2	Date	180703		Weather	
Location (GPS)	Latitude	° 37	′ 32	″N 58	Arrival time	Departure time
	Longitude	° 120	′ 14	″E 31	14:07	14:40
Recorded by			Sampled by			

In situ Measurement of Porewater quality				
Color/odor				
YSI data	pH	Temp (°C)	DO (mg/L)	Salinity

In situ Measurement of Seawater quality				
Color/odor				
Width/depth/velocity				
YSI data	pH	Temp (°C)	DO (mg/L)	Salinity

Checklists of Collected Samples

Seawater	
POCs	HMs
Ch	Ch

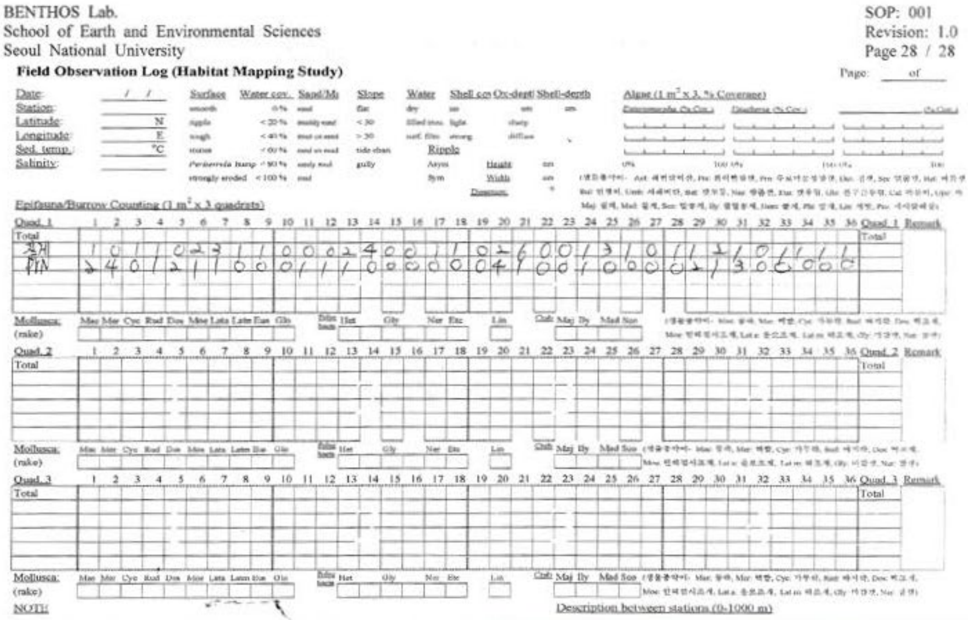
Sediment		
General property	POCs	HMs
✓	✓	✓

Biota			
MPB assemblage	Chl-a	Meiofauna & Microbiome	Macrofauna
✓	✓	✓	✓

Graphical Description & Remark

- Oil spill (exist ~~on~~ sediment)
- Muddy sand

Yellow Sea Ecosystem Study					
Site-ID	YT1	Date	07/03/2018	Weather	Sunny
Location (GPS)	Latitude	37.12861 ° N		Arrival time	Departure time
	Longitude	119.72772 ° E		16:00 pm	17:00 pm
Recorded by	Bin Shi	Sampled by		Lu Yang Bin Shi Jongmin Lee Seo Joon Yoon	
In situ Measurement of Riverwater or Seawater quality (Mixed water)					
Color/odor					
Width/depth/velocity	Sha River, estuary, width~10m				
HACH 40d data	pH	Temp (°C)	DO (mg/L)	Salinity (mS/cm)	
	8.24	30.4	8.48	48.4	
Corresponding soil information					
Site location	Latitude	37.10776 ° N	Landuse	Unused land	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Field Observation Log (Habitat Mapping Study)

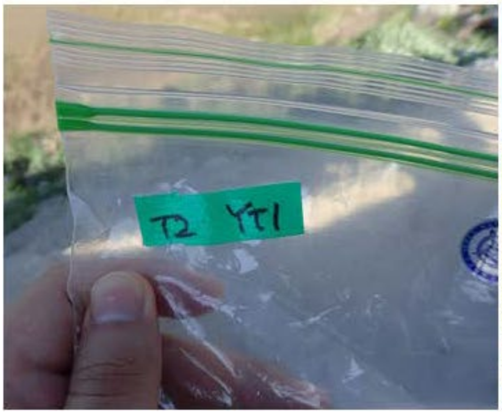
Epifauna/Burrow Counting (1 m² x 3 quadrats)

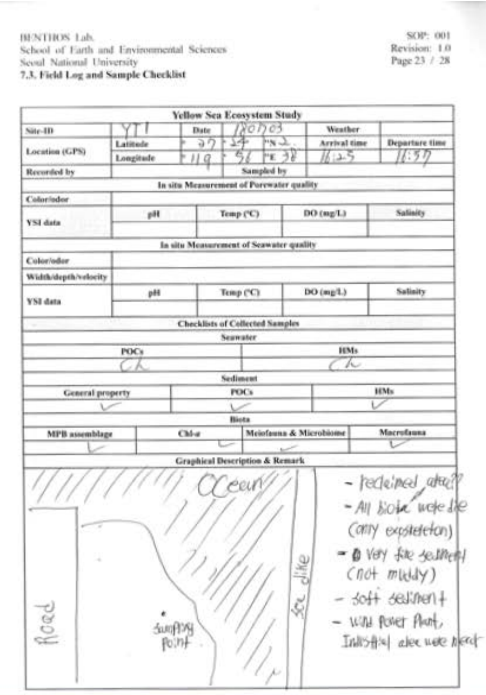
Quad. 1 · Quad. 2 · Quad. 3

Mollusca: (rake)

NOTE:

Description between stations (0-1000 m)





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Yellow Sea Ecosystem Study					
Site-ID	YT1	Date	180703	Weather	
Location (GPS)	Latitude	° 37	° 24	' N 2.	Arrival time
	Longitude	° 119	° 56	' E 38	16:25
				Departure time	16:57
Recorded by		Sampled by			

In situ Measurement of Porewater quality				
Color/odor				
YSI data	pH	Temp (°C)	DO (mg/L)	Salinity

In situ Measurement of Seawater quality				
Color/odor				
Width/depth/velocity				
YSI data	pH	Temp (°C)	DO (mg/L)	Salinity

Checklists of Collected Samples	
Seawater	
POCs	HMs
Ch	Ch

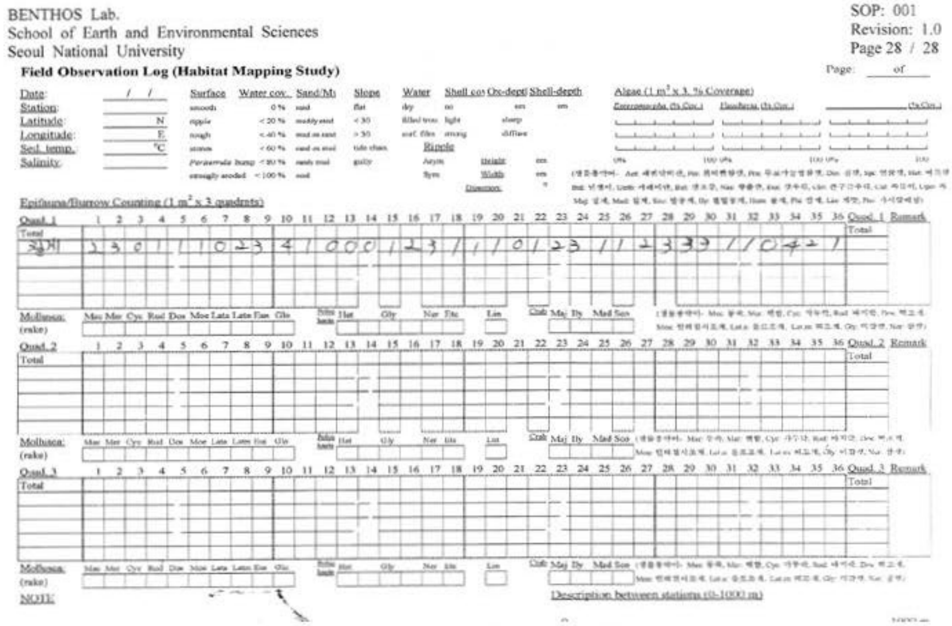
Sediment		
General property	POCs	HMs
✓	✓	✓

Biota			
MPB assemblage	Chl-a	Meiofauna & Microbiome	Macrofauna
✓	✓	✓	✓

Graphical Description & Remark

- reclaimed area?
- All biota were die (only exoskeleton)
- Very fine sediment (not muddy)
- soft sediment
- Wind power plant, Industrial area were near

Yellow Sea Ecosystem Study					
Site-ID	WF7	Date	07/04/2018	Weather	Cloudy
Location (GPS)	Latitude	37.09206 ° N		Arrival time	Departure time
	Longitude	119.55992 ° E		11:00 am	12:00 am
Recorded by	Bin Shi	Sampled by		Lu Yang Bin Shi Jongmin Lee Seo Joon Yoon	
In situ Measurement of Riverwater or Seawater quality (Mixed water)					
Color/odor					
Width/depth/velocity	Jiaolai River, estuary, width~100m				
HACH 40d data	pH	Temp (°C)	DO (mg/L)	Salinity (mS/cm)	
	3.70	29.0	21.78	56.8	
Corresponding soil information					
Site location	Latitude	° N	Landuse	Agricultural	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Field Observation Log (Habitat Mapping Study)

Date: / /
Station:
Latitude: N
Longitude: E
Sed. temp. °C
Salinity:

Epifauna/Burrow Counting (1 m² x 3 quadrats)

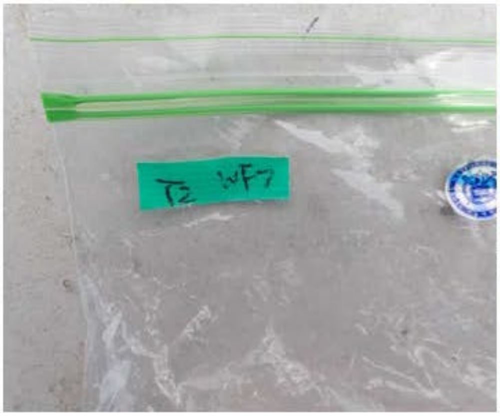
Quad. 1 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 Quad. 1 Remark

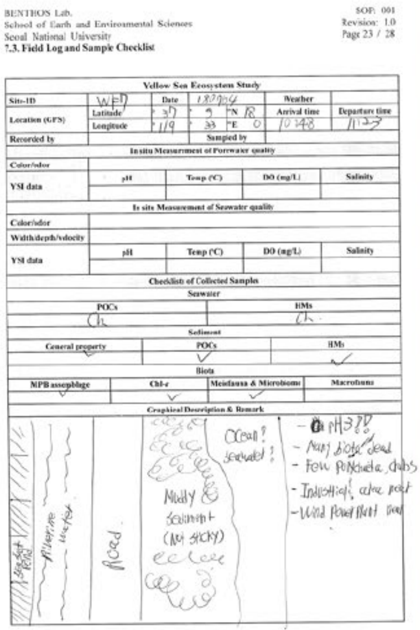
Quad. 2 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 Quad. 2 Remark

Quad. 3 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 Quad. 3 Remark

NOTE:

Description between stations (0-1000 m)

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Yellow Sea Ecosystem Study						
Site-ID	WF7	Date	180904		Weather	
Location (GPS)	Latitude	° 37	′ 9	″N R	Arrival time	Departure time
	Longitude	° 119	′ 33	″E 0	10348	11:23
Recorded by			Sampled by			

Insitu Measurment of Porewater quality				
Color/odor				
YSI data	pH	Temp (°C)	DO (mg/L)	Salinity

In situ Measurement of Seawater quality				
Color/odor				
Width/depth/velocity				
YSI data	pH	Temp (°C)	DO (mg/L)	Salinity

Checklist of Collected Samples

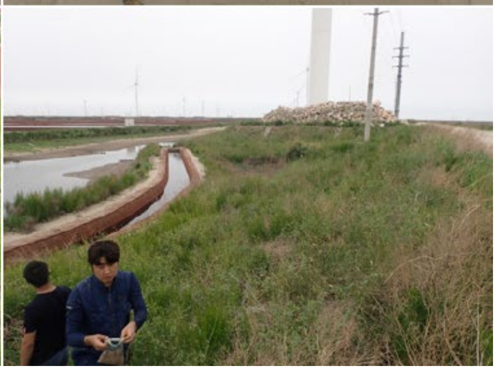
Seawater	
POCs	HMs
Ch	Ch.

Sediment		
General property	POCs	HMs
✓	✓	✓

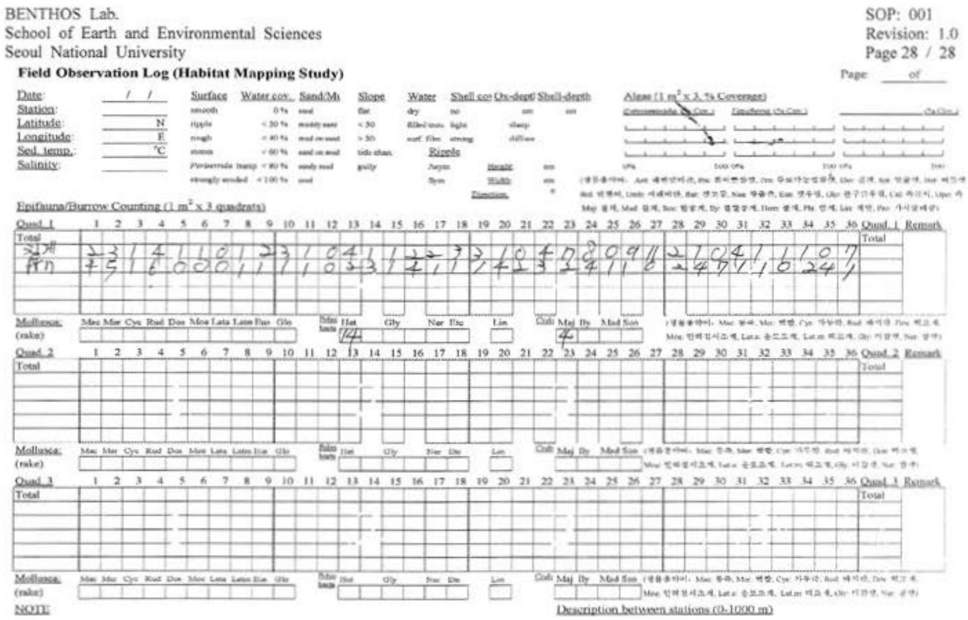
Biota			
MPB assemblage	Chl-a	Meiofauna & Microbiome	Macrofauna
✓	✓	✓	

Graphical Description & Remark

Seawater pond
Riverine water
Road
Muddy sediment (Not sticky)
Ocean? Seawater?
- pH 3?!
- Many biota dead
- Few Polychaeta, crabs
- Industrial area near
- Wind power plant near



Yellow Sea Ecosystem Study					
Site-ID	WF4	Date	07/04/2018	Weather	Cloudy
Location (GPS)	Latitude	37.07648 ° N		Arrival time	Departure time
	Longitude	119.47932 ° E		9:00 am	10:00 am
Recorded by	Bin Shi	Sampled by		Lu Yang Bin Shi Jongmin Lee Seo Joon Yoon	
In situ Measurement of Riverwater or Seawater quality (Mixed water)					
Color/odor					
Width/depth/velocity	Wei River, estuary, width~20m				
HACH 40d data	pH	Temp (°C)	DO (mg/L)	Salinity (mS/cm)	
	8.20	28.8	7.59	43.1	
Corresponding soil information					
Site location	Latitude	° N	Landuse	Municipal	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Field Observation Log (Habitat Mapping Study)

Page: of

Date: / /
Station:
Latitude: N
Longitude: E
Sed. temp.: °C
Salinity:

Surface | Water cov. | Sand/Mud | Slope | Water | Shell cov | Ox-depth | Shell-depth | Algae (1 m² x 3, % Coverage)

Ripple

Epifauna/Burrow Counting (1 m² x 3 quadrats)

Quad. 1 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 Quad. 1 Remark
Total

Mollusca: (rake) Mac Mer Cyc Rud Dos Moe Lata Latm Bus Glo
Hat 14 Gly Ner Ilo Lin
Crab Maj 4 Ily Mad Sus

Quad. 2 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 Quad. 2 Remark
Total

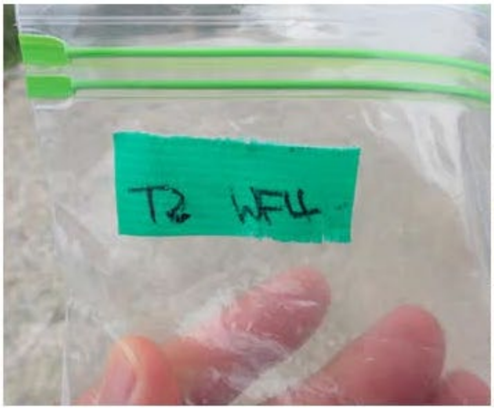
Mollusca: (rake)

Quad. 3 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 Quad. 3 Remark
Total

Mollusca: (rake)

NOTE:

Description between stations (0-1000 m)



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Yellow Sea Ecosystem Study						
Site-ID	WF4	Date	120704		Weather	
Location (GPS)	Latitude	° 37	′ 4	″N 32	Arrival time	Departure time
	Longitude	° 119	′ 28	″E 24	09:06	09:52
Recorded by			Sampled by			

In situ Measurement of Porewater quality				
Color/odor				
YSI data	pH	Temp (°C)	DO (mg/L)	Salinity

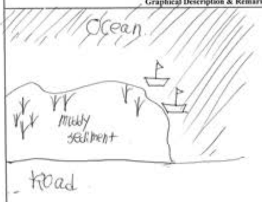
In situ Measurement of Seawater quality				
Color/odor				
Width/depth/velocity				
YSI data	pH	Temp (°C)	DO (mg/L)	Salinity

Checklists of Collected Samples	
Seawater	
POCs	HMs
Ch	Ch

Sediment		
General property	POCs	HMs ✓
✓	✓	

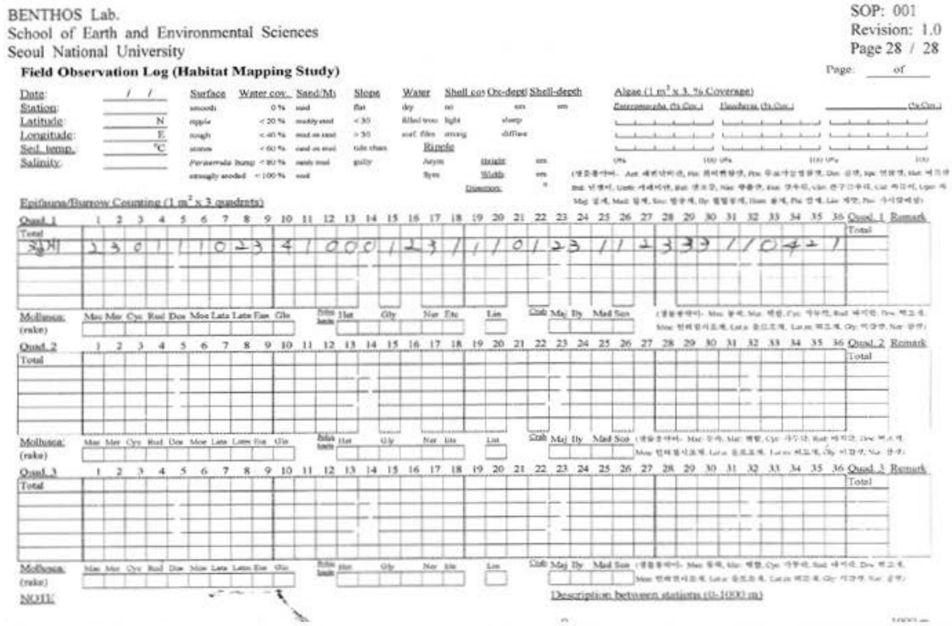
Biota			
MPB assemblage	Chl-a	Meiofauna & Microbiome	Macrofauna
✓	✓	✓	✓

Graphical Description & Remark



- Many burrows (Crabs, Polychaeta)
- Halophyte exist (Suaeda ??)

Yellow Sea Ecosystem Study					
Site-ID	WF7	Date	07/04/2018	Weather	Cloudy
Location (GPS)	Latitude	37.09206 ° N		Arrival time	Departure time
	Longitude	119.55992 ° E		11:00 am	12:00 am
Recorded by	Bin Shi	Sampled by		Lu Yang Bin Shi Jongmin Lee Seo Joon Yoon	
In situ Measurement of Riverwater or Seawater quality (Mixed water)					
Color/odor					
Width/depth/velocity	Jiaolai River, estuary, width~100m				
HACH 40d data	pH	Temp (°C)	DO (mg/L)	Salinity (mS/cm)	
	3.70	29.0	21.78	56.8	
Corresponding soil information					
Site location	Latitude	° N	Landuse	Agricultural	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Field Observation Log (Habitat Mapping Study)

Date: / /
Station:
Latitude: N
Longitude: E
Sed. temp.: °C
Salinity:

Epifauna/Burrow Counting (1 m² x 3 quadrats)

Quad. 1
Total

Mollusca: (rake)

Quad. 2
Total

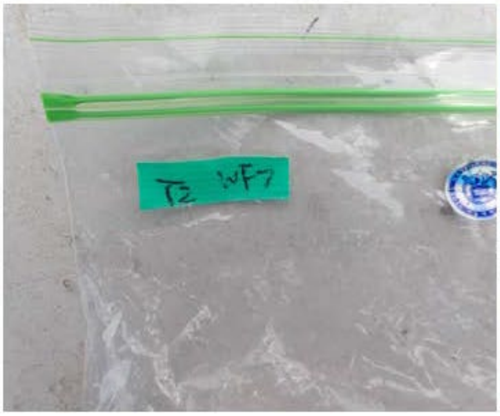
Mollusca: (rake)

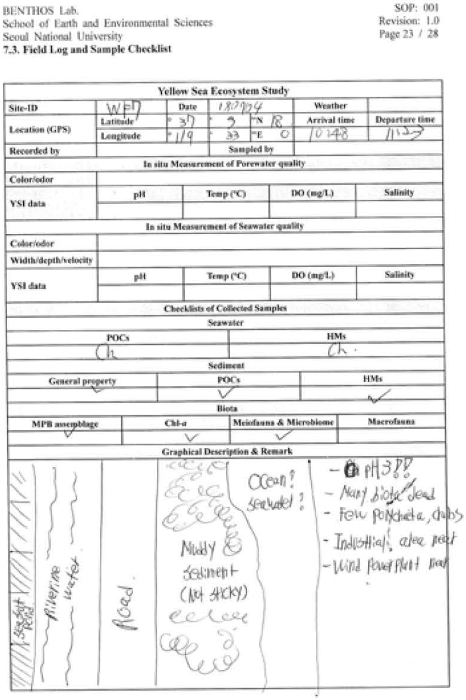
Quad. 3
Total

Mollusca: (rake)

NOTE:

Description between stations (0-1000 m)





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Yellow Sea Ecosystem Study						
Site-ID	WF17	Date	180724		Weather	
Location (GPS)	Latitude	° 37	′ 3	″N 18	Arrival time	Departure time
	Longitude	° 119	′ 33	″E 0	10:48	11:23
Recorded by			Sampled by			

In situ Measurement of Porewater quality				
Color/odor				
YSI data	pH	Temp (°C)	DO (mg/L)	Salinity

In situ Measurement of Seawater quality				
Color/odor				
Width/depth/velocity				
YSI data	pH	Temp (°C)	DO (mg/L)	Salinity

Checklists of Collected Samples

Seawater	
POCs	HMs
Ch	Ch.

Sediment		
General property	POCs	HMs
✓	✓	✓

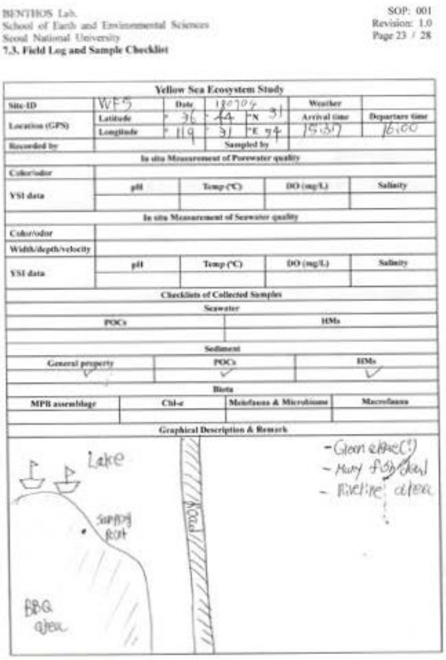
Biota			
MPB assemblage	Chl-a	Meiofauna & Microbiome	Macrofauna
✓	✓	✓	

Graphical Description & Remark

Salt pond
Riverine water
Road
Muddy sediment (Not sticky)
Ocean? seawater?

- pH 3?!
- Many biota dead
- Few polychaeta, crabs
- Industrial area near
- Wind Power Plant near

Yellow Sea Ecosystem Study					
Site-ID	WF6	Date	07/04/2018	Weather	Sunny
Location (GPS)	Latitude	36.74207 ° N		Arrival time	Departure time
	Longitude	119.53735 ° E		13:00 pm	14:30 pm
Recorded by	Bin Shi	Sampled by		Lu Yang Bin Shi Jongmin Lee Seo Joon Yoon	
In situ Measurement of Riverwater or Seawater quality (Mixed water)					
Color/odor					
Width/depth/velocity	Jiaolai River, upstream, width~50m, algae around				
HACH 40d data	pH	Temp (°C)	DO (mg/L)	Salinity (mS/cm)	
	7.38	26.1	0.32	3.30	
Corresponding soil information					
Site location	Latitude	37.06769 ° N	Landuse	Agricultural	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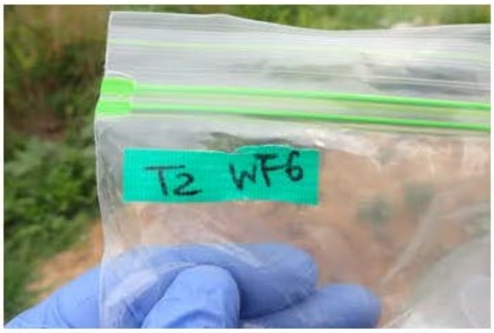
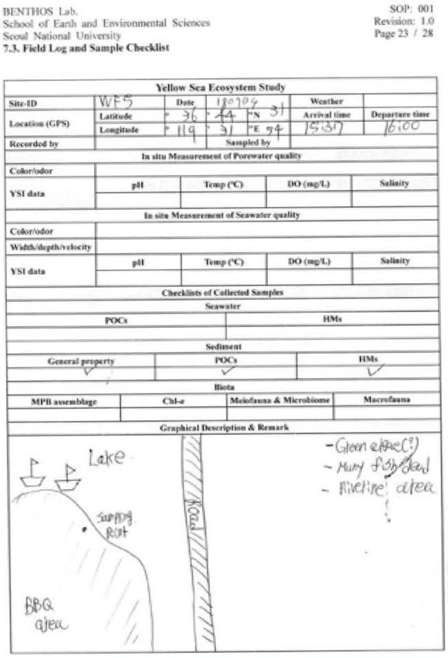
Yellow Sea Ecosystem Study					
Site-ID	WF5	Date	180704	Weather	
Location (GPS)	Latitude	° 36 ' 44 ° N 31		Arrival time	Departure time
	Longitude	° 119 ' 31 ° E 94		15:30	16:00
Recorded by		Sampled by			
In situ Measurement of Porewater quality					
Color/odor					
YSI data	pH	Temp (°C)	DO (mg/L)	Salinity	
In situ Measurement of Seawater quality					
Color/odor					
Width/depth/velocity					
YSI data	pH	Temp (°C)	DO (mg/L)	Salinity	
Checklists of Collected Samples					
Seawater					
POCs	HMs				
Sediment					
General property	POCs	HMs			
✓	✓	✓			
Biota					
MPB assemblage	Chl-a	Meiofauna & Microbiome	Macrofauna		
Graphical Description & Remark					

Lake
Road




BOX

Yellow Sea Ecosystem Study					
Site-ID	WF5	Date	07/04/2018	Weather	Sunny
Location (GPS)	Latitude	36.58023 ° N		Arrival time	Departure time
	Longitude	119.38462 ° E		15:00 pm	16:00 pm
Recorded by	Bin Shi	Sampled by	Lu Yang Bin Shi Jongmin Lee Seo Joon Yoon		
In situ Measurement of Riverwater or Seawater quality (Freshwater)					
Color/odor					
Width/depth/velocity	Wei River, upstream, width~100m				
HACH 40d data	pH	Temp (°C)	DO (mg/L)	Salinity (mS/cm)	
	9.18	31.2	18.1	1.71	
Corresponding soil information					
Site location	Latitude	° N	Landuse	Agricultural	



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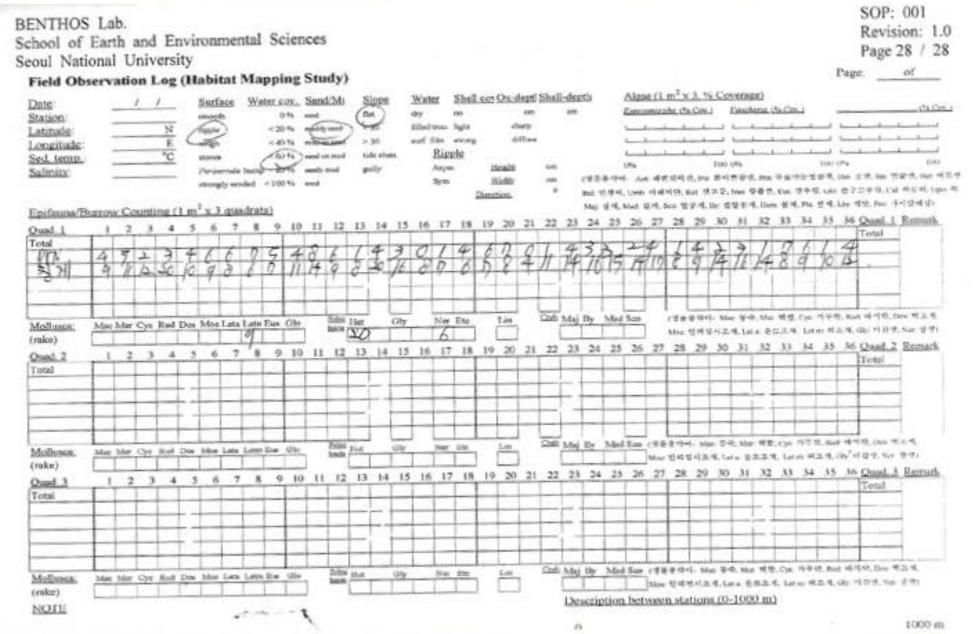
Yellow Sea Ecosystem Study							
Site-ID	WF5	Date	180704		Weather		
Location (GPS)	Latitude	° 36	' 44	"N 31	Arrival time	Departure time	
	Longitude	° 119	' 31	"E 94	15:31	16:00	
Recorded by		Sampled by					
In situ Measurement of Porewater quality							
Color/odor							
YSI data	pH	Temp (°C)	DO (mg/L)	Salinity			
In situ Measurement of Seawater quality							
Color/odor							
Width/depth/velocity							
YSI data	pH	Temp (°C)	DO (mg/L)	Salinity			
Checklists of Collected Samples							
Seawater							
POCs	HMs						
Sediment							
General property	POCs	HMs					
✓	✓	✓					
Biota							
MPB assemblage	Chl-a	Meiofauna & Microbiome	Macrofauna				
Graphical Description & Remark							

Yellow Sea Ecosystem Study							
Site-ID	WF2	Date	07/05/2018		Weather	Sunny	
Location (GPS)	Latitude	37.13543 ° N			Arrival time	Departure time	
	Longitude	119.28702 ° E			10:00 am	11:00 am	
Recorded by	Bin Shi		Sampled by		Lu Yang Bin Shi Jongmin Lee Seo Joon Yoon		
In situ Measurement of Riverwater or Seawater quality (Mixed water)							
Color/odor							
Width/depth/velocity	Yu River, estuary, width~100m						
HACH 40d data	pH	Temp (°C)		DO (mg/L)		Salinity (mS/cm)	
	8.19	29.8		8.88		41.3	
Corresponding soil information							
Site location	Latitude	° N		Landuse		Agricultural	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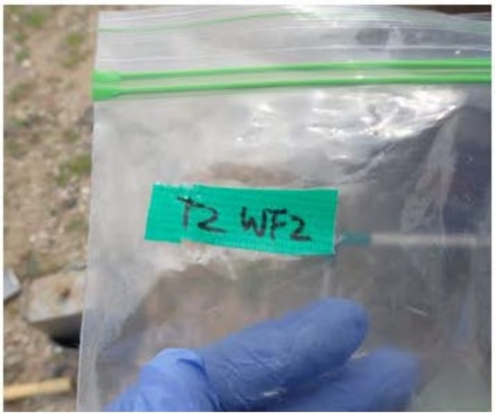
Field Observation Log (Habitat Mapping Study)



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Yellow Sea Ecosystem Study						
Site-ID	WFJ	Date	18.07.05		Weather	
Location (GPS)	Latitude	° 37	′ 17	″N 34	Arrival time	Departure time
	Longitude	° 119	′ 15	″E 48	10:03	10:44
Recorded by			Sampled by			

In situ Measurement of Porewater quality				
Color/odor				
YSI data	pH	Temp (°C)	DO (mg/L)	Salinity

In situ Measurement of Seawater quality				
Color/odor				
Width/depth/velocity				
YSI data	pH	Temp (°C)	DO (mg/L)	Salinity

Checklists of Collected Samples

Seawater	
POCs	HMs
Ch	Ch

Sediment		
General property	POCs	HMs
✓	✓	✓

Biota			
MPB assemblage	Chl-a	Meiofauna & Microbiome	Macrofauna
✓	✓	✓	✓

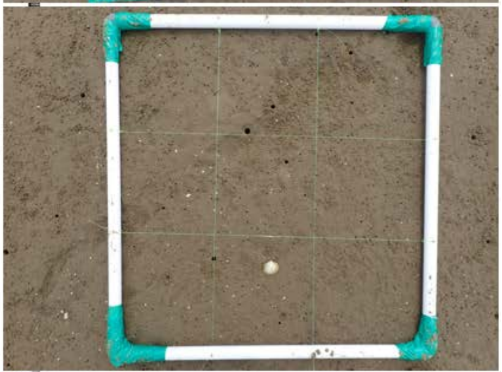
Graphical Description & Remark

Ocean

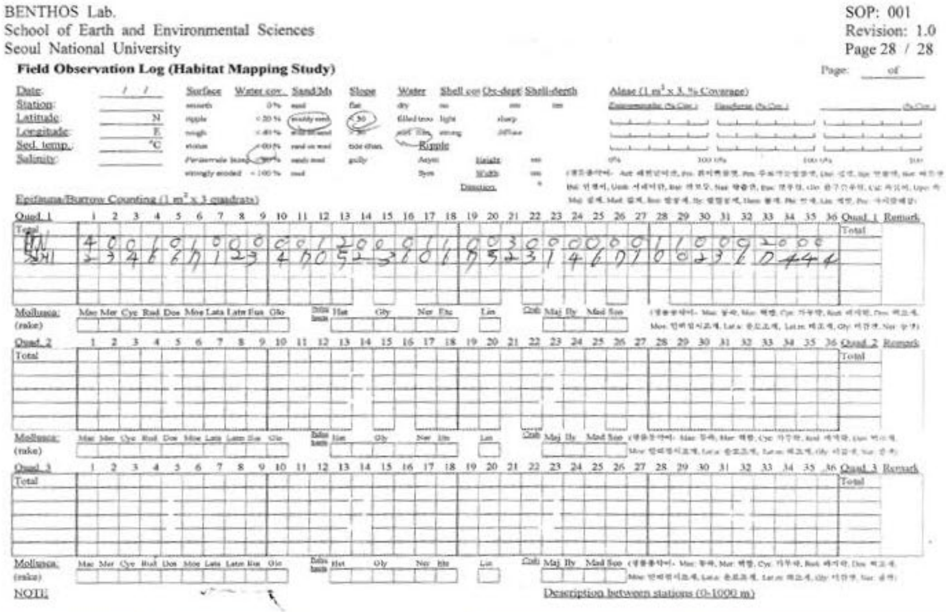
sampling point

Road

-Many burrows (crabs, polychaeta)



Yellow Sea Ecosystem Study					
Site-ID	WF8	Date	07/05/2018	Weather	Sunny
Location (GPS)	Latitude	37.13299 ° N		Arrival time	Departure time
	Longitude	119.18600 ° E		11:00 am	12:00 am
Recorded by	Bin Shi	Sampled by		Lu Yang Bin Shi Jongmin Lee Seo Joon Yoon	
In situ Measurement of Riverwater or Seawater quality (Seawater)					
Color/odor					
Width/depth/velocity	Bailang River, estuary, width~500m				
HACH 40d data	pH	Temp (°C)	DO (mg/L)	Salinity (mS/cm)	
	8.54	31.3	8.99	64.3	
Corresponding soil information					
Site location	Latitude	° N	Landuse	Municipal	



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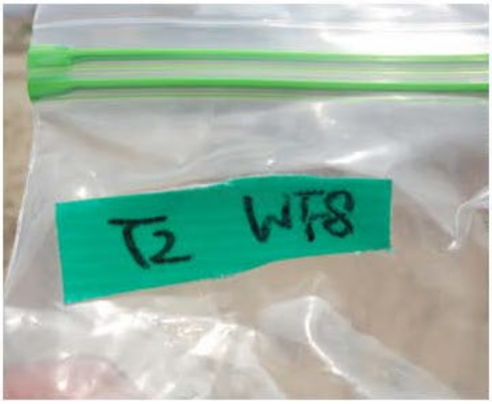
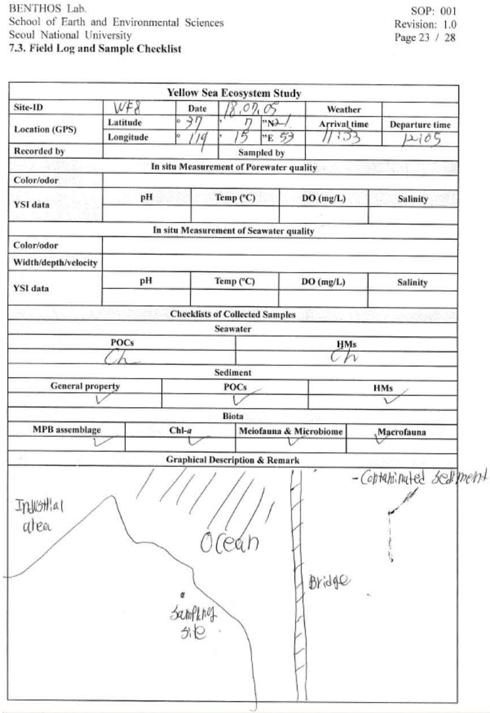
Field Observation Log (Habitat Mapping Study)





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Yellow Sea Ecosystem Study						
Site-ID	WF8	Date	18.07.05		Weather	
Location (GPS)	Latitude	° 37	' 7	" N 21	Arrival time	Departure time
	Longitude	° 119	' 15	" E 59	11:33	12:05
Recorded by			Sampled by			

In situ Measurement of Porewater quality				
Color/odor				
YSI data	pH	Temp (°C)	DO (mg/L)	Salinity

In situ Measurement of Seawater quality				
Color/odor				
Width/depth/velocity				
YSI data	pH	Temp (°C)	DO (mg/L)	Salinity

Checklists of Collected Samples

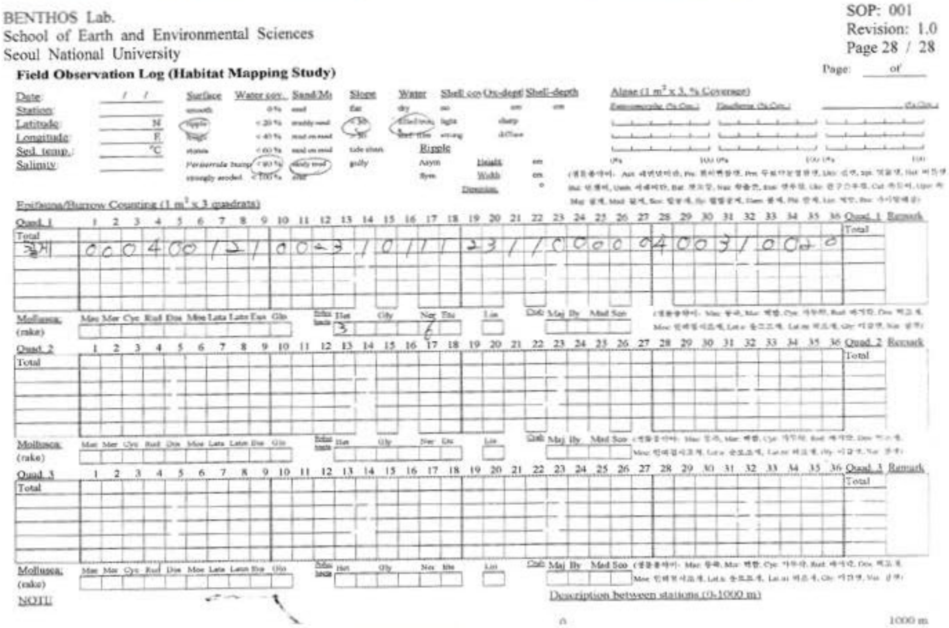
Seawater	
POCs	HMs
Ch	Ch

Sediment		
General property	POCs	HMs
✓	✓	✓

Biota			
MPB assemblage	Chl-*a*	Meiofauna & Microbiome	Macrofauna
✓	✓	✓	✓

Graphical Description & Remark

Yellow Sea Ecosystem Study						
Site-ID	WF3	Date	07/05/2018		Weather	Sunny
Location (GPS)	Latitude	37.14009 ° N			Arrival time	Departure time
	Longitude	119.14338 ° E			12:00 am	13:00 pm
Recorded by	Bin Shi		Sampled by		Lu Yang Bin Shi Jongmin Lee Seo Joon Yoon	
In situ Measurement of Riverwater or Seawater quality (Mixed water)						
Color/odor						
Width/depth/velocity	Mi River, estuary, width~200m					
HACH 40d data	pH	Temp (°C)		DO (mg/L)	Salinity (mS/cm)	
	8.80	32.1		12.6	53.3	
Corresponding soil information						
Site location	Latitude	° N		Landuse	Industrial	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Field Observation Log (Habitat Mapping Study)

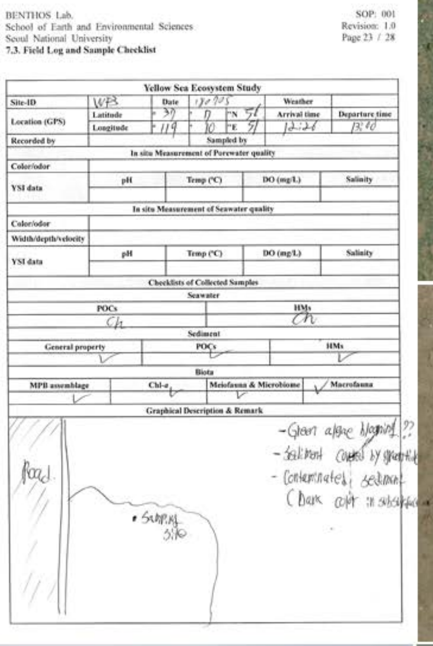
Epifauna/Burrow Counting (1 m² x 3 quadrats)

Quad. 1 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 Quad. 1 Remark

Quad. 2

Quad. 3

Description between stations (0-1000 m)



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Yellow Sea Ecosystem Study							
Site-ID	WP3	Date	170705		Weather		
Location (GPS)	Latitude	° 37	° 17	'N 56	Arrival time	Departure time	
	Longitude	° 119	° 10	'E 51	12:26	13:40	
Recorded by			Sampled by				

In situ Measurement of Porewater quality				
Color/odor				
YSI data	pH	Temp (°C)	DO (mg/L)	Salinity

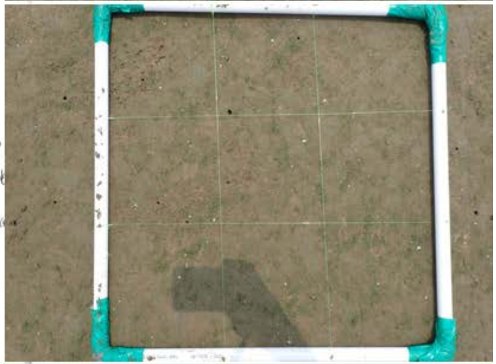
In situ Measurement of Seawater quality				
Color/odor				
Width/depth/velocity				
YSI data	pH	Temp (°C)	DO (mg/L)	Salinity

Checklists of Collected Samples	
Seawater	
POCs	HMs
Ch	Ch

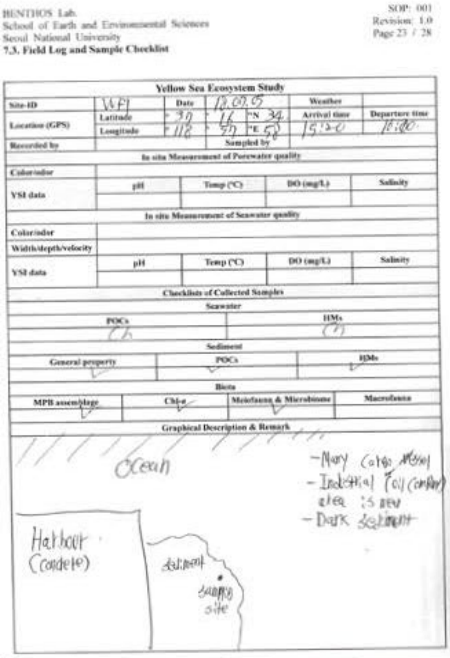
Sediment		
General property	POCs	HMs
✓	✓	✓

Biota			
MPB assemblage	Chl-a	Meiofauna & Microbiome	Macrofauna
✓	✓	✓	✓

Graphical Description & Remark



Yellow Sea Ecosystem Study					
Site-ID	WF1	Date	07/05/2018	Weather	Sunny
Location (GPS)	Latitude	37.27514 ° N		Arrival time	Departure time
	Longitude	118.98481 ° E		15:30 pm	16:30 pm
Recorded by	Bin Shi		Sampled by	Lu Yang Bin Shi Jongmin Lee Seo Joon Yoon	
In situ Measurement of Riverwater or Seawater quality (Mixed water)					
Color/odor					
Width/depth/velocity	Xiaoqing River, estuary, width~500m				
HACH 40d data	pH	Temp (°C)	DO (mg/L)	Salinity (mS/cm)	
	7.87	30.0	4.8	10.5	
Corresponding soil information					
Site location	Latitude	° N	Landuse	Agricultural	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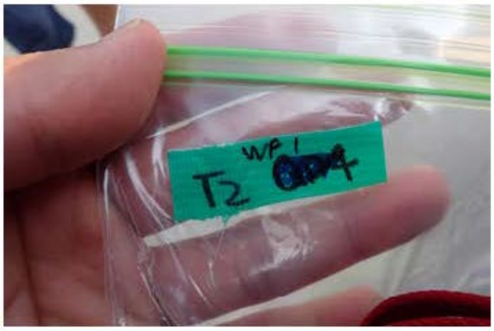
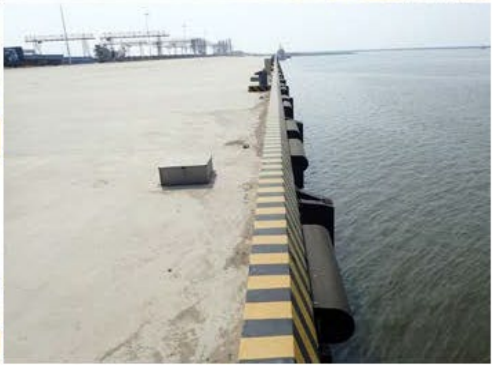
Yellow Sea Ecosystem Study					
Site-ID	WF1	Date	18.07.05	Weather	
Location (GPS)	Latitude	° 37	° 16 ′N 34	Arrival time	Departure time
	Longitude	° 118	° 59 ′E 58	15:20	16:00
Recorded by		Sampled by			
In situ Measurement of Porewater quality					
Color/odor					
YSI data	pH	Temp (°C)	DO (mg/L)	Salinity	
In situ Measurement of Seawater quality					
Color/odor					
Width/depth/velocity					
YSI data	pH	Temp (°C)	DO (mg/L)	Salinity	
Checklists of Collected Samples					
Seawater					
POCs	HMs				
Sediment					
General property	POCs	HMs			
Biota					
MPB assemblage	Chl-a	Meiofauna & Microbiome	Macrofauna		
Graphical Description & Remark					

Ocean
Harbour (concrete)
sediment
sampling site
- Many cargo vessel
- Industrial (oil company) area is near
- Dark sediment

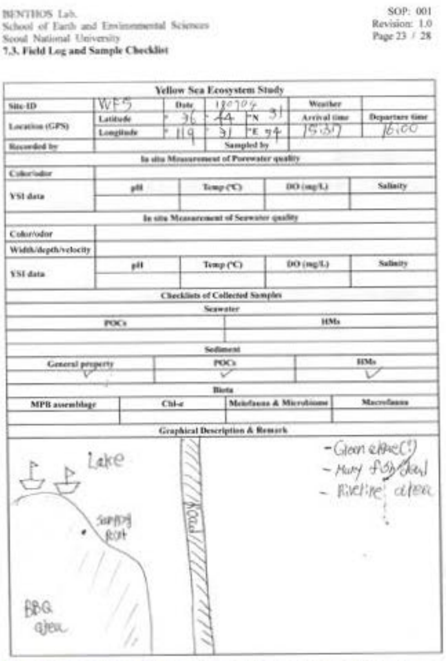









Yellow Sea Ecosystem Study					
Site-ID	DY5	Date	07/05/2018	Weather	Sunny
Location (GPS)	Latitude	37.13629 ° N		Arrival time	Departure time
	Longitude	118.43219 ° E		16:30 pm	17:00 pm
Recorded by	Bin Shi	Sampled by		Lu Yang Bin Shi Jongmin Lee Seo Joon Yoon	
In situ Measurement of Riverwater or Seawater quality (Mixed water)					
Color/odor					
Width/depth/velocity	Xiaoqing River, upstream, width~100m				
HACH 40d data	pH	Temp (°C)	DO (mg/L)	Salinity (mS/cm)	
	8.09	30.5	9.44	2.48	
Corresponding soil information					
Site location	Latitude	° N	Landuse	Agricultural	



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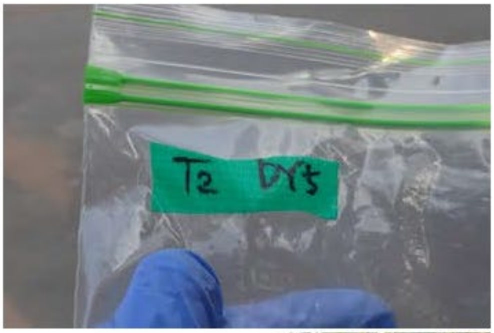
Yellow Sea Ecosystem Study					
Site-ID	WF5	Date	180704	Weather	
Location (GPS)	Latitude	° 36 ° 44	′N 31	Arrival time	Departure time
	Longitude	° 119 ° 31	′E 94	15:30	16:00
Recorded by		Sampled by			
In situ Measurement of Porewater quality					
Color/odor					
YSI data	pH	Temp (°C)	DO (mg/L)	Salinity	
In situ Measurement of Seawater quality					
Color/odor					
Width/depth/velocity					
YSI data	pH	Temp (°C)	DO (mg/L)	Salinity	
Checklists of Collected Samples					
Seawater					
POCs	HMs				
Sediment					
General property	POCs	HMs			
✓	✓	✓			
Biota					
MPB assemblage	Chl-a	Meiofauna & Microbiome	Macrofauna		
Graphical Description & Remark					

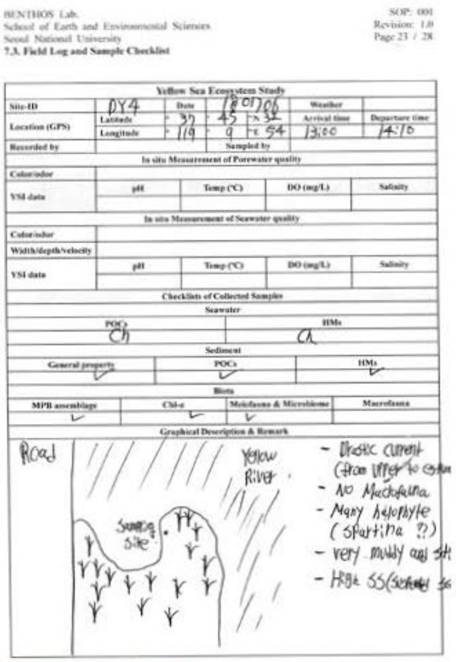
Lake

Road

- Green algae(?)



Yellow Sea Ecosystem Study					
Site-ID	DY4	Date	07/06/2018	Weather	Sunny
Location (GPS)	Latitude	37.76145 ° N		Arrival time	Departure time
	Longitude	119.17063 ° E		12:30 pm	14:00 pm
Recorded by	Bin Shi	Sampled by		Lu Yang Bin Shi Jongmin Lee Seo Joon Yoon	
In situ Measurement of Riverwater or Seawater quality (Freshwater)					
Color/odor					
Width/depth/velocity	Yellow River, estuary				
HACH 40d data	pH	Temp (°C)	DO (mg/L)	Salinity (mS/cm)	
	8.41	33.1	8.42	1.10	
Corresponding soil information					
Site location	Latitude	° N	Landuse	Agricultural	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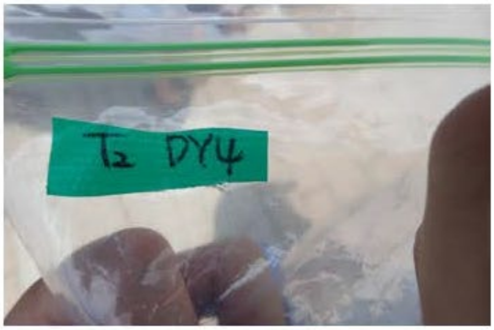
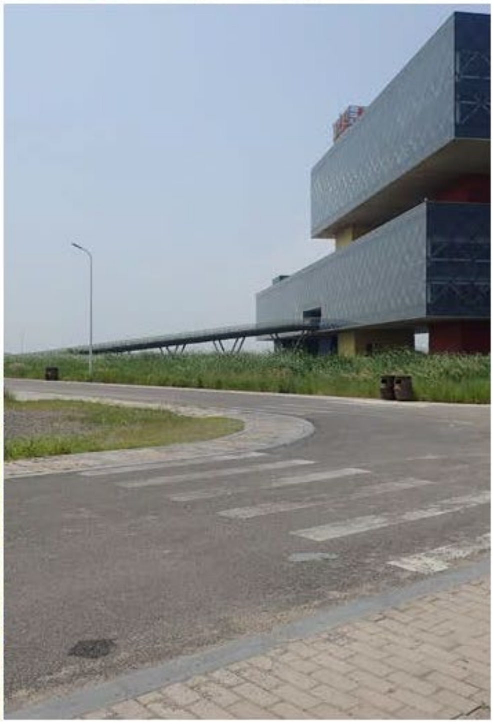
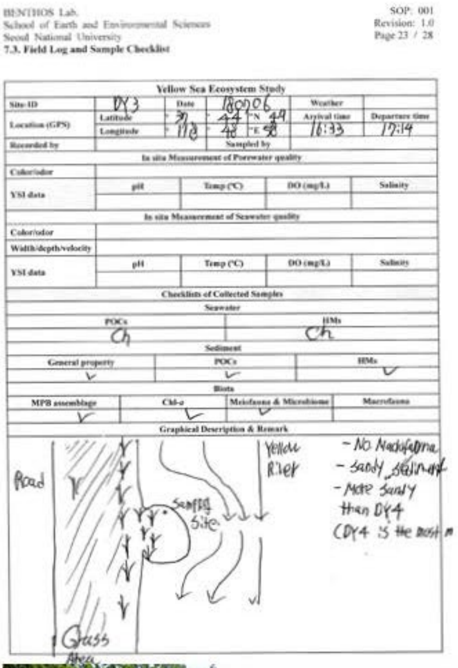
Yellow Sea Ecosystem Study						
Site-ID	DY4	Date	180706	Weather		
Location (GPS)	Latitude	37	45	N 32	Arrival time	Departure time
	Longitude	119	9	E 54	13:00	14:10
Recorded by			Sampled by			
In situ Measurement of Porewater quality						
Color/odor						
YSI data	pH	Temp (°C)	DO (mg/L)	Salinity		
In situ Measurement of Seawater quality						
Color/odor						
Width/depth/velocity						
YSI data	pH	Temp (°C)	DO (mg/L)	Salinity		
Checklists of Collected Samples						
Seawater						
POCs	Ch	HMs	Cl			
Sediment						
General property	✓	POCs	✓	HMs	✓	
Biota						
MPB assemblage	✓	Chl-a	✓	Meiofauna & Microbiome	✓	Macrofauna
Graphical Description & Remark						

Road
Yellow River
Sampling site
- Drastic current (from upper to ...)
- No Macrofauna
- Many halophyte (Spartina ??)
- very muddy and silt
- High SS(...)





Yellow Sea Ecosystem Study					
Site-ID	DY3	Date	07/06/2018	Weather	Sunny
Location (GPS)	Latitude	37.74812 ° N		Arrival time	Departure time
	Longitude	118.82139 ° E		16:20 pm	16:50 pm
Recorded by	Bin Shi	Sampled by		Lu Yang Bin Shi Jongmin Lee Seo Joon Yoon	
In situ Measurement of Riverwater or Seawater quality (Freshwater)					
Color/odor					
Width/depth/velocity	Yellow River				
HACH 40d data	pH	Temp (°C)	DO (mg/L)	Salinity (mS/cm)	
	—	—	—	—	
Corresponding soil information					
Site location	Latitude	° N	Landuse	Agricultural	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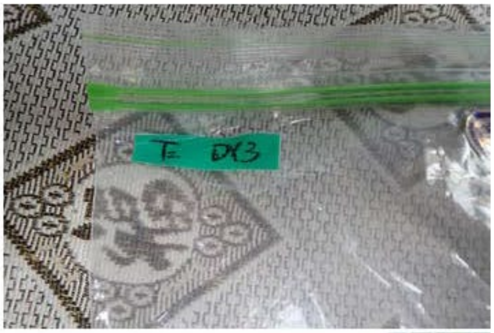
Yellow Sea Ecosystem Study					
Site-ID	DY3	Date	180706	Weather	
Location (GPS)	Latitude	° 37	° 44 ′N 49	Arrival time	Departure time
	Longitude	° 118	° 48 ′E 58	16:33	17:14
Recorded by		Sampled by			
In situ Measurement of Porewater quality					
Color/odor					
YSI data	pH	Temp (°C)	DO (mg/L)	Salinity	
In situ Measurement of Seawater quality					
Color/odor					
Width/depth/velocity					
YSI data	pH	Temp (°C)	DO (mg/L)	Salinity	
Checklists of Collected Samples					
Seawater					
POCs	Ch	HMs	Ch		
Sediment					
General property	✓	POCs	✓	HMs	✓
Biota					
MPB assemblage	✓	Chl-a	✓	Meiofauna & Microbiome	✓
Macrofauna					
Graphical Description & Remark					








Yellow Sea Ecosystem Study					
Site-ID	DY2	Date	07/06/2018	Weather	Sunny
Location (GPS)	Latitude	37.60460 ° N		Arrival time	Departure time
	Longitude	118.53839 ° E		17:00 pm	18:00 pm
Recorded by	Bin Shi	Sampled by		Lu Yang Bin Shi Jongmin Lee Seo Joon Yoon	
In situ Measurement of Riverwater or Seawater quality (Freshwater)					
Color/odor					
Width/depth/velocity	Yellow River				
HACH 40d data	pH	Temp (°C)	DO (mg/L)	Salinity (mS/cm)	
	8.23	30.1	7.64	0.77	
Corresponding soil information					
Site location	Latitude	° N	Landuse	Municipal	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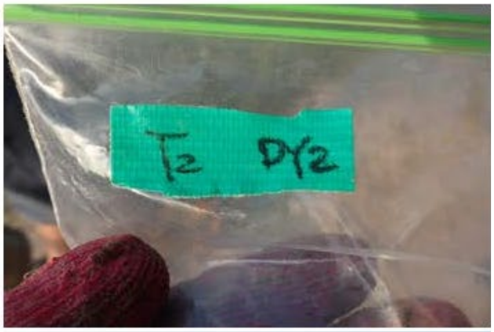
Yellow Sea Ecosystem Study						
Site ID	DY2	Date	180706		Weather	
Location (GPS)	Latitude	° 37	' 36	"N 12	Arrival time	Departure time
	Longitude	° 118	' 31	"E 54	18:21	19:51
Recorded by			Sampled by			

In situ Measurement of Porewater quality: Color/odor; YSI data: pH, Temp (°C), DO (mg/L), Salinity

In situ Measurement of Seawater quality: Color/odor; Width/depth/velocity; YSI data: pH, Temp (°C), DO (mg/L), Salinity

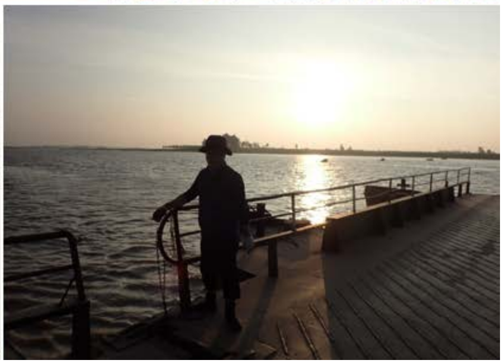
Checklists of Collected Samples
Seawater: POCs Ch; HMs Ch
Sediment: General property ✓; POCs ✓; HMs ✓
Biota: MPB assemblage; Chl-a; Meiofauna; Microbiome ✓; Macrofauna

Graphical Description & Remark
Road
Yellow River. - No Macrofauna
- Beside the river
Muddy sand sedi.

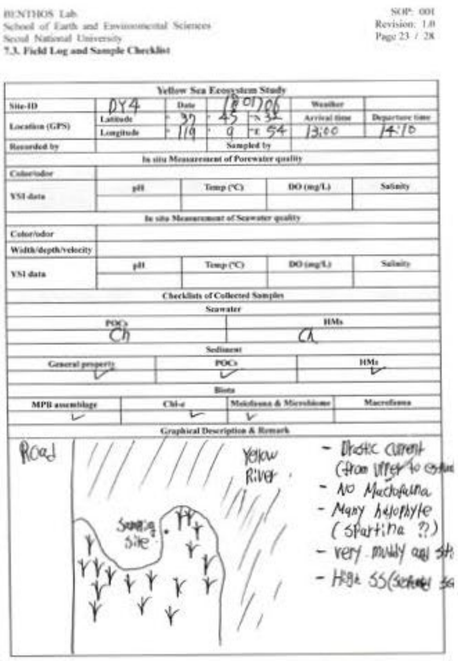








Yellow Sea Ecosystem Study						
Site-ID	DY1	Date	07/07/2018		Weather	Sunny
Location (GPS)	Latitude	37.48508 ° N			Arrival time	Departure time
	Longitude	118.26911 ° E			10:00 am	10:30 am
Recorded by	Bin Shi		Sampled by		Lu Yang Bin Shi Jongmin Lee Seo Joon Yoon	
In situ Measurement of Riverwater or Seawater quality (Freshwater)						
Color/odor						
Width/depth/velocity	Yellow River					
HACH 40d data	pH	Temp (°C)		DO (mg/L)	Salinity (mS/cm)	
	8.47	29.3		7.36	1.04	
Corresponding soil information						
Site location	Latitude	° N		Landuse	Municipal	



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Yellow Sea Ecosystem Study						
Site-ID	DY4	Date	180706		Weather	
Location (GPS)	Latitude	° 37	° 45	″N 32	Arrival time	Departure time
	Longitude	° 119	° 9	″E 54	13:00	14:10
Recorded by			Sampled by			
In situ Measurement of Porewater quality						
Color/odor						
YSI data	pH	Temp (°C)		DO (mg/L)	Salinity	
In situ Measurement of Seawater quality						
Color/odor						
Width/depth/velocity						
YSI data	pH	Temp (°C)		DO (mg/L)	Salinity	
Checklists of Collected Samples						
Seawater						
POCs			HMs			
Ch			Ch			
Sediment						
General property		POCs		HMs		
✓		✓		✓		
Biota						
MPB assemblage	Chl-a		Meiofauna & Microbiome		Macrofauna	
✓	✓		✓			
Graphical Description & Remark						


DY-1
DY-1
DY-1
DY-1

Yellow Sea Ecosystem Study					
Site-ID	BZ5	Date	20180707	Weather	Sunny
Location (GPS)	Latitude	37.24967 ° N		Arrival time	Departure time
	Longitude	117.72314 ° E		15:00 pm	16:00 pm
Recorded by	Bin Shi	Sampled by		Lu Yang Bin Shi Jongmin Lee Seo Joon Yoon	
In situ Measurement of Riverwater or Seawater quality (Freshwater)					
Color/odor					
Width/depth/velocity	Yellow River				
HACH 40d data	pH	Temp (°C)	DO (mg/L)	Salinity (mS/cm)	
	8.20	30.5	5.09	0.83	
Corresponding soil information					
Site location	Latitude	° N	Landuse	Agricultural	

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Yellow Sea Ecosystem Study						
Site-ID	BZ5	Date	180707		Weather	
Location (GPS)	Latitude	° 37	° 14	' N 56	Arrival time	Departure time
	Longitude	° 117	° 43	' E 6	15:30	16:00
Recorded by			Sampled by			
In situ Measurement of Porewater quality						
Color/odor						
YSI data	pH	Temp (°C)	DO (mg/L)	Salinity		
In situ Measurement of Seawater quality						
Color/odor						
Width/depth/velocity						
YSI data	pH	Temp (°C)	DO (mg/L)	Salinity		
Checklists of Collected Samples						
Seawater						
POCs	Ch	HMs	Ch			
Sediment						
General property	✓	POCs	✓	HMs	✓	
Biota						
MPB assemblage		Chl-a		Meiofauna & Microbiome		Macrofauna
Graphical Description & Remark						

sunny site
Corn farm
- No Macro fauna
- Beside river

Yellow Sea Ecosystem Study						
Site-ID	BZ6	Date	07/07/2018		Weather	Sunny
Location (GPS)	Latitude	37.33501 ° N			Arrival time	Departure time
	Longitude	118.05764 ° E			12:00 am	13:00 pm
Recorded by	Bin Shi		Sampled by		Lu Yang Bin Shi Jongmin Lee Seo Joon Yoon	
In situ Measurement of Riverwater or Seawater quality (Freshwater)						
Color/odor						
Width/depth/velocity	Yellow River					
HACH 40d data	pH	Temp (°C)		DO (mg/L)	Salinity (mS/cm)	
	8.47	29.9		7.1	0.78	
Corresponding soil information						
Site location	Latitude	° N		Landuse	Industrial	

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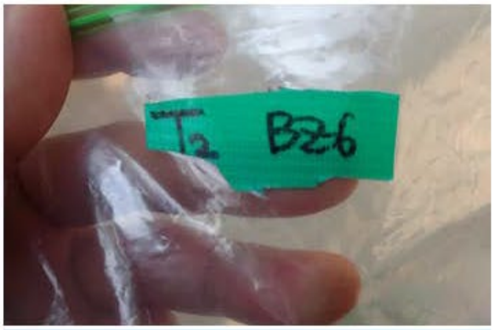
Yellow Sea Ecosystem Study						
Site-ID	BZ6	Date	180707		Weather	
Location (GPS)	Latitude	° 37	° 59	° N	Arrival time	Departure time
	Longitude	° 118	° 15	° E 47	12:03	12:41
Recorded by			Sampled by			
In situ Measurement of Porewater quality						
Color/odor						
YSI data	pH	Temp (°C)		DO (mg/L)	Salinity	
In situ Measurement of Seawater quality						
Color/odor						
Width/depth/velocity						
YSI data	pH	Temp (°C)		DO (mg/L)	Salinity	
Checklists of Collected Samples						
Seawater						
POCs			HMs			
Sediment						
General property	POCs		HMs			
Biota						
MPB assemblage	Chl-a		Meiofauna & Microbiome		Macrofauna	
Graphical Description & Remark						

River
Samp Site
- No Macrofauna
- Besides Tao




B2-6

Yellow Sea Ecosystem Study					
Site-ID	BZ4	Date	07/07/2018	Weather	Sunny
Location (GPS)	Latitude	37.50097 ° N		Arrival time	Departure time
	Longitude	117.85402 ° E		17:30 pm	18:30 pm
Recorded by	Bin Shi	Sampled by	Lu Yang Bin Shi Jongmin Lee Seo Joon Yoon		
In situ Measurement of Riverwater or Seawater quality (Freshwater)					
Color/odor					
Width/depth/velocity	Tuhai River, upstream, width~100m				
HACH 40d data	pH	Temp (°C)	DO (mg/L)	Salinity (mS/cm)	
	8.90	32.2	16.25	1.90	
Corresponding soil information					
Site location	Latitude	° N	Landuse	Agricultural	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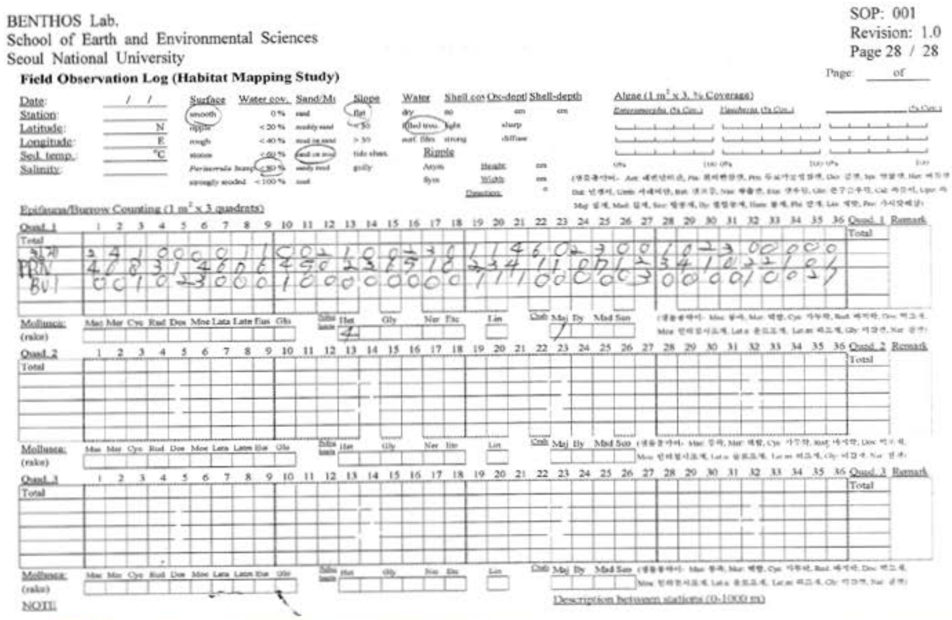
Yellow Sea Ecosystem Study						
Site-ID	BZ4	Date	180707		Weather	
Location (GPS)	Latitude	°37	'14	"N 50	Arrival time	Departure time
	Longitude	°117	'43	"E 1	1753	1750
Recorded by			Sampled by			
In situ Measurement of Porewater quality						
Color/odor						
YSI data	pH	Temp (°C)	DO (mg/L)	Salinity		
In situ Measurement of Seawater quality						
Color/odor						
Width/depth/velocity						
YSI data	pH	Temp (°C)	DO (mg/L)	Salinity		
Checklists of Collected Samples						
Seawater						
POCs	HMs					
Sediment						
General property	POCs	HMs				
✓	✓	✓				
Biota						
MPB assemblage	Chl-a	Meiofauna & Microbiome	Macrofauna			
Graphical Description & Remark						

sampling site.
-No Macrofaune
-Beside river
Road.


SAILING

Yellow Sea Ecosystem Study					
Site-ID	BZ3	Date	07/08/2018	Weather	Cloudy/Rainy
Location (GPS)	Latitude	38.14603 ° N		Arrival time	Departure time
	Longitude	118.05282 ° E		13:30 pm	14:00 pm
Recorded by	Bin Shi	Sampled by		Shuqin Chen Bin Shi Jongmin Lee Seo Joon Yoon	
In situ Measurement of Riverwater or Seawater quality (Mixed water)					
Color/odor					
Width/depth/velocity	Tuhai River, estuary, width~15m (Estuary width~1000m)				
HACH 40d data	pH	Temp (°C)	DO (mg/L)	Salinity (mS/cm)	
	8.40	27.2	8.40	27.0	
Corresponding soil information					
Site location	Latitude	° N	Landuse	Unused land	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Field Observation Log (Habitat Mapping Study)

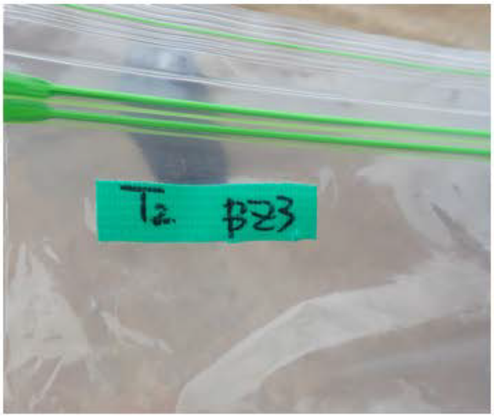
Epifauna/Burrow Counting (1 m² x 3 quadrats)

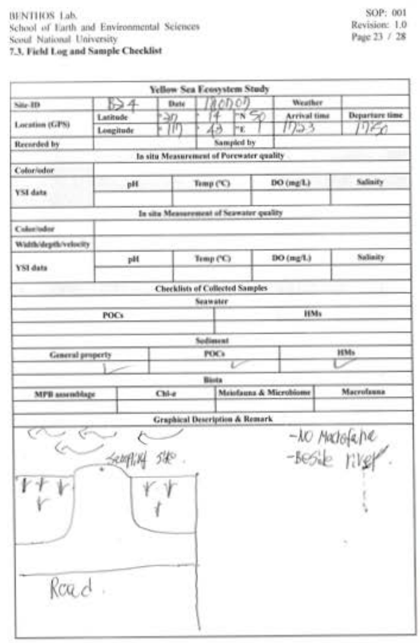
Quad. 1
Quad. 2
Quad. 3

Mollusca: (rake)

NOTE

Description between stations (0-1000 m)





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Yellow Sea Ecosystem Study						
Site-ID	B2-4	Date	180709		Weather	
Location (GPS)	Latitude	°39	°14	'N 50	Arrival time	Departure time
	Longitude	°119	°43	'E 1	1723	1750
Recorded by			Sampled by			

In situ Measurement of Porewater quality				
Color/odor				
YSI data	pH	Temp (°C)	DO (mg/L)	Salinity

In situ Measurement of Seawater quality				
Color/odor				
Width/depth/velocity				
YSI data	pH	Temp (°C)	DO (mg/L)	Salinity

Checklists of Collected Samples

Seawater	
POCs	HMs

Sediment		
General property	POCs	HMs
✓	✓	✓

Biota			
MPB assemblage	Chl-a	Meiofauna & Microbiome	Macrofauna

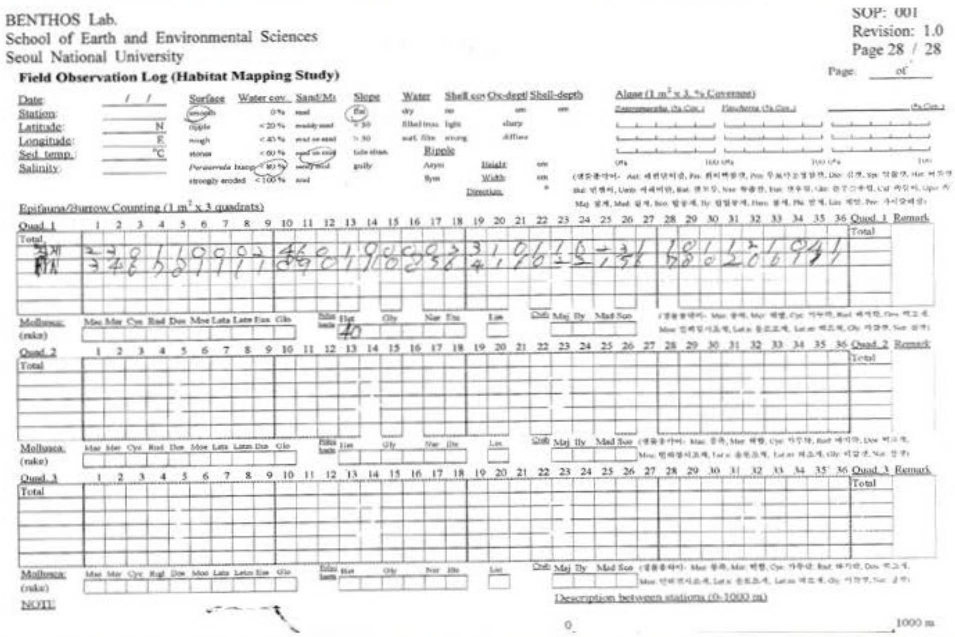
Graphical Description & Remark

Sampling site.

Road.

-No Macrofauna
-Beside river.

Yellow Sea Ecosystem Study					
Site-ID	BZ2	Date	07/08/2018	Weather	Cloudy
Location (GPS)	Latitude	38.20055 ° N		Arrival time	Departure time
	Longitude	118.00458 ° E		15:00 pm	15:40 pm
Recorded by	Bin Shi	Sampled by		Shuqin Chen Bin Shi Jongmin Lee Seo Joon Yoon	
In situ Measurement of Riverwater or Seawater quality (Seawater)					
Color/odor					
Width/depth/velocity	Majia River, estuary, width~200m				
HACH 40d data	pH	Temp (°C)	DO (mg/L)	Salinity (mS/cm)	
	7.62	28.0	5.29	53.9	
Corresponding soil information					
Site location	Latitude	° N	Landuse	Unused land	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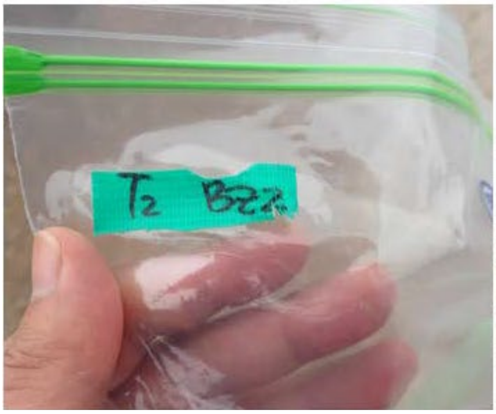
Field Observation Log (Habitat Mapping Study)

Epifauna/Burrow Counting (1 m² x 3 quadrats)



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7.3. Field Log and Sample Checklist

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Yellow Sea Ecosystem Study							
Site-ID	BZ	Date	180506		Weather		
Location (GPS)	Latitude	°38	′8	″N 45	Arrival time	Departure time	
	Longitude	°118	′2	″E 13	14:59	15:41	
Recorded by			Sampled by				

In situ Measurement of Porewater quality				
Color/odor				
YSI data	pH	Temp (°C)	DO (mg/L)	Salinity

In situ Measurement of Seawater quality				
Color/odor				
Width/depth/velocity				
YSI data	pH	Temp (°C)	DO (mg/L)	Salinity

Checklists of Collected Samples	
Seawater	
POCs	HMs
Ch	Ch

Sediment		
General property	POCs	HMs

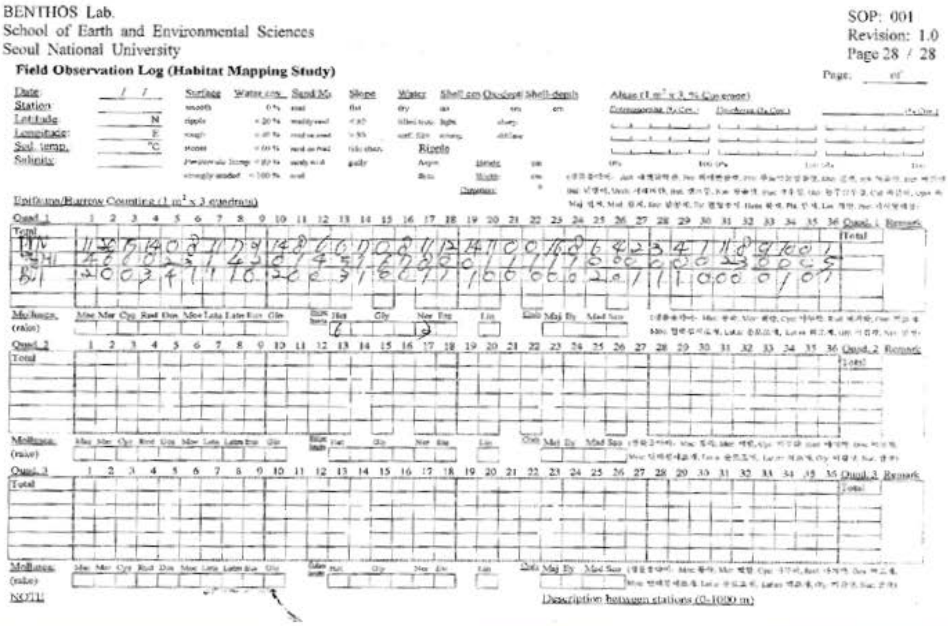
Biota			
MPB assemblage	Chl-a	Meiofauna & Microbiome	Macrofauna

Graphical Description & Remark

Ocean
Sampling site
road

- Reclaimed area?
- Many cargo ...

Yellow Sea Ecosystem Study					
Site-ID	BZ1	Date	07/08/2018	Weather	Sunny
Location (GPS)	Latitude	38.26367 ° N		Arrival time	Departure time
	Longitude	117.85111 ° E		17:40 pm	18:20 pm
Recorded by	Bin Shi	Sampled by		Shuqin Chen Bin Shi Jongmin Lee Seo Joon Yoon	
In situ Measurement of Riverwater or Seawater quality (Seawater)					
Color/odor					
Width/depth/velocity	Zhangweixin River, estuary, width~500m				
HACH 40d data	pH	Temp (°C)		DO (mg/L)	Salinity (mS/cm)
	8.34	28.0		7.33	50.9
Corresponding soil information					
Site location	Latitude	° N		Landuse	Agricultural



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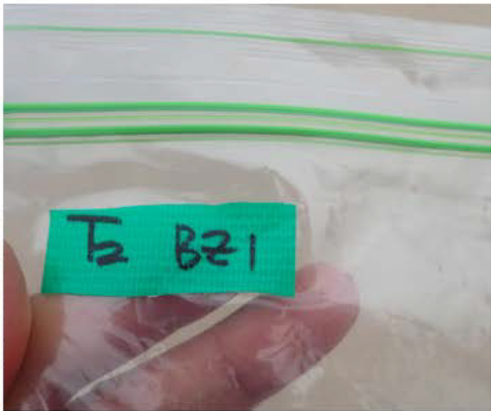
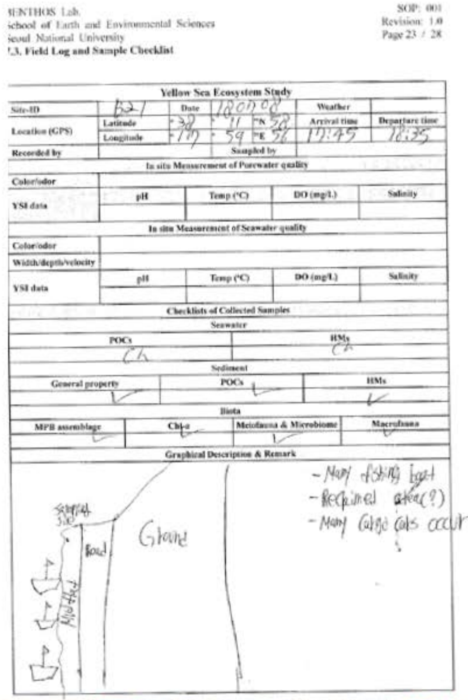
Field Observation Log (Habitat Mapping Study)





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Yellow Sea Ecosystem Study					
Site-ID	B21	Date	180708	Weather	
Location (GPS)	Latitude	°38	′11	″N 58	Arrival time
	Longitude	°117	′59	″E 56	17:45 / Departure time 18:35
Recorded by			Sampled by		

In situ Measurement of Porewater quality				
Color/odor				
YSI data	pH	Temp (°C)	DO (mg/L)	Salinity

In situ Measurement of Seawater quality				
Color/odor				
Width/depth/velocity				
YSI data	pH	Temp (°C)	DO (mg/L)	Salinity

Checklists of Collected Samples

Seawater	
POCs	HMs
Ch	Ch

Sediment		
General property	POCs	HMs
✓	✓	✓

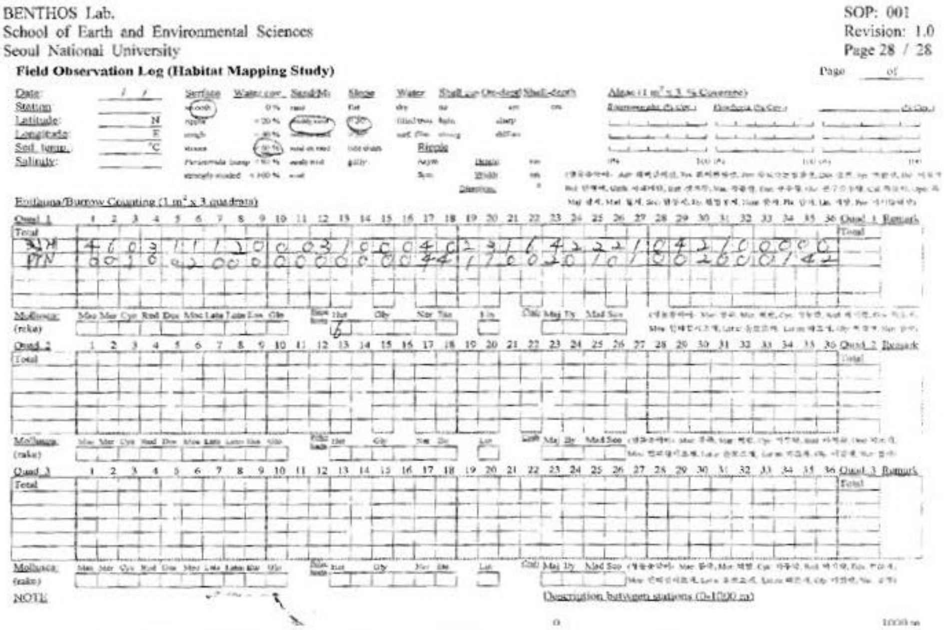
Biota			
MPB assemblage	Chl-a	Meiofauna & Microbiome	Macrofauna
✓	✓	✓	✓

Graphical Description & Remark

Sampling site
Road
Ground

- Many fishing boat
- Reclaimed area(?)
- Many cargo cars occur

Yellow Sea Ecosystem Study					
Site-ID	TJ5	Date	07/09/2018	Weather	Couldy
Location (GPS)	Latitude	38.96945 ° N		Arrival time	Departure time
	Longitude	117.73153 ° E		10:00 am	10:30 am
Recorded by	Bin Shi	Sampled by		Shuqin Chen Bin Shi Jongmin Lee Seo Joon Yoon	
In situ Measurement of Riverwater or Seawater quality (Mixed water)					
Color/odor					
Width/depth/velocity	Hai River, estuary, width~500m				
HACH 40d data	pH	Temp (°C)	DO (mg/L)	Salinity (mS/cm)	
	8.39	26.4	7.70	26.6	
Corresponding soil information					
Site location	Latitude	° N	Landuse	Municipal	



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Field Observation Log (Habitat Mapping Study)

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Date: / /
Station:
Latitude: N
Longitude: E
Soil temp.: °C
Salinity:

Epifauna/Burrow Counting (1 m² x 3 quadrats)

Quad 1 — Quad 1 Remark

Mollusca (rake)

Quad 2 — Quad 2 Remark

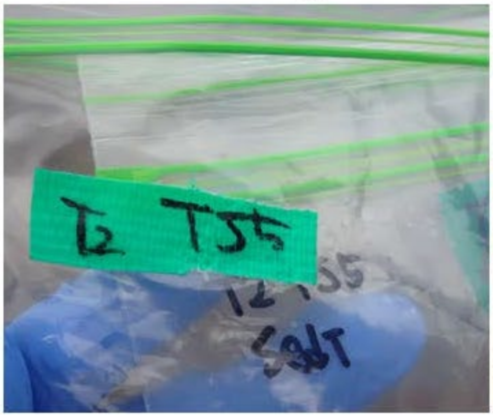
Mollusca (rake)

Quad 3 — Quad 3 Remark

Mollusca (rake)

NOTE:

Description between stations (0~1000 m)



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Yellow Sea Ecosystem Study							
Site-ID	TJ5		Date	180709		Weather	
Location (GPS)	Latitude	° 38	' 58	"N 7		Arrival time	Departure time
	Longitude	° 117	' 43	"E 37		09:19	09:50
Recorded by			Sampled by				

In situ Measurement of Porewater quality				
Color/odor				
YSI data	pH	Temp (°C)	DO (mg/L)	Salinity

In situ Measurement of Seawater quality				
Color/odor				
Width/depth/velocity				
YSI data	pH	Temp (°C)	DO (mg/L)	Salinity

Checklists of Collected Samples

Seawater	
POCs	HMs

Sediment		
General property	POCs	HMs
✓	✓	✓

Biota			
MPB assemblage	Chl-*a*	Meiofauna & Microbiome	Macrofauna
✓	✓	✓	✓

Graphical Description & Remark

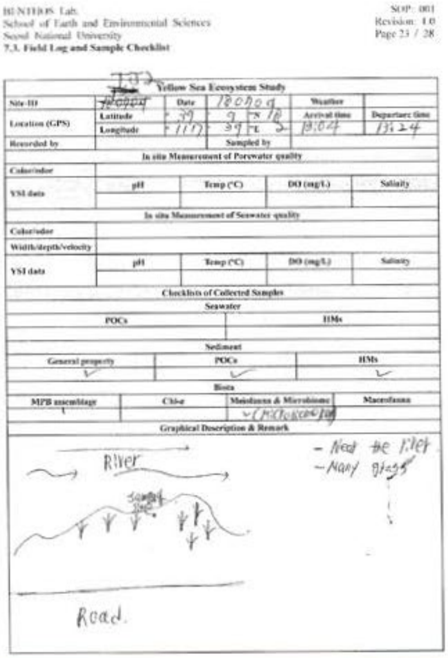
Ocean

Sampling site

Bridge

- Near the harbor
- Spartina(?) exist
- Industrial area near

Yellow Sea Ecosystem Study					
Site-ID	TJ2	Date	07/09/2018	Weather	Cloudy
Location (GPS)	Latitude	39.16400 ° N		Arrival time	Departure time
	Longitude	117.66228 ° E		12:30 pm	13:30 pm
Recorded by	Bin Shi	Sampled by		Shuqin Chen Bin Shi Jongmin Lee Seo Joon Yoon	
In situ Measurement of Riverwater or Seawater quality (Freshwater)					
Color/odor					
Width/depth/velocity	Chaobai River, downstream, width~200m				
HACH 40d data	pH	Temp (°C)	DO (mg/L)	Salinity (mS/cm)	
	9.29	26.8	10.24	1.34	
Corresponding soil information					
Site location	Latitude	° N	Land use	Unused land	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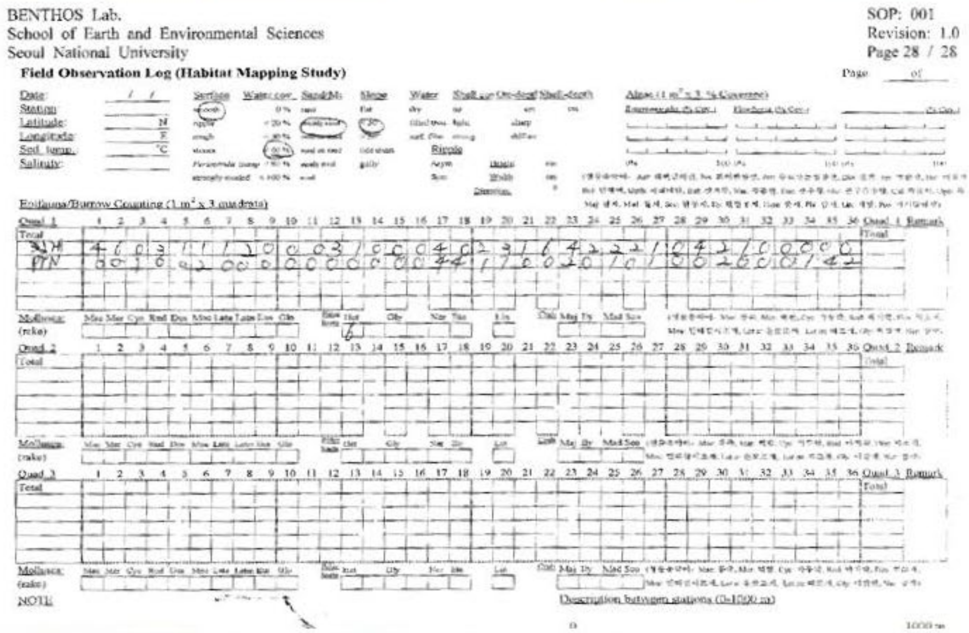
Yellow Sea Ecosystem Study					
Site-ID	TJ2	Date	180709	Weather	
Location (GPS)	Latitude	39	9 N 18	Arrival time	Departure time
	Longitude	117	39 E 5	13:04	13:24
Recorded by		Sampled by			
In situ Measurement of Porewater quality					
Color/odor					
YSI data	pH	Temp (°C)	DO (mg/L)	Salinity	
In situ Measurement of Seawater quality					
Color/odor					
Width/depth/velocity					
YSI data	pH	Temp (°C)	DO (mg/L)	Salinity	
Checklists of Collected Samples					
Seawater					
POCs		HMs			
Sediment					
General property	POCs	HMs			
✓	✓	✓			
Biota					
MPB assemblage	Chl-a	Meiofauna & Microbiome	Macrofauna		
		✓(Microbiome)			
Graphical Description & Remark					

River
Sample site
Road.
- Near the River
- Many grass






Yellow Sea Ecosystem Study					
Site-ID	TJ3	Date	07/09/2018	Weather	Rainy
Location (GPS)	Latitude	39.09377° N		Arrival time	Departure time
	Longitude	117.73036° E		15:30 pm	16:30 pm
Recorded by	Bin Shi	Sampled by		Shuqin Chen Bin Shi Jongmin Lee Seo Joon Yoon	
In situ Measurement of Riverwater or Seawater quality (Mixed water)					
Color/odor					
Width/depth/velocity	Yongding river, estuary, width~500m				
HACH 40d data	pH	Temp (°C)	DO (mg/L)	Salinity (mS/cm)	
	8.07	25.8	5.78	36.8	
Corresponding soil information					
Site location	Latitude	° N	Landuse	Municipal	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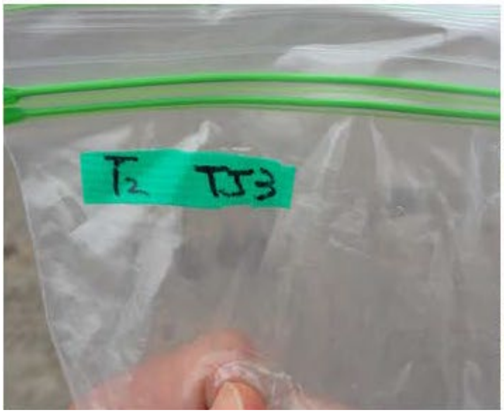
Field Observation Log (Habitat Mapping Study)



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Yellow Sea Ecosystem Study						
Site-ID	TJ3	Date	180709		Weather	
Location (GPS)	Latitude	°39	°5	"N 33	Arrival time	Departure time
	Longitude	°117	°44	"E 47	15:32	17:09
Recorded by			Sampled by			

In situ Measurement of Porewater quality				
Color/odor				
YSI data	pH	Temp (℃)	DO (mg/L)	Salinity

In situ Measurement of Seawater quality				
Color/odor				
Width/depth/velocity				
YSI data	pH	Temp (℃)	DO (mg/L)	Salinity

Checklists of Collected Samples

Seawater	
POCs	HMs

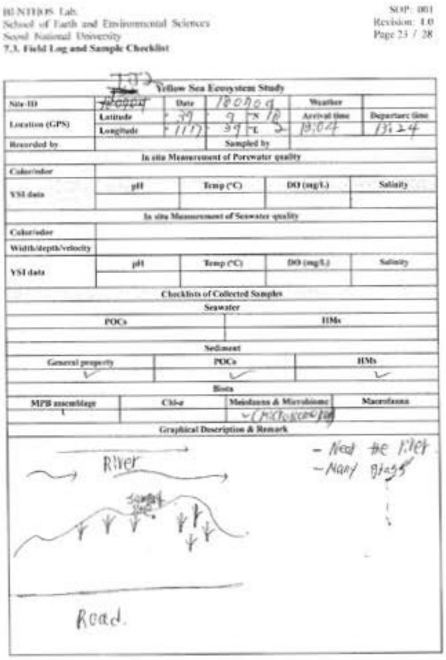
Sediment		
General property	POCs	HMs
✓	✓	✓

Biota			
MPB assemblage	Chl-a	Meiofauna & Microbiome	Macrofauna
✓	✓	✓	✓

Graphical Description & Remark

- Spartina (?) exist
- Sampling areas are under construction. (National Park)
- Fishing boats are

Yellow Sea Ecosystem Study					
Site-ID	TJ1	Date	07/09/2018	Weather	Cloudy/Rainy
Location (GPS)	Latitude	39.20002 ° N		Arrival time	Departure time
	Longitude	117.76406 ° E		14:00 pm	14:50 pm
Recorded by	Bin Shi	Sampled by		Shuqin Chen Bin Shi Jongmin Lee Seo Joon Yoon	
In situ Measurement of Riverwater or Seawater quality (Mixed water)					
Color/odor					
Width/depth/velocity	Jiyun River, downstream, width~300m				
HACH 40d data	pH	Temp (°C)	DO (mg/L)	Salinity (mS/cm)	
	9.45	26.2	9.36	4.25	
Corresponding soil information					
Site location	Latitude	° N	Landuse	Industrial	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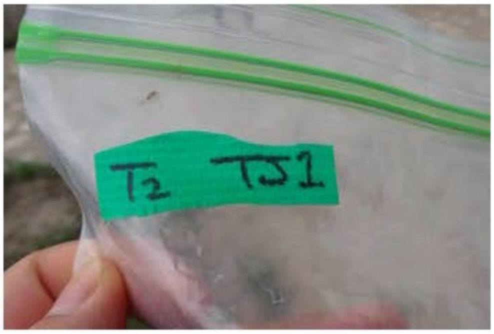
Yellow Sea Ecosystem Study					
Site-ID	TJ1	Date	180709	Weather	
Location (GPS)	Latitude	39	9 N	Arrival time	Departure time
	Longitude	117	39 E	13:04	13:24
Recorded by		Sampled by			
In situ Measurement of Porewater quality					
Color/odor					
YSI data	pH	Temp (°C)	DO (mg/L)	Salinity	
In situ Measurement of Seawater quality					
Color/odor					
Width/depth/velocity					
YSI data	pH	Temp (°C)	DO (mg/L)	Salinity	
Checklists of Collected Samples					
Seawater					
POCs	HMs				
Sediment					
General property	POCs	HMs			
✓	✓	✓			
Biota					
MPB assemblage	Chl-a	Meiofauna & Microbiome	Macrofauna		
		✓ (Microbiome)			
Graphical Description & Remark					

River

- Near the river
- Many grass

Road

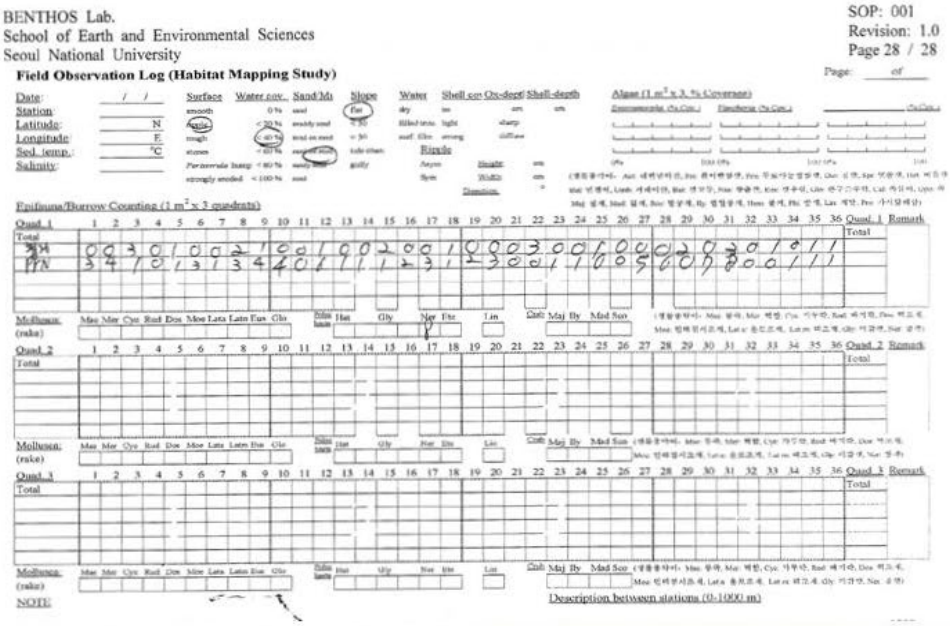








Yellow Sea Ecosystem Study					
Site-ID	TJ6	Date	07/10/2018	Weather	Sunny
Location (GPS)	Latitude	38.76674 ° N		Arrival time	Departure time
	Longitude	117.56939 ° E		9:30 am	10:30 am
Recorded by	Bin Shi	Sampled by	Shuqin Chen Bin Shi Jongmin Lee Seo Joon Yoon		
In situ Measurement of Riverwater or Seawater quality (Mixed water)					
Color/odor					
Width/depth/velocity	Duliujian River, estuary, width~500m				
HACH 40d data	pH	Temp (°C)	DO (mg/L)	Salinity (mS/cm)	
	8.26	29.3	8.80	50.0	
Corresponding soil information					
Site location	Latitude	° N	Landuse	Municipal	



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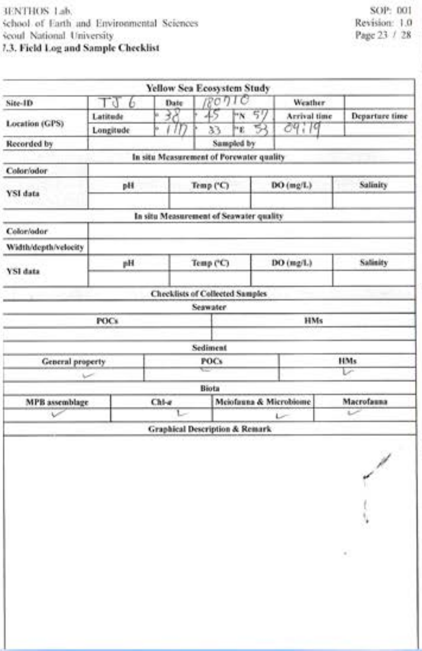
Field Observation Log (Habitat Mapping Study)



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Yellow Sea Ecosystem Study

Site-ID	TJ 6	Date	180710		Weather	
Location (GPS)	Latitude	° 38	′ 45	″N 57	Arrival time	Departure time
	Longitude	° 117	′ 33	″E 53	09:19	
Recorded by			Sampled by			

In situ Measurement of Porewater quality

Color/odor				
YSI data	pH	Temp (°C)	DO (mg/L)	Salinity

In situ Measurement of Seawater quality

Color/odor				
Width/depth/velocity				
YSI data	pH	Temp (°C)	DO (mg/L)	Salinity

Checklists of Collected Samples

Seawater

POCs	HMs

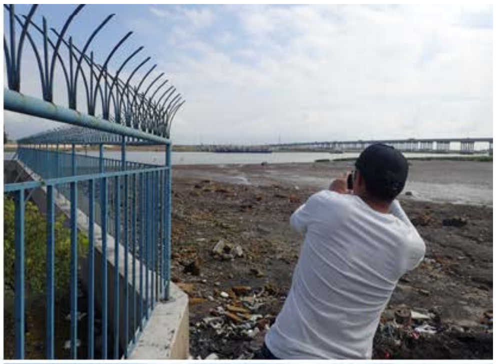
Sediment

General property	POCs	HMs
✓	✓	✓

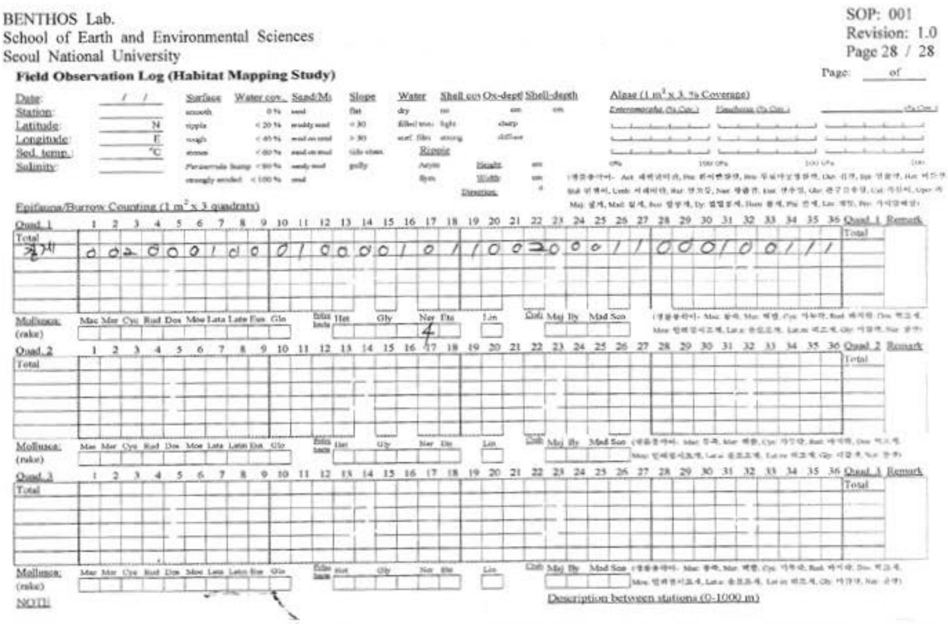
Biota

MPB assemblage	Chl-a	Meiofauna & Microbiome	Macrofauna
✓	✓	✓	✓

Graphical Description & Remark



Yellow Sea Ecosystem Study					
Site-ID	TJ7	Date	07/10/2018	Weather	Sunny
Location (GPS)	Latitude	38.65465 ° N		Arrival time	Departure time
	Longitude	117.54466 ° E		11:30 pm	12:30 pm
Recorded by	Bin Shi	Sampled by		Shuqin Chen Bin Shi Jongmin Lee Seo Joon Yoon	
In situ Measurement of Riverwater or Seawater quality (Mixed water)					
Color/odor					
Width/depth/velocity	Ziya River, estuary, width~300m				
HACH 40d data	pH	Temp (°C)	DO (mg/L)	Salinity (mS/cm)	
	8.19	29.1	6.35	34.4	
Corresponding soil information					
Site location	Latitude	° N	Landuse	Municipal	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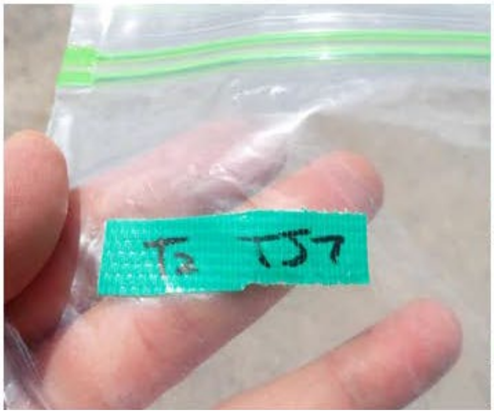
Epifauna/Burrow Counting (1 m² x 3 quadrats)

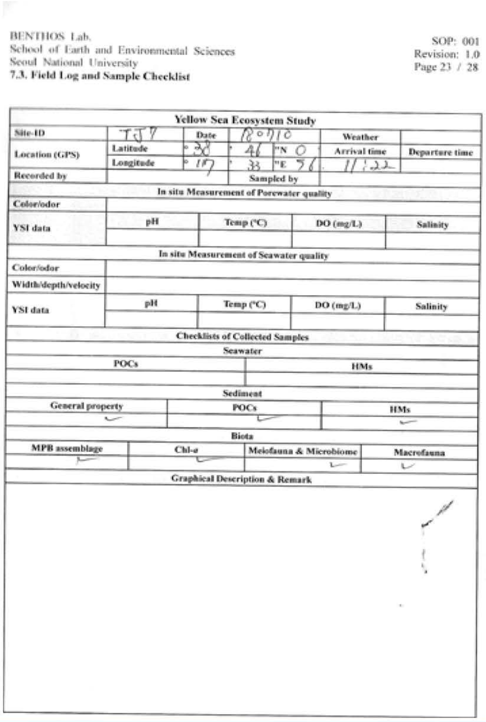
Quad. 1 … Quad. 2 … Quad. 3 …

Mollusca (rake)

NOTE

Description between stations (0-1000 m)





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Yellow Sea Ecosystem Study							
Site-ID	TJ7	Date	180710			Weather	
Location (GPS)	Latitude	° 38	' 46	"N 0		Arrival time	Departure time
	Longitude	° 117	' 33	"E 56		11:22	
Recorded by			Sampled by				

In situ Measurement of Porewater quality				
Color/odor				
YSI data	pH	Temp (°C)	DO (mg/L)	Salinity

In situ Measurement of Seawater quality				
Color/odor				
Width/depth/velocity				
YSI data	pH	Temp (°C)	DO (mg/L)	Salinity

Checklists of Collected Samples

Seawater	
POCs	HMs

Sediment		
General property	POCs	HMs
✓	✓	✓

Biota			
MPB assemblage	Chl-a	Meiofauna & Microbiome	Macrofauna
✓	✓	✓	✓

Graphical Description & Remark

<table>
<tr><th colspan="7">Yellow Sea Ecosystem Study</th></tr>
<tr><td>Site-ID</td><td>TJ4</td><td>Date</td><td>07/10/2018</td><td>Weather</td><td colspan="2">Sunny→Cloudy</td></tr>
<tr><td rowspan="2">Location (GPS)</td><td>Latitude</td><td colspan="2">39.02143 ° N</td><td>Arrival time</td><td colspan="2">Departure time</td></tr>
<tr><td>Longitude</td><td colspan="2">117.46213 ° E</td><td>15:00 pm</td><td colspan="2">15:40 pm</td></tr>
<tr><td>Recorded by</td><td colspan="2">Bin Shi</td><td>Sampled by</td><td colspan="3">Shuqin Chen
Bin Shi
Jongmin Lee
Seo Joon Yoon</td></tr>
<tr><td colspan="7">In situ Measurement of Riverwater or Seawater quality (Mixed water)</td></tr>
<tr><td>Color/odor</td><td colspan="6"></td></tr>
<tr><td>Width/depth/velocity</td><td colspan="6">Hai river, upstream, width~300m</td></tr>
<tr><td rowspan="2">HACH 40d data</td><td>pH</td><td colspan="2">Temp (°C)</td><td>DO (mg/L)</td><td colspan="2">Salinity (mS/cm)</td></tr>
<tr><td>9.00</td><td colspan="2">27.9</td><td>10.09</td><td colspan="2">11.6</td></tr>
<tr><td colspan="7">Corresponding soil information</td></tr>
<tr><td>Site location</td><td>Latitude</td><td colspan="2">° N</td><td>Landuse</td><td colspan="2">Municipal</td></tr>
</table>

Yellow Sea Ecosystem Study					
Site-ID	TS1	Date	07/10/2018	Weather	Sunny
Location (GPS)	Latitude	39.22014 ° N		Arrival time	Departure time
	Longitude	118.07413 ° E		17:20 pm	17:50 pm
Recorded by	Bin Shi	Sampled by		Shuqin Chen Bin Shi Jongmin Lee Seo Joon Yoon	
In situ Measurement of Riverwater or Seawater quality (Mixed water)					
Color/odor					
Width/depth/velocity	Tang River, estuary, width~200m				
HACH 40d data	pH	Temp (°C)		DO (mg/L)	Salinity (mS/cm)
	8.05	26.9		6.02	6.03
Corresponding soil information					
Site location	Latitude	° N		Landuse	Agricultural

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Field Observation Log (Habitat Mapping Study)

Date: / /
Station:
Latitude: N
Longitude: E
Sed. temp.: °C
Salinity:

Surface: smooth, ripple, rough, stones, *Periserrula* hump, strongly eroded
Water cov.: 0 %, < 20 %, < 40 %, < 60 %, < 80 %, < 100 %
Sand/Mud: sand, muddy sand, mud on sand, sand on mud, sandy mud, mud
Slope: flat, < 30, > 30, tide chan., gully
Water: dry, filled trou., surf. film
Shell cov.: no, light, strong
Ox-depth: cm
Shell-depth: cm; sharp, diffuse
Ripple: Asym, Sym; Height: cm; Width: cm; Direction: °

Algae (1 m² x 3, % Coverage)
Enteromorpha (% Cov.) 0% 100
Vaucheria (% Cov.) 0% 100
(% Cov.) 0% 100

(생물종약어- Act: 해변말미잘, Prs: 흰이빨참갯, Prn: 두토막눈썹참갯, Dio: 십갯, Spi: 얼굴갯, Het: 버들갯, Bul: 민챙이, Umb: 서해비단, Bat: 갯고둥, Nas: 왕좁쌀, Eus: 갯우렁, Glo: 큰구슬우렁, Cal: 쏙붙이, Upo: 쏙, Maj: 칠게, Mad: 길게, Sco: 밤게, Ily: 펄털콩게, Hem: 풀게, Phi: 만게, Lin: 개맛, Pro: 가시닻해삼)

Epifauna/Burrow Counting (1 m² x 3 quadrats)

Quad. 1: 1–36, Quad. 1 Total, Remark
Total
집게: 2 3 0 0 1 0 0 4 1 0 0 0 0 1 0 0 2 3 4 5 0 0 1 1 2 0 0 0 1 0 1 3 1 2 0 2
PTN: 4 6 2 3 1 1 0 0 1 0 0 9 0 0 1 1 5 4 1 1 0 0 2 3 1 0 0 2 3 4 0 0 1 0 0 1

Mollusca: (rake) Mac Mer Cyc Rud Dos Moe Lata Latm Eus Glo
Polychaeta: Het 36, Gly, Ner, Etc
Lin
Crab: Maj Ily Mad Sco
(생물종약어- Mac: 동죽, Mer: 백합, Cyc: 가무락, Rud: 바지락, Dos: 떡조개, Moe: 민때죽시조개, Lat.a: 윤모조개, Lat.m: 떡조개, Gly: 미갑갯, Ner: 참갯)

Quad. 2: 1–36, Quad. 2 Total, Remark
Total

Mollusca: (rake) Mac Mer Cyc Rud Dos Moe Lata Latm Eus Glo
Polychaeta: Het, Gly, Ner, Etc
Lin
Crab: Maj Ily Mad Sco

Quad. 3: 1–36, Quad. 3 Total, Remark
Total

Mollusca: (rake) Mac Mer Cyc Rud Dos Moe Lata Latm Eus Glo
Polychaeta: Het, Gly, Ner, Etc
Lin
Crab: Maj Ily Mad Sco

NOTE

Description between stations (0-1000 m)
0 st. — 1000 m st.

Designed by Coastal Ecosystem Engineering Lab. (Anyang U.) and Laboratory of Marine Benthic Ecology. (Seoul National U.)

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Yellow Sea Ecosystem Study							
Site-ID	T3 1	Date	180710		Weather		
Location (GPS)	Latitude	° 39	' 1	" N 13	Arrival time		Departure time
	Longitude	° 117	' 27	" E 28	17:10		18:10
Recorded by			Sampled by				

In situ Measurement of Porewater quality

Color/odor				
YSI data	pH	Temp (ºC)	DO (mg/L)	Salinity

In situ Measurement of Seawater quality

Color/odor				
Width/depth/velocity				
YSI data	pH	Temp (ºC)	DO (mg/L)	Salinity

Checklists of Collected Samples

Seawater

POCs	HMs

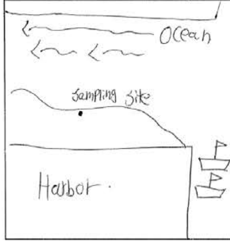
Sediment

General property	POCs	HMs
V	V	V

Biota

MPB assemblage	Chl-*a*	Meiofauna & Microbiome	Macrofauna
V	V	V	V

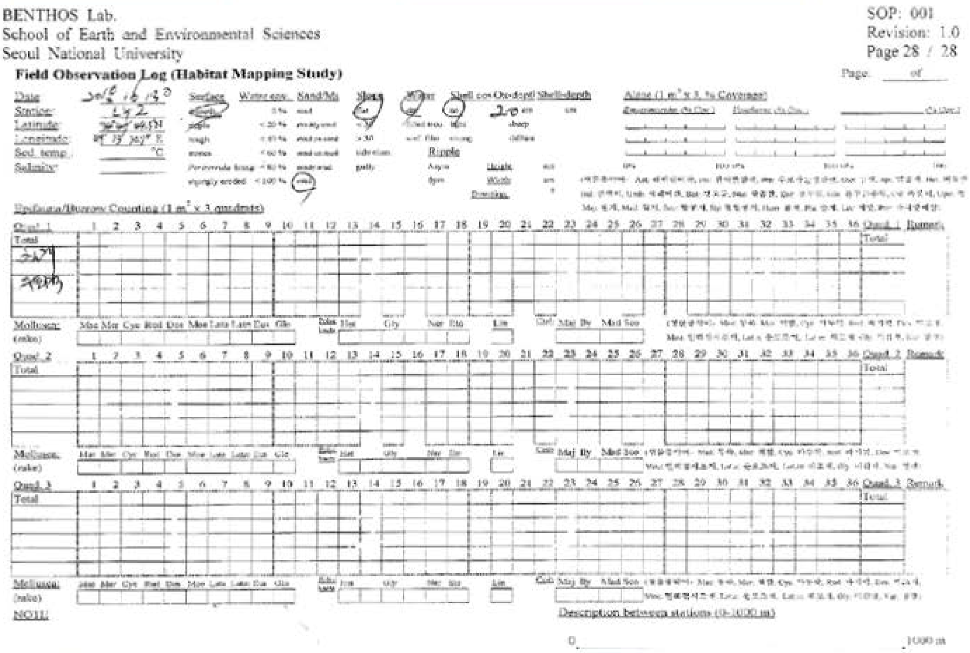
Graphical Description & Remark



- Very muddy site
- Near the Harbor.

(※) - Macrofauna sample lost

Yellow Sea Ecosystem Study					
Site-ID	LY2	Date	06/30/2018	Weather	Cloudy
Location (GPS)	Latitude	34.79629 ° N		Arrival time	Departure time
	Longitude	119.22444 ° E		18:45 pm	19:30 pm
Recorded by	Wenyou Hu	Sampled by		Moojoon Lee Dohyeong Kim Kang Tian Peng Liu	
In situ Measurement of Riverwater or Seawater quality (Seawater)					
Color/odor					
YSI data	pH	Temp (°C)	DO (mg/L)	Salinity (mS/cm)	
	7.72	25.8	7.01	30.7	
Corresponding soil information					
Site location	Latitude	34.78888 ° N	Landuse	Farmland/Fallow	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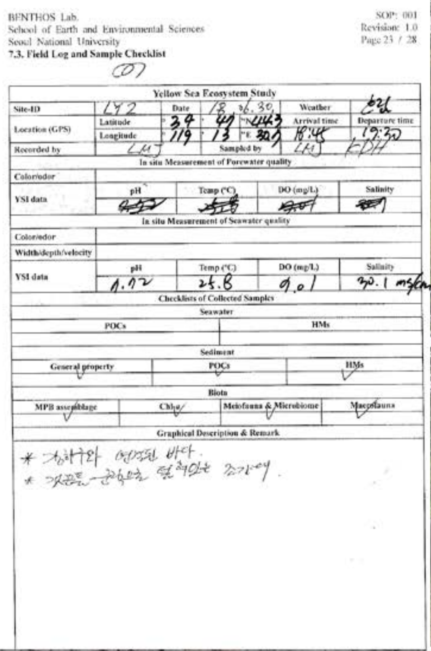
Field Observation Log (Habitat Mapping Study)

Date: 2018.06.30
Station: LY2



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07

Yellow Sea Ecosystem Study							
Site-ID	LY2		Date	18.06.30.		Weather	흐림
Location (GPS)	Latitude	34°	44'	443" N		Arrival time	Departure time
	Longitude	119°	13'	307" E		18:45	19:30
Recorded by	LHJ			Sampled by		LHJ	KDH

In situ Measurement of Porewater quality				
Color/odor				
YSI data	pH	Temp (°C)	DO (mg/L)	Salinity
	~~[illegible]~~	~~[illegible]~~	~~[illegible]~~	~~[illegible]~~

In situ Measurement of Seawater quality				
Color/odor				
Width/depth/velocity				
YSI data	pH	Temp (°C)	DO (mg/L)	Salinity
	7.72	25.8	9.01	30.1 ms/cm

Checklists of Collected Samples

Seawater	
POCs	HMs

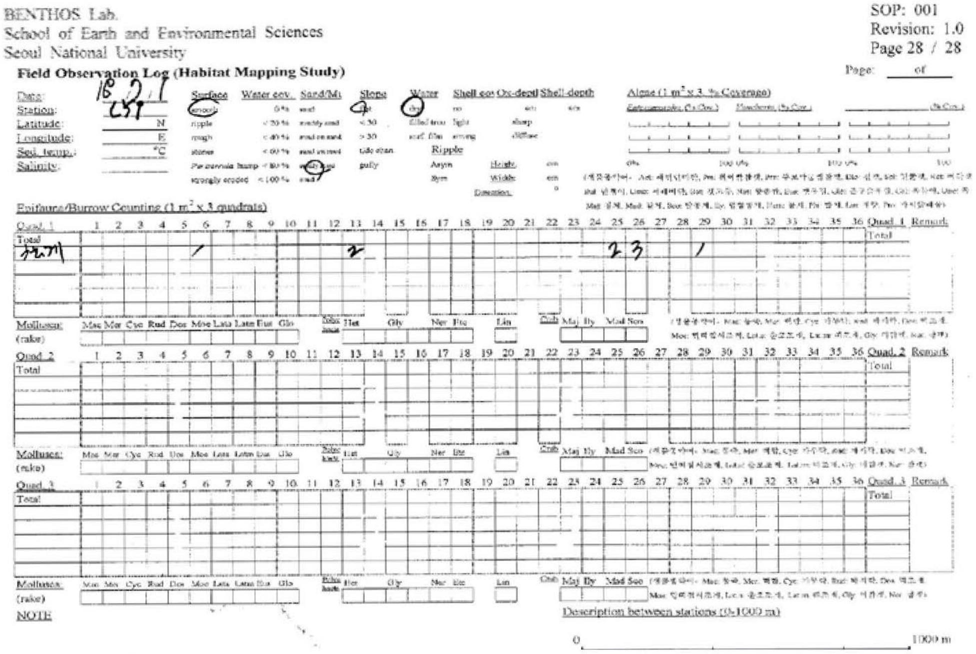
Sediment		
General property ✓	POCs ✓	HMs ✓

Biota			
MPB assemblage ✓	Chl-a ✓	Meiofauna & Microbiome ✓	Macrofauna ✓

Graphical Description & Remark

* 장하구와 연결된 바다.
* 갯골들 - 곤죽으로 덮혀있는 조간대.

Yellow Sea Ecosystem Study					
Site-ID	LY1	Date	07/01/2018	Weather	Cloudy
Location (GPS)	Latitude	34.90228 ° N		Arrival time	Departure time
	Longitude	119.19606 ° E		10:35 am	11:30 am
Recorded by	Wenyou Hu	Sampled by		Moojoon Lee Dohyeong Kim Kang Tian Peng Liu	
In situ Measurement of Riverwater or Seawater quality (Seawater)					
Color/odor					
YSI data	pH	Temp (°C)	DO (mg/L)	Salinity (mS/cm)	
	7.76	28.0	7.37	46.6	
Corresponding soil information					
Site location	Latitude	34.90501 ° N	Landuse	Farmland/Fallow	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Field Observation Log (Habitat Mapping Study)

Date: 18.7.1
Station: LY1
Latitude: N
Longitude: E
Sed. temp.: °C
Salinity:

Epifauna/Burrow Counting (1 m² x 3 quadrats)

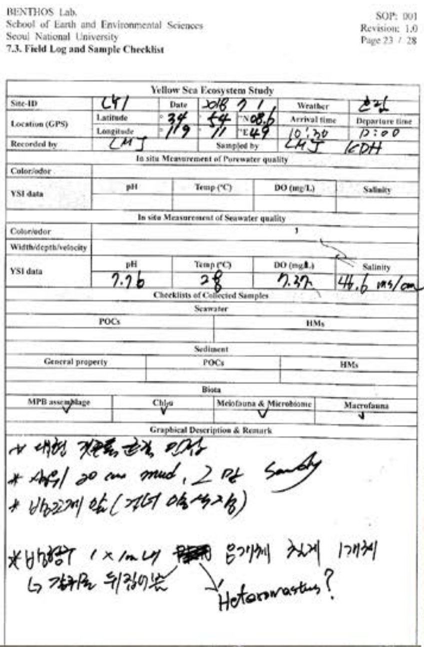
Quad. 1 Total
Quad. 2 Total
Quad. 3 Total

Mollusca (rake)

NOTE

Description between stations (0-1000 m)

0 1000 m



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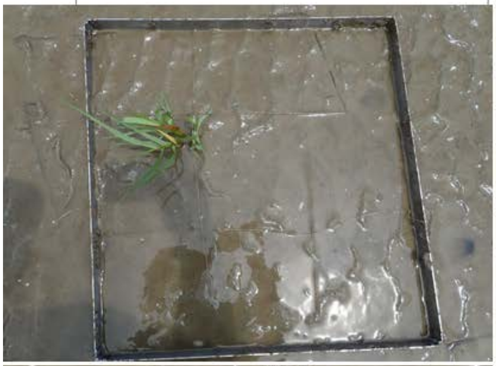
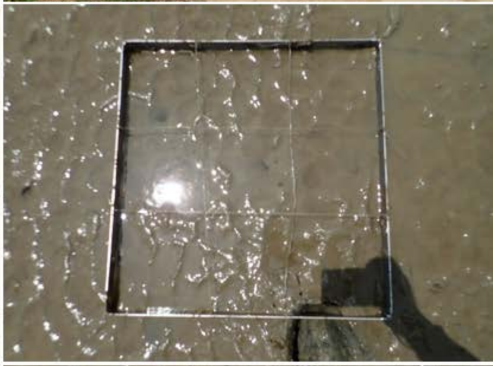
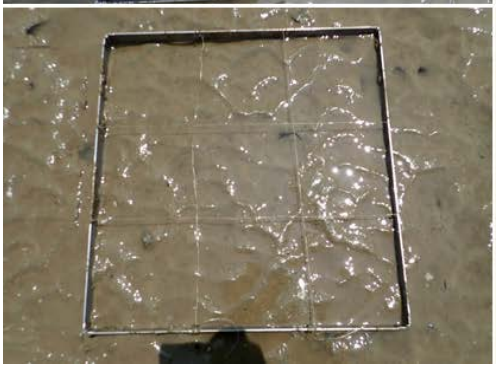
Yellow Sea Ecosystem Study							
Site-ID	C41	Date	2018 7 1			Weather	흐림
Location (GPS)	Latitude	° 34	' 54	"N 08.6		Arrival time	Departure time
	Longitude	° 119	' 11	"E 49		10:30	12:00
Recorded by	LMJ		Sampled by			LHJ	KDH
In situ Measurement of Porewater quality							
Color/odor							
YSI data	pH		Temp (°C)		DO (mg/L)		Salinity
In situ Measurement of Seawater quality							
Color/odor							
Width/depth/velocity							
YSI data	pH		Temp (°C)		DO (mg/L)		Salinity
	7.76		28		7.37		44.6 ms/cm
Checklists of Collected Samples							
Seawater							
POCs				HMs			
Sediment							
General property		POCs			HMs		
Biota							
MPB assemblage ✓		Chl-a ✓		Meiofauna & Microbiome ✓		Macrofauna ✓	
Graphical Description & Remark							

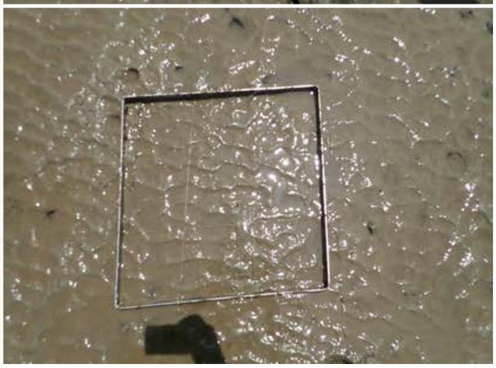
* 대형 저서동물 관찰 안됨
* 상위 20 cm mud, 그 아래 sandy
* 방게 없음 (갯벌 이용 생각됨)

* 방형구 1×1m 내 ~~[illegible]~~ 흰이빨 칠게 1개체
↳ 갯지렁이 뒤집어놓은
Heteromastus?

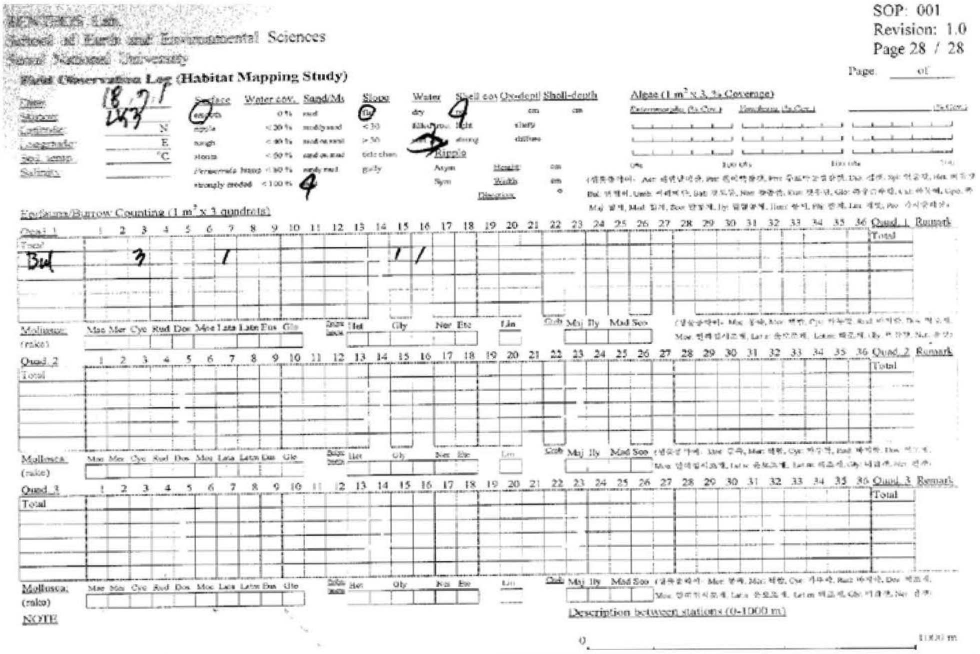








Yellow Sea Ecosystem Study					
Site-ID	LY3	Date	07/01/2018	Weather	Cloudy
Location (GPS)	Latitude	34.50263 ° N		Arrival time	Departure time
	Longitude	119.77197 ° E		15:35 pm	16:40 pm
Recorded by	Wenyou Hu	Sampled by		Moojoon Lee Dohyeong Kim Kang Tian Peng Liu	
In situ Measurement of Riverwater or Seawater quality (Seawater)					
Color/odor					
YSI data	pH	Temp (°C)	DO (mg/L)	Salinity (mS/cm)	
	7.65	28.4	7.40	33.7	
Corresponding soil information					
Site location	Latitude	34.48425 ° N	Landuse	Fallow	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Field Observation Log (Habitat Mapping Study)

18.7.1
LY3

Infauna/Burrow Counting (1 m² x 3 quadrats)

Quad 1 Remark

Bul 3 1 1 1

Quad 2 Remark

Quad 3 Remark

Description between stations (0-1000 m)

NOTE

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Yellow Sea Ecosystem Study					
Site-ID	L43	Date	2018 7 1	Weather	맑음
Location (GPS)	Latitude	34°	39' 03.3"N	Arrival time	Departure time
	Longitude	119°	46' 19.9"E	15:30	16:30
Recorded by		Sampled by			
In situ Measurement of Porewater quality					
Color/odor					
YSI data	pH	Temp (°C)	DO (mg/L)	Salinity	
In situ Measurement of Seawater quality					
Color/odor					
Width/depth/velocity					
YSI data	pH	Temp (°C)	DO (mg/L)	Salinity	
	7.65	28.4	7.40	33.7 ms/cm	

Checklists of Collected Samples			
Seawater			
POCs	HMs		
Sediment			
General property	POCs	HMs	
Biota			
MPB assemblage	Chl-a	Meiofauna & Microbiome	Macrofauna

Graphical Description & Remark

* [illegible]
* 상부 30cm watery mud, 하부 compact mud

Yellow Sea Ecosystem Study					
Site-ID	LY4	Date	07/01/2018	Weather	Sunny
Location (GPS)	Latitude	34.15371 ° N		Arrival time	Departure time
	Longitude	118.83660 ° E		18:45 pm	19:45 pm
Recorded by	Wenyou Hu		Sampled by	Moojoon Lee Dohyeong Kim Kang Tian Peng Liu	
In situ Measurement of Riverwater or Seawater quality (Seawater)					
Color/odor					
YSI data	pH	Temp (°C)		DO (mg/L)	Salinity (mS/cm)
	7.89	28		8.0	530
Corresponding soil information					
Site location	Latitude	34.16703 ° N		Landuse	Farmland/Soybean

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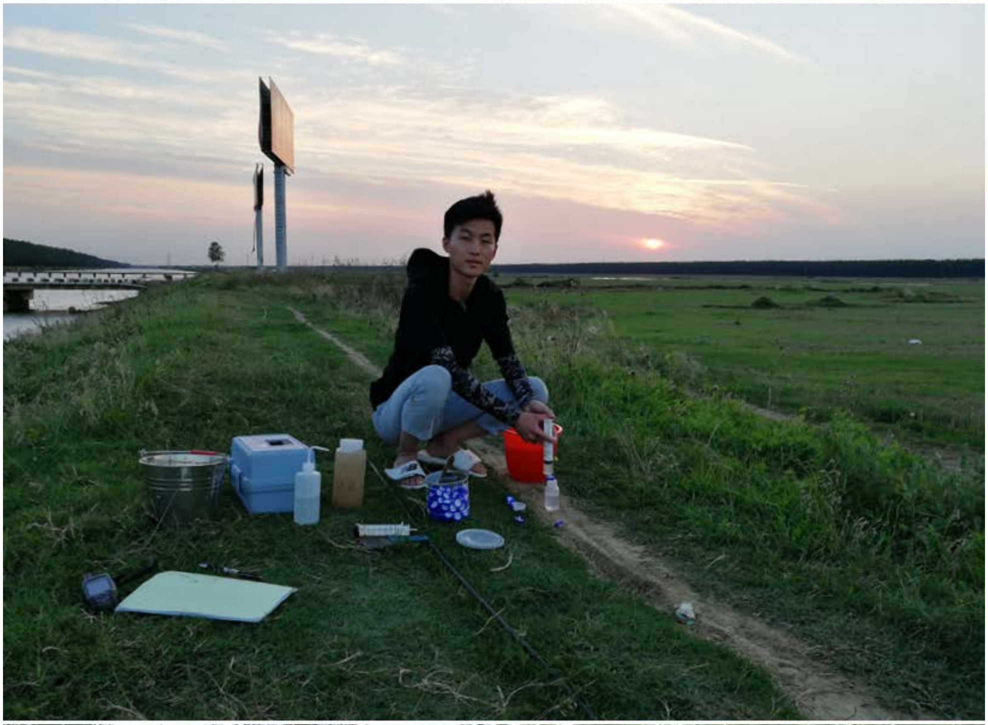
Yellow Sea Ecosystem Study						
Site-ID	LY3	Date	2018 7 1		Weather	[illegible]
Location (GPS)	Latitude	° 34	' 39	" N 02.3	Arrival time	Departure time
	Longitude	° 119	' 46	" E 19.9	15:20	16:30
Recorded by			Sampled by			
In situ Measurement of Porewater quality						
Color/odor						
YSI data	pH	Temp (°C)	DO (mg/L)	Salinity		
In situ Measurement of Seawater quality						
Color/odor						
Width/depth/velocity						
YSI data	pH	Temp (°C)	DO (mg/L)	Salinity		
	7.65	28.4	7.40	33.2 ms/cm		

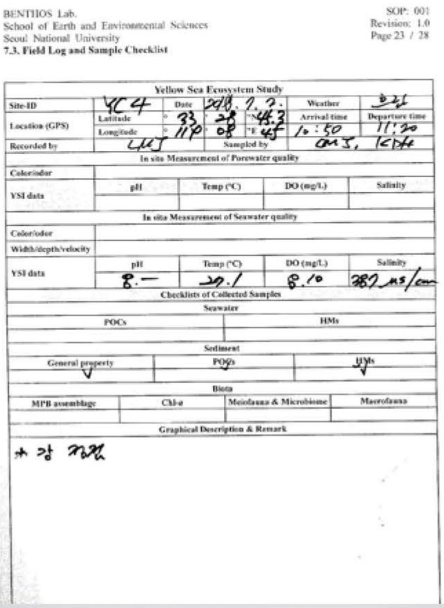
Checklists of Collected Samples			
Seawater			
POCs		HMs	
Sediment			
General property	POCs	HMs	
Biota			
MPB assemblage	Chl-a	Meiofauna & Microbiome	Macrofauna
Graphical Description & Remark			

* [illegible]
* [illegible] 30cm watery mud, 하부 compact mud





Yellow Sea Ecosystem Study					
Site-ID	**YC4**	**Date**	**07/02/2018**	**Weather**	**Cloudy**
Location (GPS)	**Latitude**	**33.47932 ° N**		**Arrival time**	**Departure time**
	Longitude	**119.14596 ° E**		**10:45 am**	**11:20 am**
Recorded by	Wenyou Hu		**Sampled by**	Moojoon Lee Dohyeong Kim Kang Tian Peng Liu	
In situ Measurement of Riverwater or Seawater quality (Seawater)					
Color/odor					
YSI data	**pH**	**Temp (°C)**		**DO (mg/L)**	**Salinity (mS/cm)**
	8.00	**27.1**		**8.10**	**387**
Corresponding soil information					
Site location	**Latitude**	**33.48158 ° N**		**Landuse**	**Farmland/Wheat**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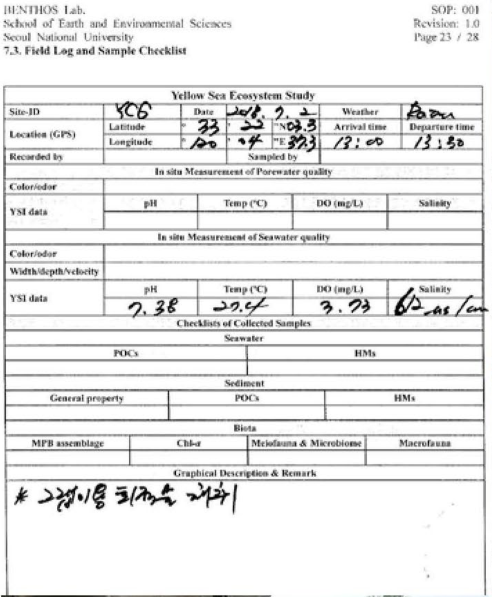
Yellow Sea Ecosystem Study					
Site-ID	YC4	Date	2018. 7. 2.	Weather	흐림
Location (GPS)	Latitude	° 33 ° 28 ' 43.3 "N		Arrival time	Departure time
	Longitude	° 119 ° 08 ' 45 "E		10:50	11:20
Recorded by			Sampled by		
In situ Measurement of Porewater quality					
Color/odor					
YSI data	pH	Temp (°C)		DO (mg/L)	Salinity
In situ Measurement of Seawater quality					
Color/odor					
Width/depth/velocity					
YSI data	pH	Temp (°C)		DO (mg/L)	Salinity
	8.—	27.1		8.10	387 ms/cm
Checklists of Collected Samples					
Seawater					
POCs			HMs		
Sediment					
General property ✓		POCs ✓		HMs ✓	
Biota					
MPB assemblage	Chl-a		Meiofauna & Microbiome		Macrofauna
Graphical Description & Remark					





Yellow Sea Ecosystem Study					
Site-ID	YC6	Date	07/02/2018	Weather	Rain
Location (GPS)	Latitude	33.36742° N		Arrival time	Departure time
	Longitude	120.07700 ° E		13:00 am	13:30 am
Recorded by	Wenyou Hu	Sampled by	Moojoon Lee Dohyeong Kim Kang Tian Peng Liu		
In situ Measurement of Riverwater or Seawater quality (Seawater)					
Color/odor					
YSI data	pH	Temp (^{o}C)	DO (mg/L)	Salinity (mS/cm)	
	7.38	27.4	3.73	612	
Corresponding soil information					
Site location	Latitude	33.36190 ° N	Landuse	Woodland	



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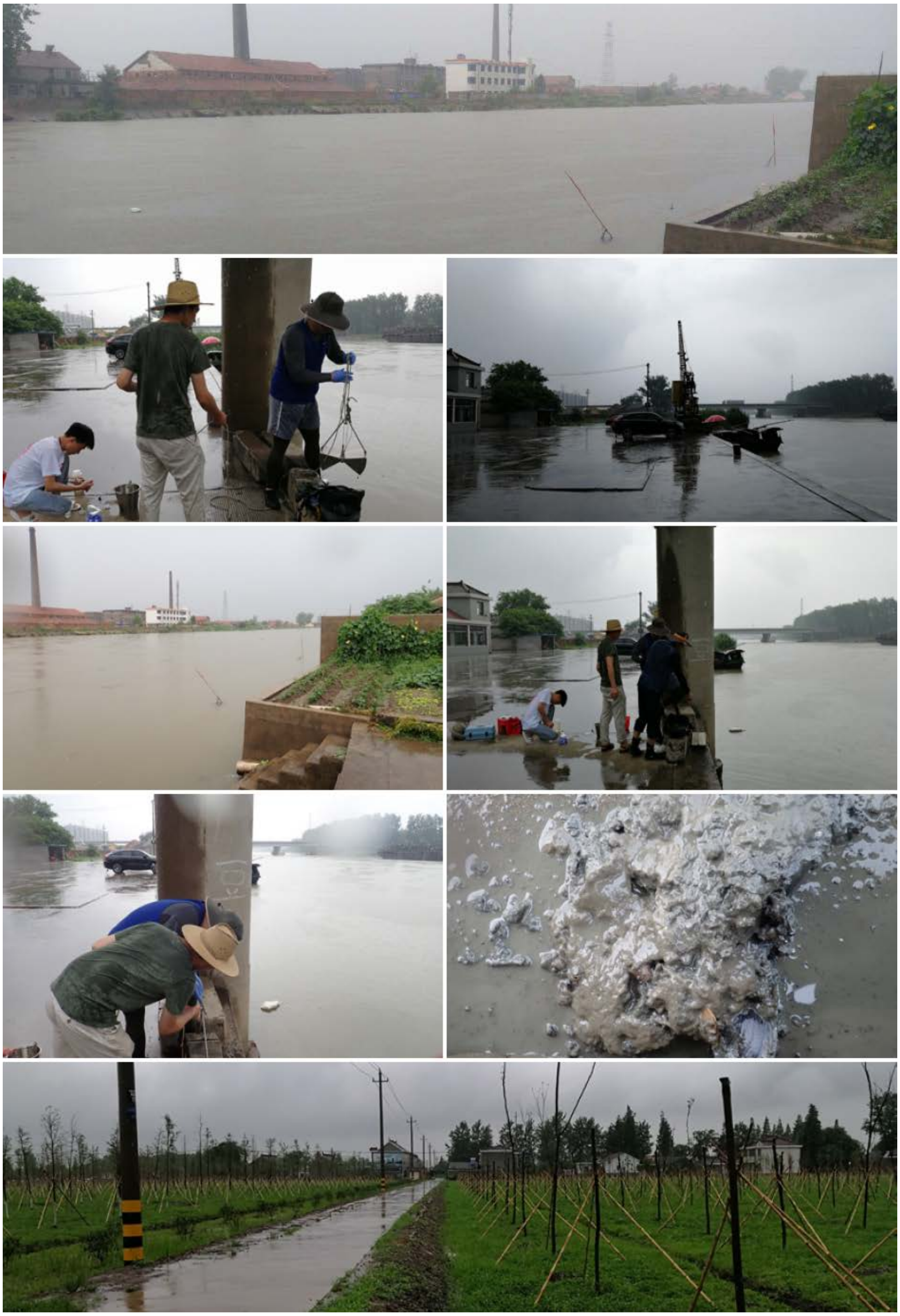
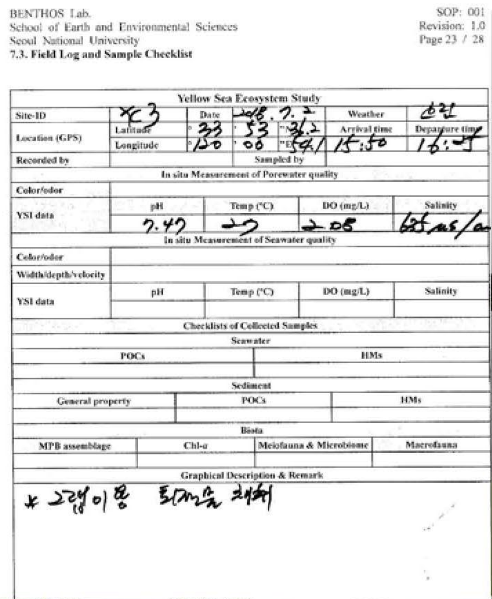
Yellow Sea Ecosystem Study							
Site-ID	YC6	Date	2018. 7. 2		Weather	[illegible]	
Location (GPS)	Latitude	° 33	' 22	"N 03.3	Arrival time	Departure time	
	Longitude	° 120	' 04	"E 37.3	13:00	13:30	
Recorded by			Sampled by				
In situ Measurement of Porewater quality							
Color/odor							
YSI data	pH	Temp (°C)	DO (mg/L)	Salinity			
In situ Measurement of Seawater quality							
Color/odor							
Width/depth/velocity							
YSI data	pH	Temp (°C)	DO (mg/L)	Salinity			
	7.38	27.4	3.73	612 ms/cm			
Checklists of Collected Samples							
Seawater							
POCs	HMs						
Sediment							
General property	POCs	HMs					
Biota							
MPB assemblage	Chl-a	Meiofauna & Microbiome	Macrofauna				
Graphical Description & Remark							
* [illegible]							



Yellow Sea Ecosystem Study					
Site-ID	YC3	Date	07/02/2018	Weather	Cloudy
Location (GPS)	Latitude	33.89336 ° N		Arrival time	Departure time
	Longitude	120.01502 ° E		15:50 pm	16:25 pm
Recorded by	Wenyou Hu	Sampled by		Moojoon Lee Dohyeong Kim Kang Tian Peng Liu	
In situ Measurement of Riverwater or Seawater quality (Seawater)					
Color/odor					
YSI data	pH	Temp (°C)	DO (mg/L)	Salinity (mS/cm)	
	7.47	27.0	2.08	635	
Corresponding soil information					
Site location	Latitude	33.89336 ° N	Landuse	Wheat/Maize	



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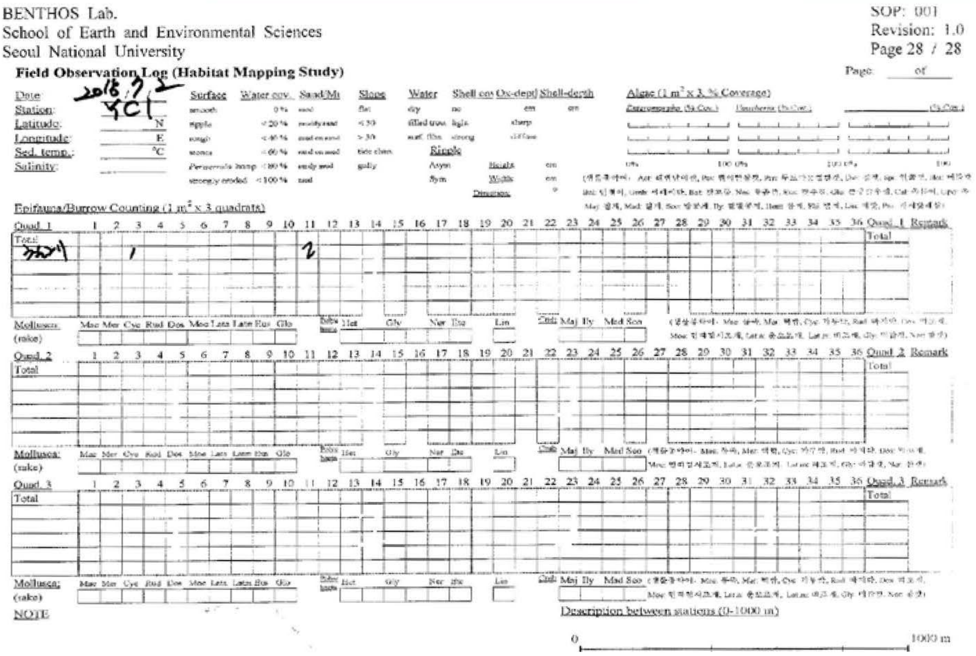
Yellow Sea Ecosystem Study					
Site-ID	YC3	Date	2018. 7. 2	Weather	흐림
Location (GPS)	Latitude	° 33 ' 53 " N 31.2		Arrival time	Departure time
	Longitude	° 120 ' 00 " E 54.1		15:50	16:25
Recorded by		Sampled by			
In situ Measurement of Porewater quality					
Color/odor					
YSI data	pH	Temp (°C)	DO (mg/L)	Salinity	
	7.47	27	2.08	635 mS/cm	
In situ Measurement of Seawater quality					
Color/odor					
Width/depth/velocity					
YSI data	pH	Temp (°C)	DO (mg/L)	Salinity	
Checklists of Collected Samples					
Seawater					
POCs			HMs		
Sediment					
General property	POCs		HMs		
Biota					
MPB assemblage	Chl-a	Meiofauna & Microbiome	Macrofauna		
Graphical Description & Remark					

Yellow Sea Ecosystem Study					
Site-ID	YC1	Date	07/02/2018	Weather	Cloudy
Location (GPS)	Latitude	34.11277 ° N		Arrival time	Departure time
	Longitude	120.32386 ° E		17:40 pm	18:35 pm
Recorded by	Wenyou Hu	Sampled by		Moojoon Lee Dohyeong Kim Kang Tian Peng Liu	
In situ Measurement of Riverwater or Seawater quality (Seawater)					
Color/odor					
YSI data	pH	Temp (°C)	DO (mg/L)	Salinity (mS/cm)	
	7.84	25.4	7.15	15.02	
Corresponding soil information					
Site location	Latitude	34.11277 ° N	Landuse	Wheat/Maize	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Field Observation Log (Habitat Mapping Study)

Date: 2018.7.2
Station: YC1
Latitude: N
Longitude: E
Sed. temp.: °C
Salinity:

Epifauna/Burrow Counting (1 m² x 3 quadrats)

Quad. 1 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 Quad. 1 Remark

Mollusca: (rake)

Quad. 2 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 Quad. 2 Remark

Mollusca: (rake)

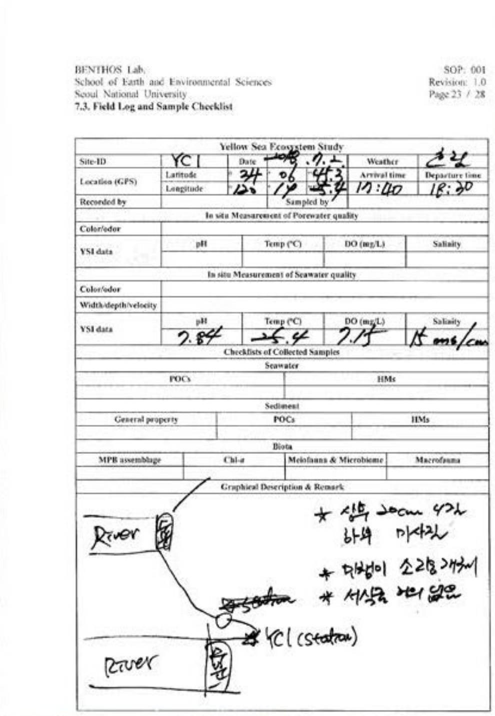
Quad. 3 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 Quad. 3 Remark

Mollusca: (rake)

NOTE

Description between stations (0-1000 m)

0 1000 m



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Yellow Sea Ecosystem Study						
Site-ID	YC1	Date	~~2018~~ .7.2		Weather	흐림
Location (GPS)	Latitude	° 34	′ 06	″ 44.3	Arrival time	Departure time
	Longitude	° 120	′ 14	″ 5.4	17:40	18:30
Recorded by		Sampled by				

In situ Measurement of Porewater quality				
Color/odor				
YSI data	pH	Temp (°C)	DO (mg/L)	Salinity

In situ Measurement of Seawater quality				
Color/odor				
Width/depth/velocity				
YSI data	pH	Temp (°C)	DO (mg/L)	Salinity
	7.84	25.4	7.15	15 ms/cm

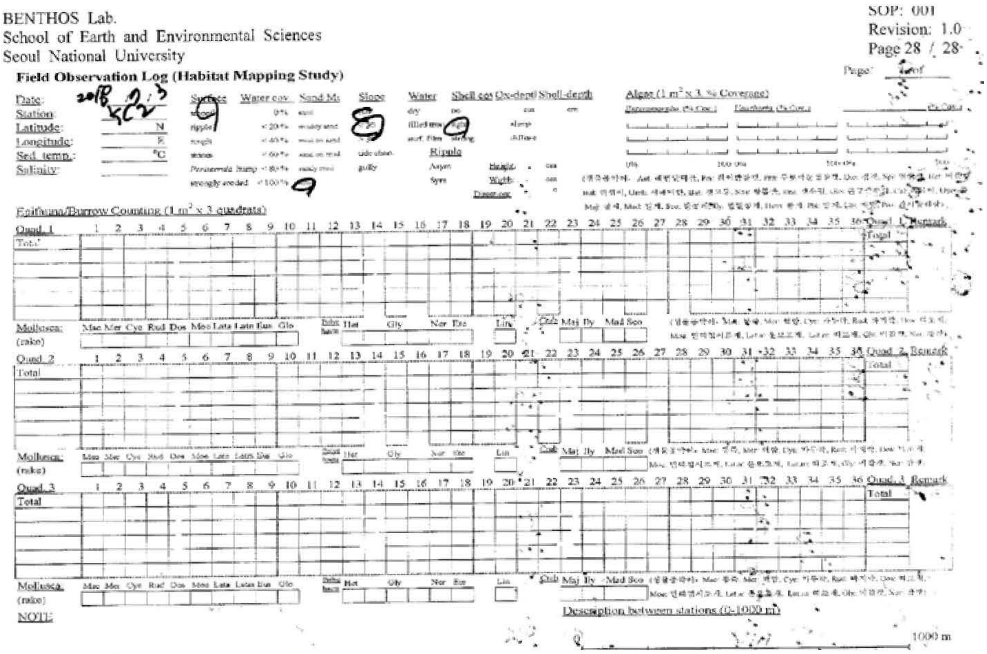
Checklists of Collected Samples			
Seawater			
POCs		HMs	
Sediment			
General property	POCs	HMs	
Biota			
MPB assemblage	Chl-a	Meiofauna & Microbiome	Macrofauna

Graphical Description & Remark

River
~~station~~
YC1 (station)
River

* 상부 20cm 니질
하부 미사질
* [illegible]
* 서식굴 거의 없음

Yellow Sea Ecosystem Study					
Site-ID	YC2	Date	07/03/2018	Weather	Cloudy
Location (GPS)	Latitude	33.81599 ° N		Arrival time	Departure time
	Longitude	120.47684 ° E		07:20 am	08:00 am
Recorded by	Wenyou Hu	Sampled by		Moojoon Lee Dohyeong Kim Kang Tian Peng Liu	
In situ Measurement of Riverwater or Seawater quality (Seawater)					
Color/odor					
YSI data	pH	Temp (°C)	DO (mg/L)	Salinity (mS/cm)	
	7.59	27.0	2.36	843	
Corresponding soil information					
Site location	Latitude	33.81599 ° N	Landuse	Farmland/Reed land	


BENTHOS Lab.
School of Earth and Environmental Sciences
Seoul National University
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Field Observation Log (Habitat Mapping Study)
Date: 2018 7.3
Station: YC2
Latitude: N
Longitude: E
Sed. temp.: °C
Salinity:
Epifauna/Burrow Counting (1 m² x 3 quadrats)
Quad. 1
Quad. 2
Quad. 3
Mollusca (rake)
NOTE:
Description between stations (0-1000 m)

7.3. Field Log and Sample Checklist

Yellow Sea Ecosystem Study							
Site-ID	YC2	Date	2018 7 3			Weather	흐림
Location (GPS)	Latitude	33 °	48 '	57.8 " N		Arrival time	Departure time
	Longitude	120 °	8 '	36.5 " E		7:10	8:00
Recorded by	CMJ		Sampled by	CMJ KDH			

In situ Measurement of Porewater quality				
Color/odor				
YSI data	pH	Temp (°C)	DO (mg/L)	Salinity

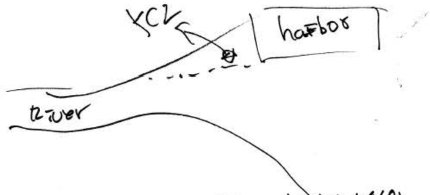
In situ Measurement of Seawater quality				
Color/odor				
Width/depth/velocity				
YSI data	pH	Temp (°C)	DO (mg/L)	Salinity
	7.59	29	2.36	843 µs/cm

Checklists of Collected Samples	
Seawater	
POCs	HMs

Sediment		
General property	POCs	HMs

Biota			
MPB assemblage	Chl-*a*	Meiofauna & Microbiome	Macrofauna

Graphical Description & Remark



*1~2mm 자갈 서식굴 다수. (사진확인 필요)

Yellow Sea Ecosystem Study					
Site-ID	YC5	Date	07/03/2018	Weather	Sunny
Location (GPS)	Latitude	33.73996 ° N		Arrival time	Departure time
	Longitude	120.54187 ° E		11:00 am	11:40 am
Recorded by	Wenyou Hu	Sampled by		Moojoon Lee Dohyeong Kim Kang Tian Peng Liu	
In situ Measurement of Riverwater or Seawater quality (Seawater)					
Color/odor					
YSI data	pH	Temp (^{o}C)	DO (mg/L)	Salinity (mS/cm)	
	7.86	28.0	7.49	20.18	
Corresponding soil information					
Site location	Latitude	33.73050 ° N	Landuse	Farmland/Fallow	

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School of Earth and Environmental Sciences
Seoul National University
7.3. Field Log and Sample Checklist

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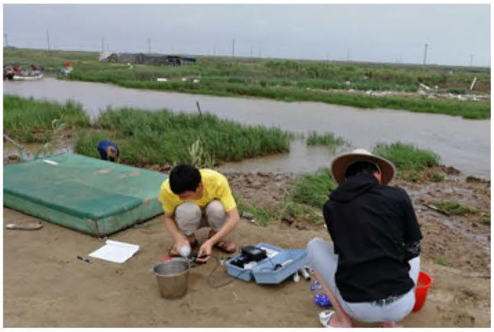
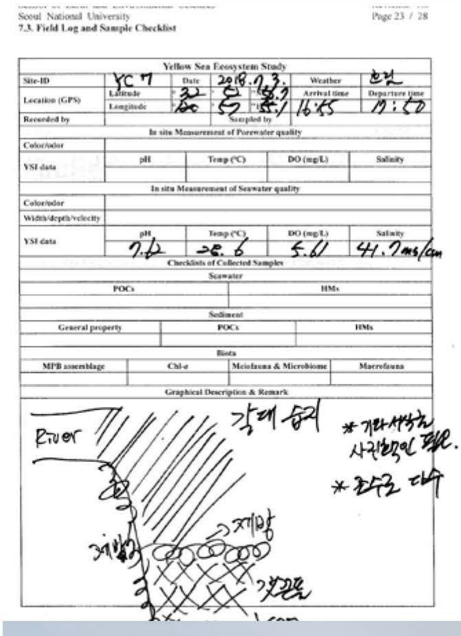
Yellow Sea Ecosystem Study					
Site-ID	YC5	Date	2018. 7. 3.	Weather	맑음
Location (GPS)	Latitude	33 44 16.6		Arrival time	Departure time
	Longitude	120 32 11.3		11:00	11:50
Recorded by		Sampled by			
In situ Measurement of Porewater quality					
Color/odor					
YSI data	pH	Temp (°C)	DO (mg/L)	Salinity	
In situ Measurement of Seawater quality					
Color/odor					
Width/depth/velocity					
YSI data	pH	Temp (°C)	DO (mg/L)	Salinity	
	7.86	28	7.49	20.18 ms/cm	
Checklists of Collected Samples					
Seawater					
POCs			HMs		
Sediment					
General property	POCs		HMs		
Biota					
MPB assemblage	Chl-a	Meiofauna & Microbiome	Macrofauna		
Graphical Description & Remark					




Yellow Sea
中韓黃海共同調査
한중황해공동조사
Joint Field Survey
中國科學院
서울대학교

Yellow Sea Ecosystem Study					
Site-ID	YC7	Date	07/03/2018	Weather	Sunny
Location (GPS)	Latitude	32.88213 ° N		Arrival time	Departure time
	Longitude	120.96457 ° E		16:50 pm	18:05 pm
Recorded by	Wenyou Hu	Sampled by		Moojoon Lee Dohyeong Kim Kang Tian Peng Liu	
In situ Measurement of Riverwater or Seawater quality (Seawater)					
Color/odor					
YSI data	pH	Temp (°C)	DO (mg/L)	Salinity (mS/cm)	
	7.62	28.6	5.61	41.7	
Corresponding soil information					
Site location	Latitude	32.88213 ° N	Landuse	Farmland/Fallow	



Seoul National University
7.3. Field Log and Sample Checklist

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Yellow Sea Ecosystem Study					
Site-ID	YC 7	Date	2018.7.3.	Weather	흐림
Location (GPS)	Latitude	32	52	Arrival time	Departure time
	Longitude	120	57	16:55	17:50
Recorded by		Sampled by			
In situ Measurement of Porewater quality					
Color/odor					
YSI data	pH	Temp (°C)	DO (mg/L)	Salinity	
In situ Measurement of Seawater quality					
Color/odor					
Width/depth/velocity					
YSI data	pH	Temp (°C)	DO (mg/L)	Salinity	
	7.62	28.6	5.61	41.7ms/cm	
Checklists of Collected Samples					
Seawater					
POCs		HMs			
Sediment					
General property	POCs	HMs			
Biota					
MPB assemblage	Chl-a	Meiofauna & Microbiome	Macrofauna		
Graphical Description & Remark					

River

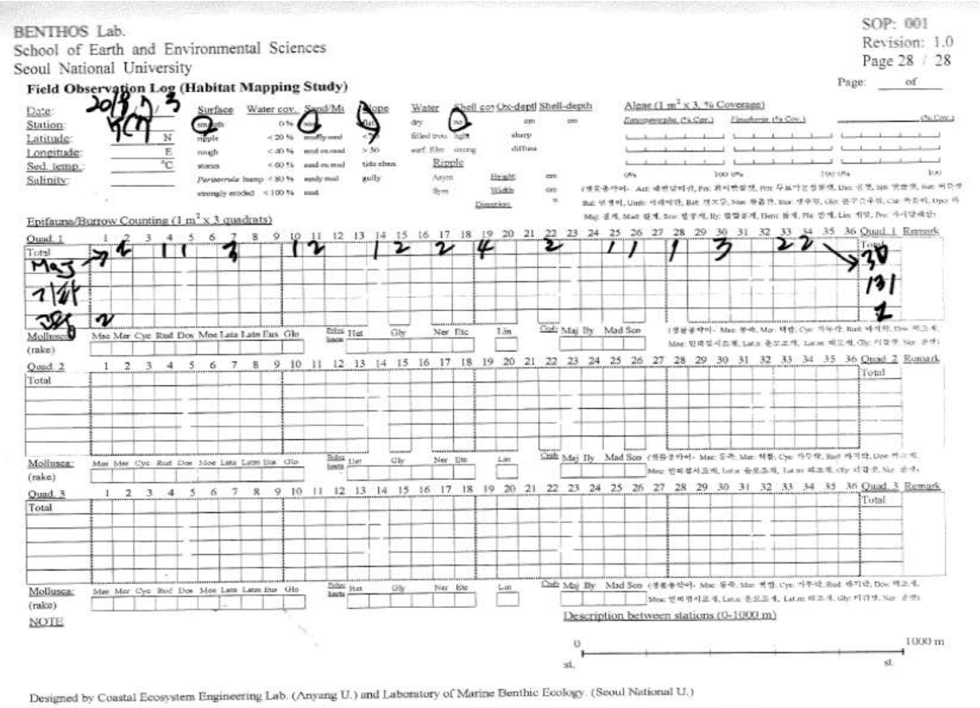
갈대 습지

* 기타 세부는 사진확인 필요.

* 조수로 다수

제방

갯골들



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Seoul National University

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Field Observation Log (Habitat Mapping Study)

Date: 2019/7/3
Station: 4C17
Latitude: N
Longitude: E
Sed. temp.: °C
Salinity:

Surface: smooth, ripple, rough, stones, *Periserrula* hump, strongly eroded
Water cov.: 0 %, < 20 %, < 40 %, < 60 %, < 80 %, < 100 %
Sand/Mud: sand, muddy sand, sand on mud, mud on sand, sandy mud, mud
Slope: flat, < 30, > 30, tide chan., gully
Water: dry, filled trou., surf. film
Shell cov.: no, light, strong
Ox-depth: cm
Shell-depth: cm
Ripple: Asym, Sym; Height cm; Width cm; Direction °

Algae (1 m² x 3, % Coverage)

Epifauna/Burrow Counting (1 m² x 3 quadrats)

Quad. 1: 1–36, Quad. 1 Total, Remark
Total / Maj / 기타 / 게 — Total 30, 131, 2

Mollusca (rake): Mac Mer Cyc Rud Dos Moe Lata Latm Eus Glo; Polinices; Het; Gly; Ner Etc; Lin
Crab: Maj Ily Mad Sco

Quad. 2: 1–36, Quad. 2 Total, Remark

Mollusca (rake)

Quad. 3: 1–36, Quad. 3 Total, Remark

Mollusca (rake)

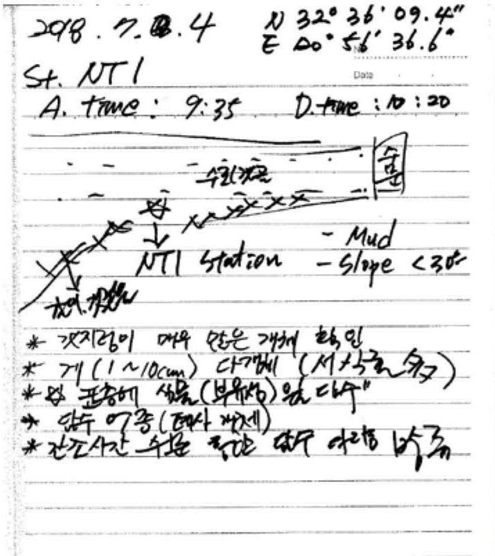
NOTE

Description between stations (0-1000 m)

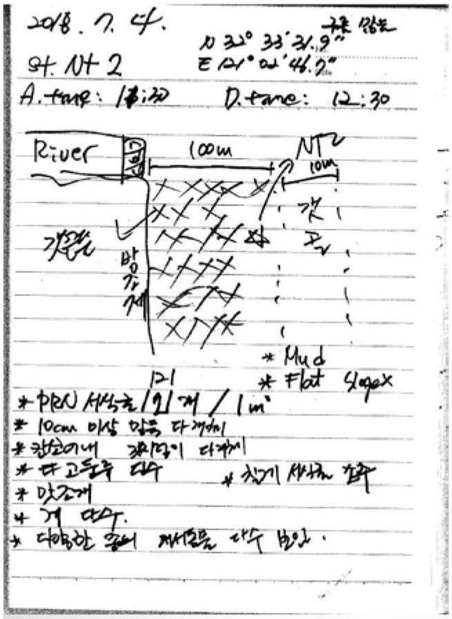
0 st. — 1000 m st.

Designed by Coastal Ecosystem Engineering Lab. (Anyang U.) and Laboratory of Marine Benthic Ecology. (Seoul National U.)

Yellow Sea Ecosystem Study					
Site-ID	NT1	Date	07/04/2018	Weather	Sunny
Location (GPS)	Latitude	32.60305 ° N		Arrival time	Departure time
	Longitude	120.94372 ° E		09:40 am	10:30 am
Recorded by	Wenyou Hu		Sampled by	Moojoon Lee Dohyeong Kim Kang Tian Peng Liu	
In situ Measurement of Riverwater or Seawater quality (Seawater)					
Color/odor					
YSI data	pH	Temp (°C)	DO (mg/L)	Salinity (mS/cm)	
	7.65	29.0	4.66	2.31	
Corresponding soil information					
Site location	Latitude	32.60028 ° N	Landuse	Farmland/Fallow	



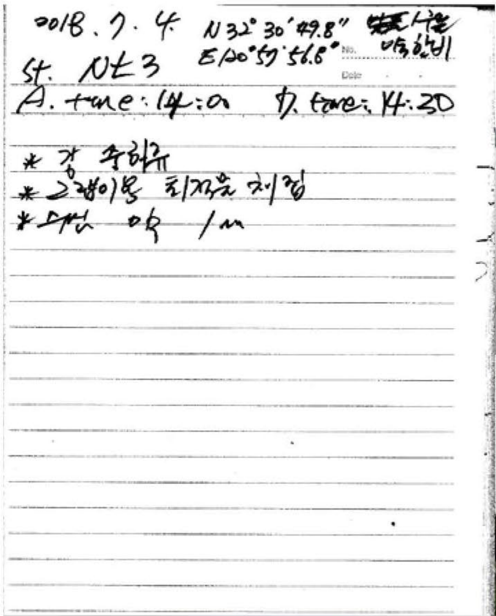
Yellow Sea Ecosystem Study					
Site-ID	NT2	Date	07/04/2018	Weather	Cloudy
Location (GPS)	Latitude	32.55767 ° N		Arrival time	Departure time
	Longitude	121.04588 ° E		11:25 am	12:10 pm
Recorded by	Wenyou Hu		Sampled by	Moojoon Lee Dohyeong Kim Kang Tian Peng Liu	
In situ Measurement of Riverwater or Seawater quality (Seawater)					
Color/odor					
YSI data	pH	Temp (°C)		DO (mg/L)	Salinity (mS/cm)
	8.58	31.5		16.25	17.17
Corresponding soil information					
Site location	Latitude	32.54843 ° N		Landuse	Farmland/Fallow







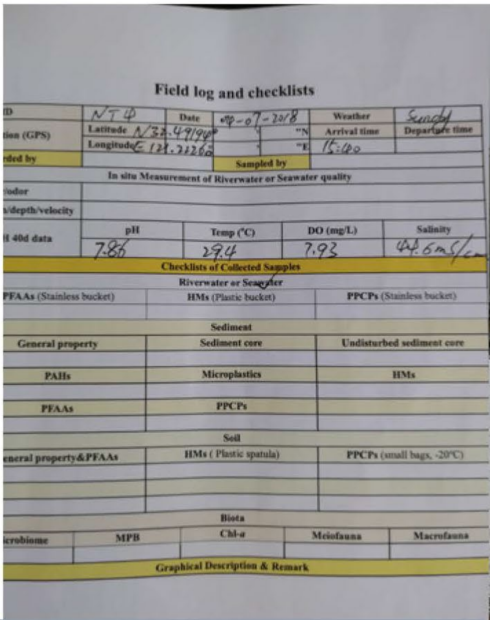
Yellow Sea Ecosystem Study					
Site-ID	NT3	Date	07/04/2018	Weather	Rain
Location (GPS)	Latitude	32.51403° N		Arrival time	Departure time
	Longitude	120.966014° E		14:00 pm	14:25 pm
Recorded by	Wenyou Hu	Sampled by		Moojoon Lee Dohyeong Kim Kang Tian Peng Liu	
In situ Measurement of Riverwater or Seawater quality (Seawater)					
Color/odor					
YSI data	pH	Temp (°C)	DO (mg/L)	Salinity (mS/cm)	
	8.15	30.0	11.68	1439	
Corresponding soil information					
Site location	Latitude	32.518599° N	Landuse	Farmland/Fallow	

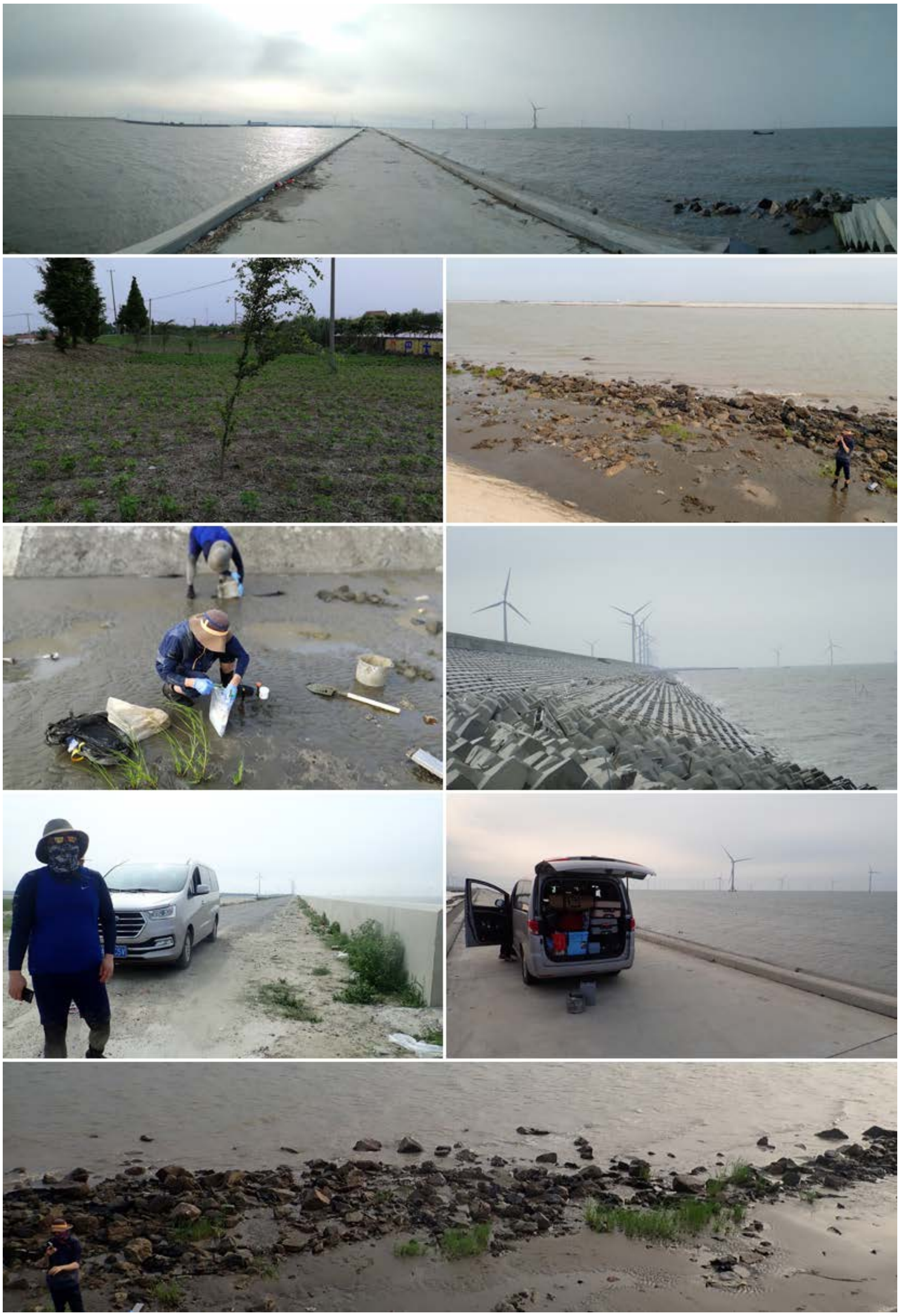




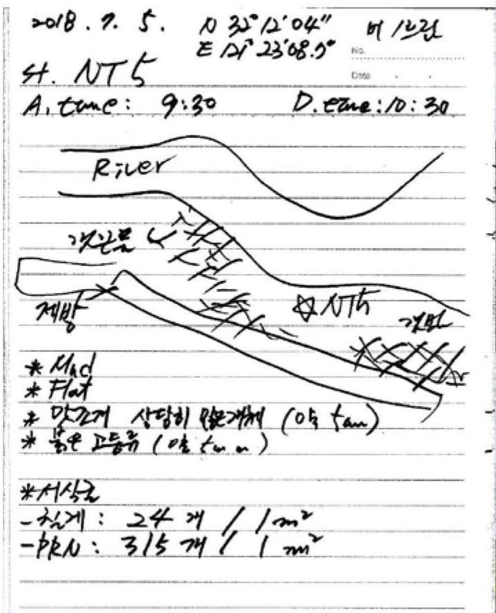


Yellow Sea Ecosystem Study					
Site-ID	NT4	Date	07/04/2018	Weather	Sunny
Location (GPS)	Latitude	32.49194 ° N		Arrival time	Departure time
	Longitude	121.22260 ° E		15:40 pm	17:40 pm
Recorded by	Wenyou Hu		Sampled by	Moojoon Lee Dohyeong Kim Kang Tian Peng Liu	
In situ Measurement of Riverwater or Seawater quality (Seawater)					
Color/odor					
YSI data	pH	Temp (°C)	DO (mg/L)	Salinity (mS/cm)	
	7.86	29.4	7.93	44.6	
Corresponding soil information					
Site location	Latitude	32.46896 ° N	Landuse	Farmland/Fallow	

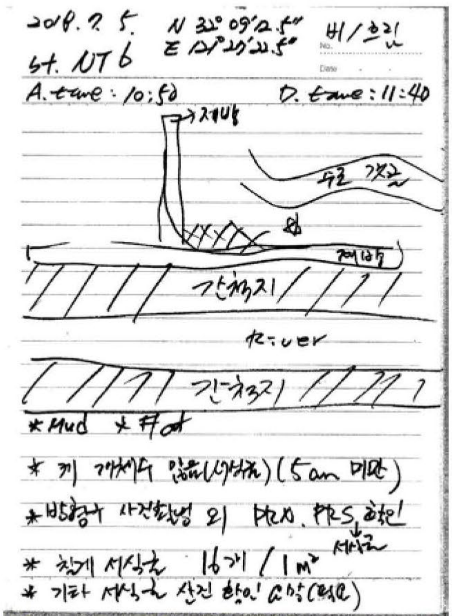




Yellow Sea Ecosystem Study						
Site-ID	NT5	Date	07/05/2018		Weather	Cloudy
Location (GPS)	Latitude	32.20158 ° N			Arrival time	Departure time
	Longitude	121.38514 ° E			07:40 am	10:20 am
Recorded by	Wenyou Hu		Sampled by		Moojoon Lee Dohyeong Kim Kang Tian Peng Liu	
In situ Measurement of Riverwater or Seawater quality **(Seawater)**						
Color/odor						
YSI data	pH		Temp (^{o}C)	DO (mg/L)	Salinity (mS/cm)	
	7.37		28.8	5.09	28.1	
Corresponding soil information						
Site location	Latitude		32.19331 ° N	Landuse	Wetland	



Yellow Sea Ecosystem Study					
Site-ID	NT6	Date	07/05/2018	Weather	Cloudy
Location (GPS)	Latitude	32.15348 ° N		Arrival time	Departure time
	Longitude	121.45621 ° E		11:10 am	11:40 am
Recorded by	Wenyou Hu	Sampled by		Moojoon Lee Dohyeong Kim Kang Tian Peng Liu	
In situ Measurement of Riverwater or Seawater quality (Seawater)					
Color/odor					
YSI data	pH	Temp (°C)	DO (mg/L)	Salinity (mS/cm)	
	7.67	27.7	6.66	43.1	
Corresponding soil information					
Site location	Latitude	32.15006 ° N	Landuse	Farmland/Fallow	

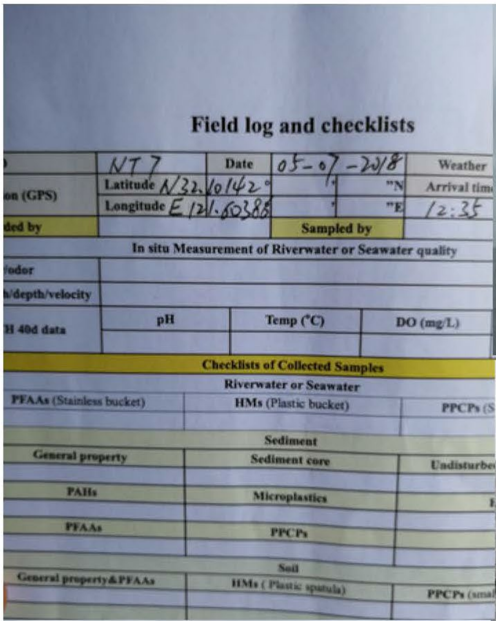









Yellow Sea Ecosystem Study						
Site-ID	NT7	Date	07/05/2018		Weather	Cloudy
Location (GPS)	Latitude	32.10142 ° N			Arrival time	Departure time
	Longitude	121.60386 ° E			12:35 pm	13:00 pm
Recorded by	Wenyou Hu		Sampled by		Moojoon Lee Dohyeong Kim Kang Tian Peng Liu	
In situ Measurement of Riverwater or Seawater quality (Seawater)						
Color/odor						
YSI data	pH		Temp (°C)		DO (mg/L)	Salinity (mS/cm)
	8.07		27.5		8.20	44.6
Corresponding soil information						
Site location	Latitude		32.07958 ° N		Landuse	Farmland/Bean



Field log and checklists

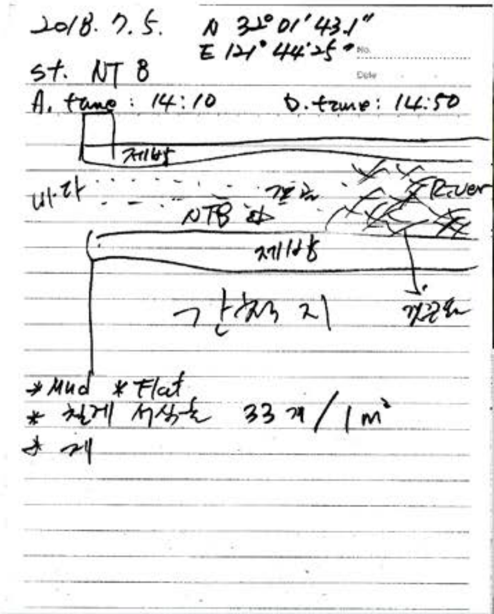
	NT7	Date	05-07-2018		Weather
on (GPS)	Latitude N 32.10142 °		'	"N	Arrival time
	Longitude E 121.60388		'	"E	12:35
ded by			Sampled by		
In situ Measurement of Riverwater or Seawater quality					
/odor					
h/depth/velocity					
H 40d data	pH	Temp (°C)	DO (mg/L)		

Checklists of Collected Samples		
Riverwater or Seawater		
PFAAs (Stainless bucket)	HMs (Plastic bucket)	PPCPs (S
Sediment		
General property	Sediment core	Undisturbe
PAHs	Microplastics	
PFAAs	PPCPs	
Soil		
General property&PFAAs	HMs (Plastic spatula)	PPCPs (smal

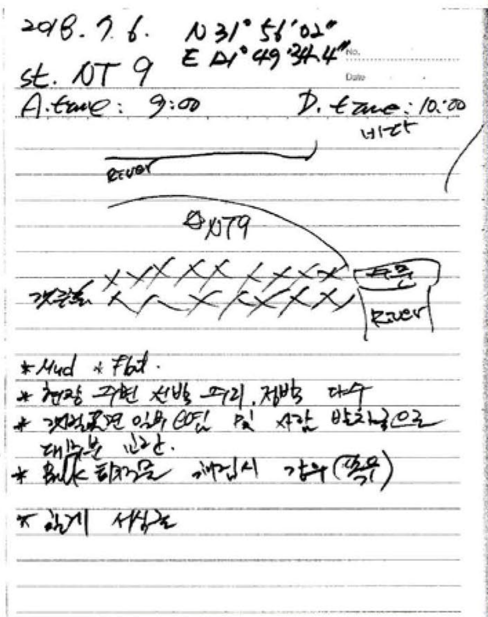




Yellow Sea Ecosystem Study					
Site-ID	NT8	Date	07/05/2018	Weather	Cloudy
Location (GPS)	Latitude	32.02919 ° N		Arrival time	Departure time
	Longitude	121.74113 ° E		13:52 pm	14:30 pm
Recorded by	Wenyou Hu		Sampled by	Moojoon Lee Dohyeong Kim Kang Tian Peng Liu	
In situ Measurement of Riverwater or Seawater quality **(Seawater)**					
Color/odor					
YSI data	pH	Temp (°C)		DO (mg/L)	Salinity (mS/cm)
	7.96	27.0		7.45	30.8
Corresponding soil information					
Site location	Latitude	32.00898 ° N		Landuse	Farmland/Corn



Yellow Sea Ecosystem Study					
Site-ID	NT9	**Date**	07/06/2018	**Weather**	Cloudy
Location (GPS)	**Latitude**	31.93365 ° N		**Arrival time**	**Departure time**
	Longitude	121.82565 ° E		09:00 am	10:00 am
Recorded by	Wenyou Hu	**Sampled by**	Moojoon Lee Dohyeong Kim Kang Tian Peng Liu		
In situ Measurement of Riverwater or Seawater quality (Seawater)					
Color/odor					
YSI data	**pH**	**Temp (°C)**	**DO (mg/L)**	**Salinity (mS/cm)**	
	7.60	26.7	4.26	33.3	
Corresponding soil information					
Site location	**Latitude**	31.93123 ° N	**Landuse**	**Farmland/Fallow**	

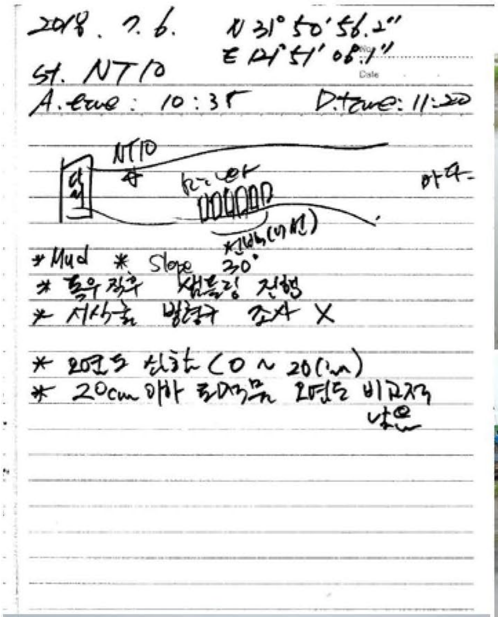




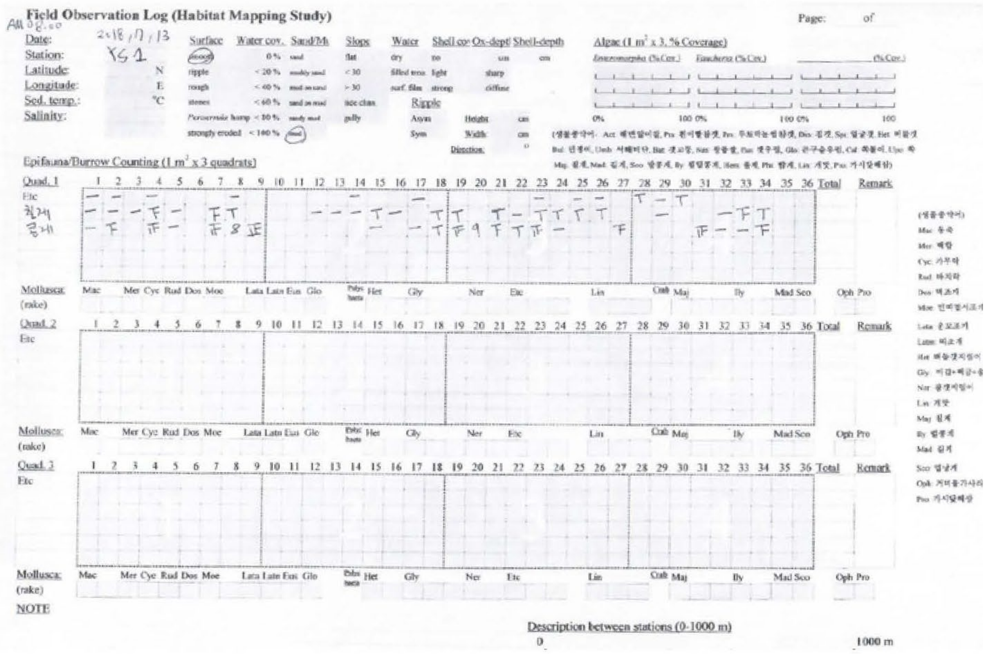




Yellow Sea Ecosystem Study					
Site-ID	NT10	Date	07/06/2018	Weather	Rainy
Location (GPS)	Latitude	31.84900 ° N		Arrival time	Departure time
	Longitude	121.85211 ° E		10:40 am	11:20 am
Recorded by	Wenyou Hu	Sampled by		Moojoon Lee Dohyeong Kim Kang Tian Peng Liu	
In situ Measurement of Riverwater or Seawater quality (Seawater)					
Color/odor					
YSI data	pH	Temp (°C)		DO (mg/L)	Salinity (mS/cm)
	7.65	27.4		3.05	201
Corresponding soil information					
Site location	Latitude	31.84907 ° N		Landuse	Farmland/Corn



Yellow Sea Ecosystem Study					
Site-ID	YS1	Date	07/13/2018	Weather	Cloudy
Location (GPS)	Latitude	35.02500 ° N		Arrival time	Departure time
	Longitude	126.61333 ° E		8:00 am	9:48 am
Recorded by	Junghyun Lee	Sampled by		Junsung Noh Junghyun Lee Seonju Kim Jooyeong Park	
In situ Measurement of Riverwater or Seawater quality (Mixed water)					
Color/odor					
Width/depth/velocity	Coastal area, outside of estuary dam				
HACH 40d data	pH	Temp (°C)	DO (mg/L)	Salinity (mS/cm)	
	8.34	28.06	7.34	26.74	
Corresponding soil information					
Site location	Latitude	° N	Landuse	Municipal	


Field Observation Log (Habitat Mapping Study)

Page: of

Date: 2018/7/13

Station: YS1

Latitude: N

Longitude: E

Sed. temp.: °C

Salinity:

Surface | Water cov. | Sand/M. | Slope | Water | Shell co | Ox-dept | Shell-depth

Algae (1 m² x 3, % Coverage)

Epifauna/Burrow Counting (1 m² x 3 quadrats)

Quad. 1 — Etc, 칠게, 굴게

Mollusca (rake): Mac Mer Cyc Rud Dos Moe Lata Latn Eus Glo Het Gly Ner Etc Lin Crab Maj Ily Mad Sco Oph Pro

Quad. 2 — Etc

Mollusca (rake)

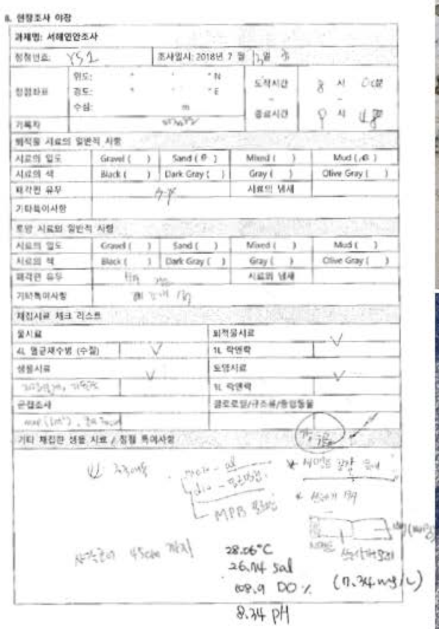
Quad. 3 — Etc

Mollusca (rake)

NOTE

Description between stations (0-1000 m)

0 1000 m



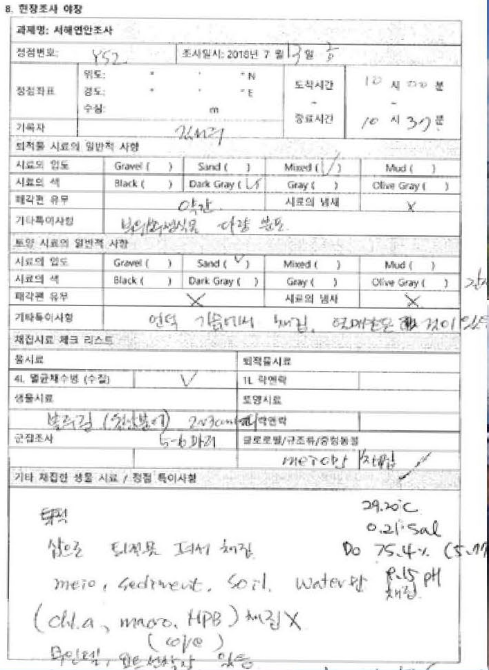
8. 현장조사 야장

과제명: 서해연안조사				
정점번호: YS2		조사일시: 2018년 7 월 13일		
정점좌표	위도: ° ' " N 경도: ° ' " E 수심: m		도착시간 - 종료시간	8 시 00분 - 9 시 40분
기록자				
퇴적물 시료의 일반적 사항				
시료의 입도	Gravel ( )	Sand ( )	Mixed ( )	Mud ( )
시료의 색	Black ( )	Dark Gray ( )	Gray ( )	Olive Gray ( )
패각편 유무			시료의 냄새	
기타특이사항				
토양 시료의 일반적 사항				
시료의 입도	Gravel ( )	Sand ( )	Mixed ( )	Mud ( )
시료의 색	Black ( )	Dark Gray ( )	Gray ( )	Olive Gray ( )
패각편 유무			시료의 냄새	
기타특이사항				
채집시료 체크 리스트				
물시료			퇴적물시료	V
4L 멸균채수병 (수질)	V		1L 락앤락	
생물시료	V		토양시료	V
			1L 락앤락	
근접조사			클로로필/규조류/중형동물	
기타 채집한 생물 시료 / 정점 특이사항				

MPB

28.06°C
26.74 sal
108.9 DO %
(7.34 mg/L)
8.34 pH

Yellow Sea Ecosystem Study					
Site-ID	YS2	Date	07/13/2018	Weather	Cloudy
Location (GPS)	Latitude	34.83833 ° N		Arrival time	Departure time
	Longitude	126.66306 ° E		10:00 am	10:37 am
Recorded by	Junghyun Lee	Sampled by		Junsung Noh Junghyun Lee Seonju Kim Jooyeong Park	
In situ Measurement of Riverwater or Seawater quality (Mixed water)					
Color/odor					
Width/depth/velocity	River, inside of estuary dam				
HACH 40d data	pH	Temp (°C)	DO (mg/L)	Salinity (mS/cm)	
	9.15	29.2	5.77	0.21	
Corresponding soil information					
Site location	Latitude	° N	Landuse	Municipal	



8. 현장조사 야장

과제명: 서해연안조사				
정점번호: YS2	조사일시: 2018년 7 월 13 일			
정점좌표	위도: ° ' " N 경도: ° ' " E 수심: m		도착시간 ~ 종료시간	10 시 00 분 ~ 10 시 37 분
기록자	김세리			
퇴적물 시료의 일반적 사항				
시료의 입도	Gravel ( )	Sand ( )	Mixed (✓)	Mud ( )
시료의 색	Black ( )	Dark Gray (✓)	Gray ( )	Olive Gray ( )
패각편 유무	약간.		시료의 냄새	X
기타특이사항	부유물 다량 분포.			
토양 시료의 일반적 사항				
시료의 입도	Gravel ( )	Sand (✓)	Mixed ( )	Mud ( )
시료의 색	Black ( )	Dark Gray ( )	Gray ( )	Olive Gray ( )
패각편 유무	X		시료의 냄새	X
기타특이사항	언덕 가운데서 채집.			
채집시료 체크 리스트				
물시료		퇴적물시료		
4L 멸균채수병 (수질)	✓	1L 락앤락		
생물시료		토양시료		
	2~3cm	락앤락		
군집조사	5-6 마리	클로로필/규조류/중형동물		
		meiofauna 채집 ✓		
기타 채집한 생물 시료 / 정점 특이사항				

29.20°C

0.21 Sal

DO 75.4% (5.77)

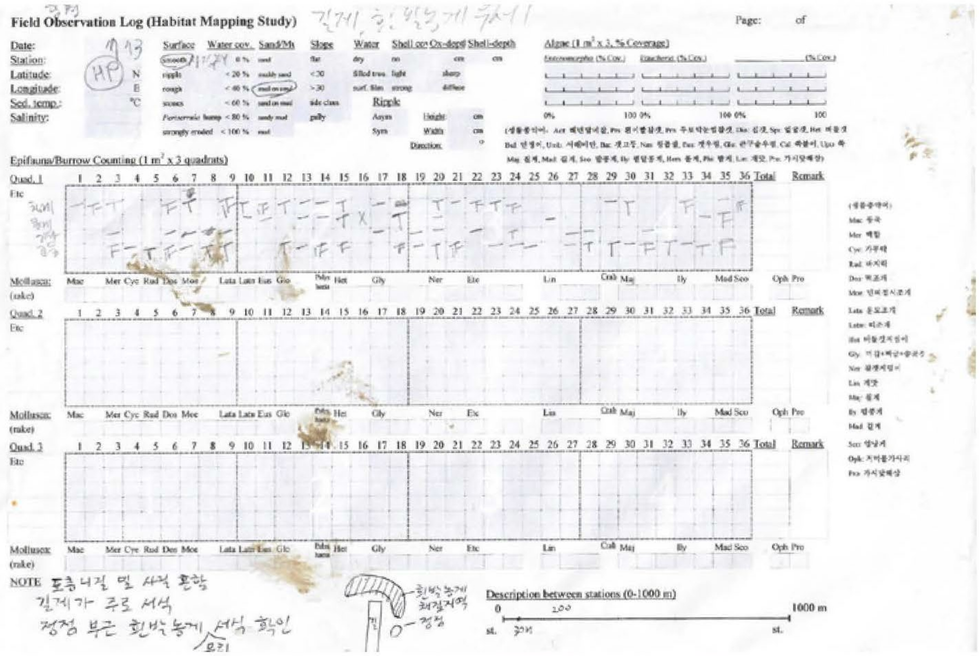
9.15 pH

meio, sediment, soil, water만 채집

(chl.a, macro, HPB) 채집 X


9.15 pH
436
-163.8
0.21 Sal
75.4 DO%
5.77

Yellow Sea Ecosystem Study					
Site-ID	HP	Date	07/13/2018	Weather	Sunny
Location (GPS)	Latitude	35.17722 ° N		Arrival time	Departure time
	Longitude	126.41361 ° E		11:30 am	12:30 pm
Recorded by	Junghyun Lee	Sampled by	Junsung Noh Junghyun Lee Seonju Kim Jooyeong Park		
In situ Measurement of Riverwater or Seawater quality (Mixed water)					
Color/odor					
Width/depth/velocity	Coastal area				
HACH 40d data	pH	Temp (°C)	DO (mg/L)	Salinity (mS/cm)	
	7.67	34.8	4.41	31.3	
Corresponding soil information					
Site location	Latitude	° N	Landuse	Agricultural	



Field Observation Log (Habitat Mapping Study)

Page: of

Date: Station: Latitude: Longitude: Sed. temp.: Salinity:

Epifauna/Burrow Counting (1 m² x 3 quadrats)

Quad. 1

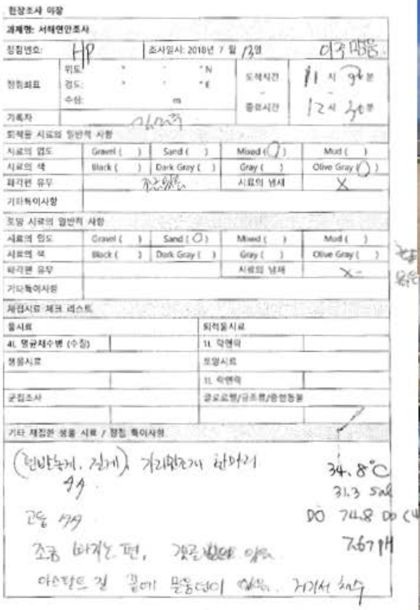
Quad. 2

Quad. 3

Molluscs: (rake)

NOTE

Description between stations (0-1000 m)

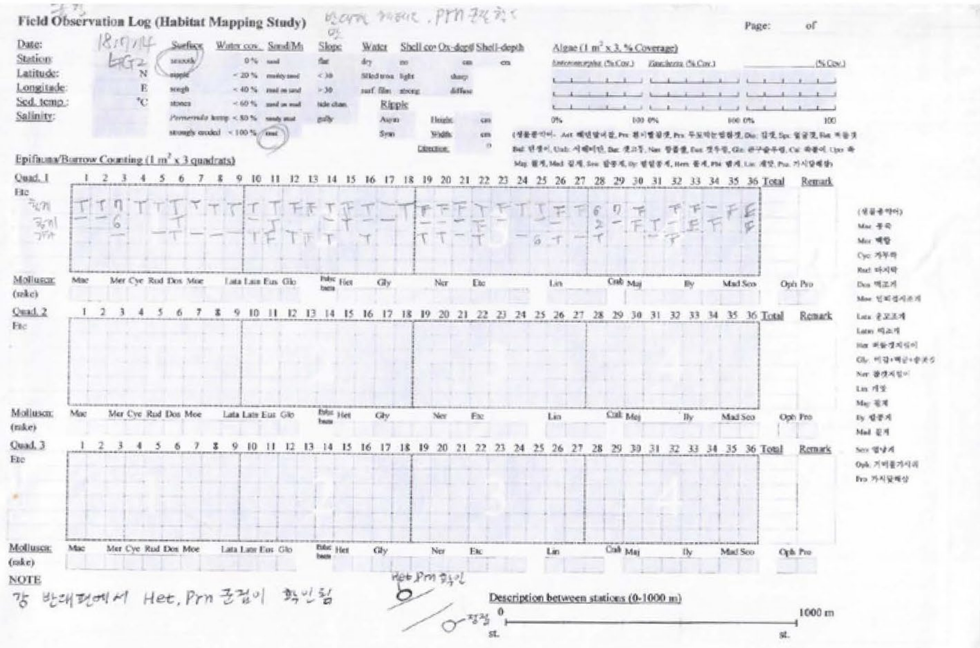


현장조사 야장

과제명: 서해연안조사				
정점번호: HP	조사일시: 2018년 7 월 13일			이곡 [illegible]
정점좌표	위도: ° ' "N 경도: ° ' "E 수심: m		도착시간 ~ 종료시간	11 시 [illegible] 분 ~ 12 시 30 분
기록자	[illegible]			
퇴적물 시료의 일반적 사항				
시료의 입도	Gravel ( )	Sand ( )	Mixed (O)	Mud ( )
시료의 색	Black ( )	Dark Gray ( )	Gray ( )	Olive Gray (O)
패각편 유무	[illegible]		시료의 냄새	X
기타특이사항				
조망 시료의 일반적 사항				
시료의 입도	Gravel ( )	Sand (O)	Mixed ( )	Mud ( )
시료의 색	Black ( )	Dark Gray ( )	Gray ( )	Olive Gray ( )
패각편 유무			시료의 냄새	X
기타특이사항				
채집시료 체크 리스트				
물시료			퇴적물시료	
4L 멸균채수병 (수질)			1L 약병	
생물시료			조망시료	
			1L 약병	
군집조사			클로로필/규조류/중형동물	
기타 채집한 생물 시료 / 정점 특이사항				

(칠게, 길게), 거리 [illegible] 20마리
34.8°C
31.3 sal
고둥 [illegible]
DO 74.8
조금 [illegible] 편, 갯골 [illegible]
7.67 pH
아스팔트 길 끝에 물웅덩이 있음. 거기서 채수

Yellow Sea Ecosystem Study						
Site-ID	GG2	Date	07/14/2018		Weather	Sunny
Location (GPS)	Latitude	36.14166 ° N			Arrival time	Departure time
	Longitude	126.76583 ° E			9:40 am	10:40 am
Recorded by	Junghyun Lee		Sampled by		Junsung Noh Junghyun Lee Seonju Kim Jooyeong Park	
In situ Measurement of Riverwater or Seawater quality (Mixed water)						
Color/odor						
Width/depth/velocity	Coastal area, outside of estuary dam					
HACH 40d data	pH		Temp (°C)		DO (mg/L)	Salinity (mS/cm)
	7.58		35.7		3.74	12.71
Corresponding soil information						
Site location	Latitude	° N			Landuse	Agricultural


Field Observation Log (Habitat Mapping Study)

Page: of

Date: 18.07.14

Station: GG2

Latitude: N

Longitude: E

Sed. temp.: °C

Salinity:

Surface | Water cov. | Sand/Mud | Slope | Water | Shell cov | Ox-depth | Shell-depth

Algae (1 m² x 3, % Coverage)

Ripple

Epifauna/Burrow Counting (1 m² x 3 quadrats)

Quad. 1 | Quad. 2 | Quad. 3 — 1–36, Total, Remark

Mollusca (rake): Mac Mer Cye Rud Dos Moe Lata Late Eus Glo Het Gly Ner Etc Lin Cab Maj Ily Mad Sco Oph Pro

NOTE

강 반대편에서 Het, Prn 군집이 확인됨

Het Prn 확인

Description between stations (0-1000 m)

0 st. — 1000 m st.

8. 현장조사 야장

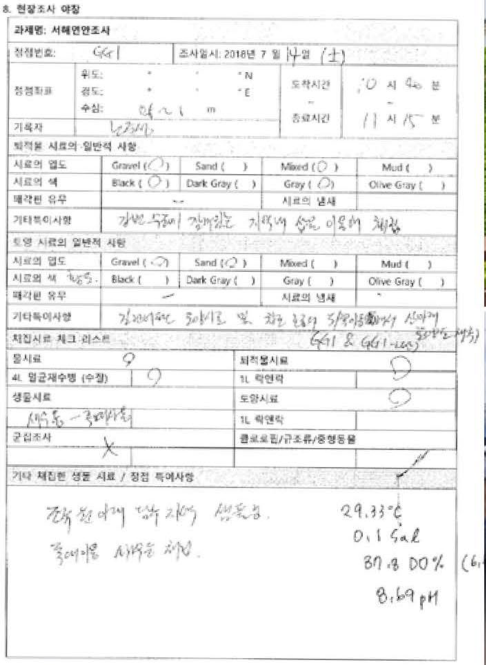
과제명: 서해연안조사				
정점번호: GG2		조사일시: 2018년 7 월 1[illegible]일		
정점위치	위도: ° ' " N 경도: ° ' " E 수심: m		도착시간 ~ 종료시간	9 시 40 분 ~ 시 분
기록자				
퇴적물 시료의 일반적 사항				
시료의 입도	Gravel ( )	Sand ( )	Mixed ( )	Mud ( )
시료의 색	Black ( )	Dark Gray ( )	Gray ( )	Olive Gray ( )
패각편 유무			시료의 냄새	
기타특이사항				
토양 시료의 일반적 사항				
시료의 입도	Gravel ( )	Sand ( )	Mixed ( )	Mud (O)
시료의 색	Black ( )	Dark Gray ( )	Gray ( )	Olive Gray ( )
패각편 유무			시료의 냄새	
기타특이사항				

채집시료 체크 리스트			
물시료		퇴적물시료 O	
4L 멸균채수병 (수질)	X	1L 약병	
생물시료		토양시료 O	
O		1L 약병	
군집조사		클로로필/규조류/중형동물	
O		O	

기타 채집한 생물 시료 / 정점 특이사항

35.7°C

Yellow Sea Ecosystem Study					
Site-ID	GG1	Date	07/14/2018	Weather	Sunny
Location (GPS)	Latitude	36.11305 ° N		Arrival time	Departure time
	Longitude	126.88111 ° E		10:40 am	11:15 am
Recorded by	Junghyun Lee	Sampled by		Junsung Noh Junghyun Lee Seonju Kim Jooyeong Park	
In situ Measurement of Riverwater or Seawater quality (Mixed water)					
Color/odor					
Width/depth/velocity	River, inside of estuary dam				
HACH 40d data	pH	Temp (°C)	DO (mg/L)	Salinity (mS/cm)	
	8.69	29.33	6.71	0.1	
Corresponding soil information					
Site location	Latitude	° N	Landuse	Agricultural	

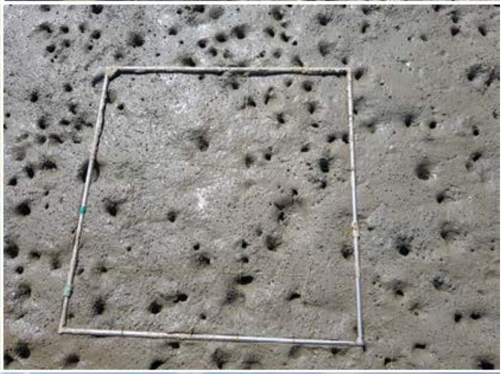


8. 현장조사 야장

과제명: 서해연안조사				
정점번호: GG1		조사일시: 2018년 7 월 14일 (土)		
정점좌표	위도: ° ' " N 경도: ° ' " E 수심: m	도착시간 ~ 종료시간	10 시 40 분 ~ 11 시 15 분	
기록자				
퇴적물 시료의 일반적 사항				
시료의 입도	Gravel (○)	Sand ( )	Mixed (○)	Mud ( )
시료의 색	Black (○)	Dark Gray ( )	Gray (○)	Olive Gray ( )
패각편 유무	–		시료의 냄새	
기타특이사항				
토양 시료의 일반적 사항				
시료의 입도	Gravel (○)	Sand (○)	Mixed ( )	Mud ( )
시료의 색	Black ( )	Dark Gray ( )	Gray ( )	Olive Gray ( )
패각편 유무	–		시료의 냄새	
기타특이사항				
채집시료 체크 리스트	GG1 & GG1-...			
물시료	○		퇴적물시료	○
4L 멸균채수병 (수질)	○		1L 락앤락	
생물시료			토양시료	○
			1L 락앤락	
군집조사	X		클로로필/규조류/중형동물	

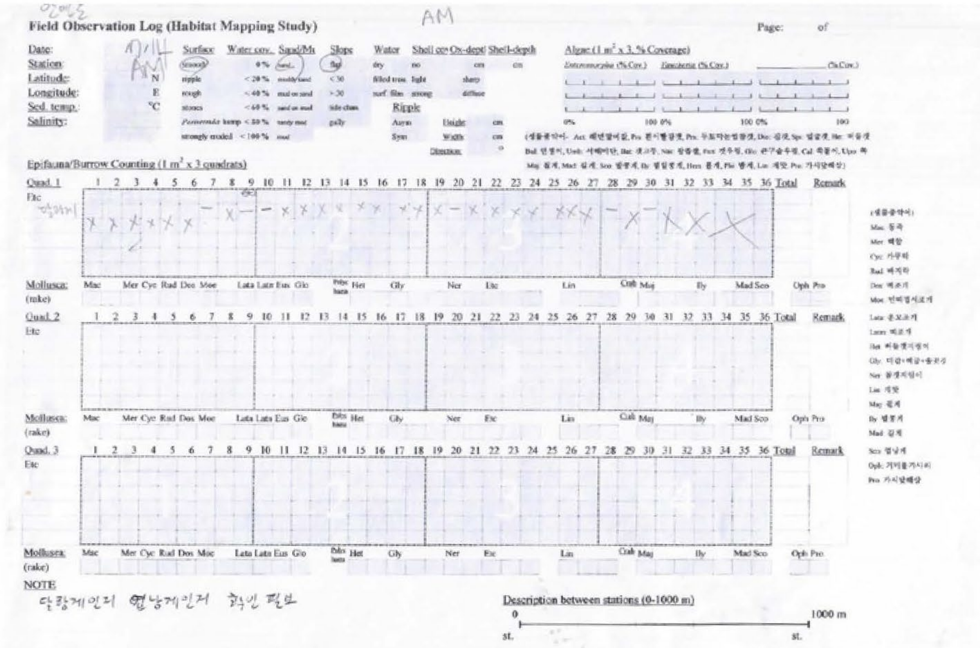
기타 채집한 생물 시료 / 정점 특이사항

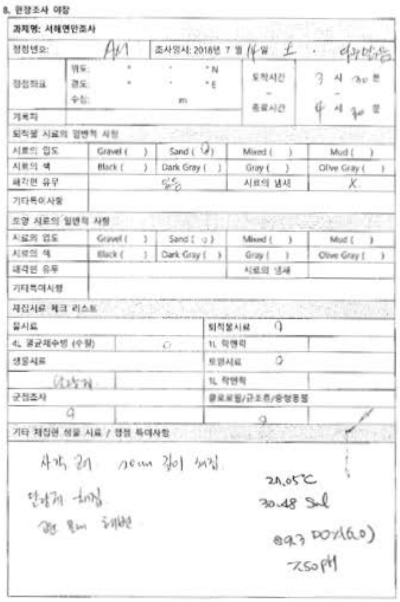
29.33°C
0.1 Sal
87.8 DO% (6.
8.69 pH




Yellow Sea
2018. 6 June ~7 July
한중황해공동조사
中韓黃海共同調査
Joint Field Survey
中國科學院
南京大學

Yellow Sea Ecosystem Study						
Site-ID	AM	Date	07/14/2018		Weather	Sunny
Location (GPS)	Latitude	36.64527 ° N			Arrival time	Departure time
	Longitude	126.48000 ° E			3:30 pm	4:30 pm
Recorded by	Junghyun Lee		Sampled by		Junsung Noh Junghyun Lee Seonju Kim Jooyeong Park	
In situ Measurement of Riverwater or Seawater quality (Mixed water)						
Color/odor						
Width/depth/velocity	Coastal area, beach					
HACH 40d data	pH	Temp (°C)		DO (mg/L)	Salinity (mS/cm)	
	7.5	27.05		6	30.48	
Corresponding soil information						
Site location	Latitude	° N		Landuse	Others	




8. 현장조사 야장

과제명: 서해연안조사				
정점번호: A11	조사일시: 2018년 7 월 14일 土 · 대천해수욕장			
정점좌표	위도: ° ' "N / 경도: ° ' "E / 수심: m		도착시간 ~ 종료시간	3 시 30 분 ~ 4 시 30 분
기록자				
퇴적물 시료의 일반적 사항				
시료의 입도	Gravel ( )	Sand (O)	Mixed ( )	Mud ( )
시료의 색	Black ( )	Dark Gray ( )	Gray ( )	Olive Gray ( )
패각편 유무	있음		시료의 냄새	X
기타특이사항				
토양 시료의 일반적 사항				
시료의 입도	Gravel ( )	Sand (O)	Mixed ( )	Mud ( )
시료의 색	Black ( )	Dark Gray ( )	Gray ( )	Olive Gray ( )
패각편 유무			시료의 냄새	
기타특이사항				

채집시료 체크 리스트			
물시료		퇴적물시료 O	
4L 멸균채수병 (수질)	O	1L 락앤락	
생물시료		토양시료 O	
달랑게		1L 락앤락	
군집조사		클로로필/균조류/중형동물	
O		O	

기타 채집된 생물 시료 / 정점 특이사항

사각 2개 30cm 깊이 채집

달랑게 채집

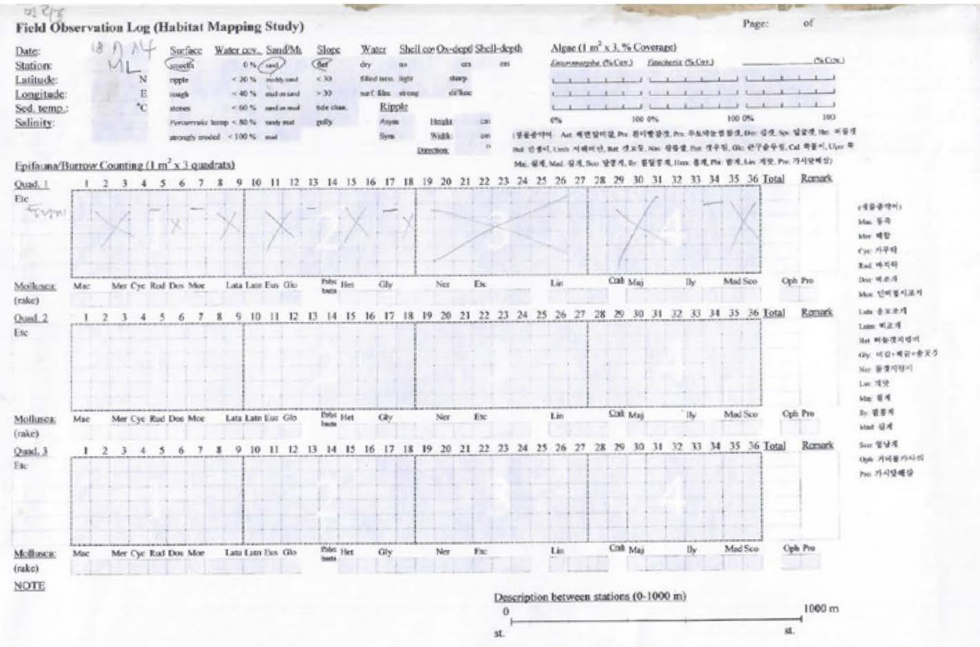
21.05°C

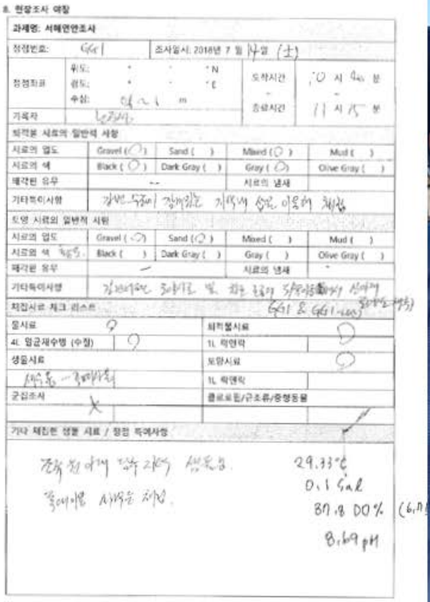
30.48 Sal

89.3 DO%(6.0)

7.50 pH

Yellow Sea Ecosystem Study					
Site-ID	ML	Date	07/14/2018	Weather	Sunny
Location (GPS)	Latitude	36.79083 ° N		Arrival time	Departure time
	Longitude	126.18472 ° E		5:25 pm	5:52 pm
Recorded by	Junghyun Lee	Sampled by		Junsung Noh Junghyun Lee Seonju Kim Jooyeong Park	
In situ Measurement of Riverwater or Seawater quality (Mixed water)					
Color/odor					
Width/depth/velocity	Coastal area, beach				
HACH 40d data	pH	Temp (°C)		DO (mg/L)	Salinity (mS/cm)
	7.61	23.05		7.49	31.18
Corresponding soil information					
Site location	Latitude	° N		Landuse	Others



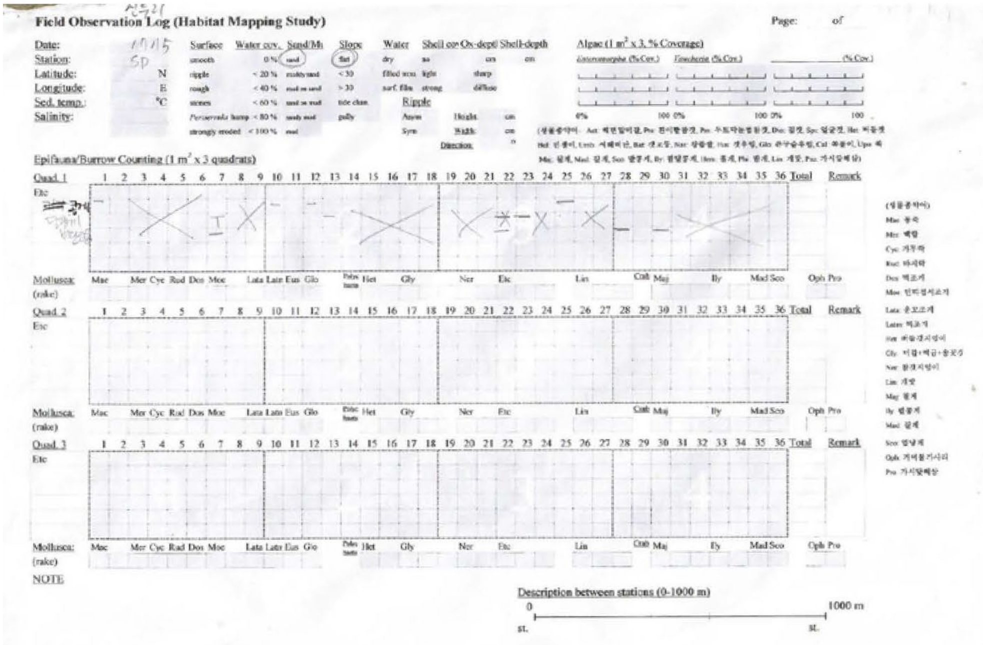


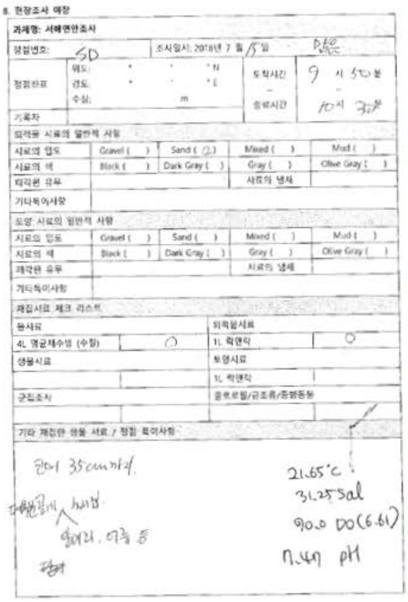
8. 현장조사 야장

과제명: 서해연안조사				
정점번호: GG1		조사일시: 2018년 7 월 14일 (土)		
정점좌표	위도: ° ' " N 경도: ° ' " E 수심: m		도착시간 ~ 종료시간	10 시 40 분 ~ 11 시 15 분
기록자				
퇴적물 시료의 일반적 사항				
시료의 입도	Gravel (○)	Sand ( )	Mixed (○)	Mud ( )
시료의 색	Black (○)	Dark Gray ( )	Gray (○)	Olive Gray ( )
패각편 유무	--		시료의 냄새	
기타특이사항				
토양 시료의 일반적 사항				
시료의 입도	Gravel (○)	Sand (○)	Mixed ( )	Mud ( )
시료의 색	Black ( )	Dark Gray ( )	Gray ( )	Olive Gray ( )
패각편 유무	-		시료의 냄새	-
기타특이사항				
채집시료 체크 리스트		GG1 & GG1-100		
물시료	○		퇴적물시료	○
4L 멸균채수병 (수질)	○		1L 락앤락	
생물시료			토양시료	○
			1L 락앤락	
군집조사	X		클로로필/규조류/중형동물	
기타 채집된 생물 시료 / 정점 특이사항				

29.33℃
0.1 Sal
87.8 DO%
8.69 pH

Yellow Sea Ecosystem Study						
Site-ID	SD	Date	07/15/2018		Weather	Sunny
Location (GPS)	Latitude	36.92000 ° N			Arrival time	Departure time
	Longitude	126.18444 ° E			9:50 am	10:30 am
Recorded by	Junghyun Lee		Sampled by		Junsung Noh Junghyun Lee Seonju Kim Jooyeong Park	
In situ Measurement of Riverwater or Seawater quality (Mixed water)						
Color/odor						
Width/depth/velocity	Coastal area, beach					
HACH 40d data	pH		Temp (°C)	DO (mg/L)	Salinity (mS/cm)	
	7.47		21.65	6.61	31.25	
Corresponding soil information						
Site location	Latitude		° N	Landuse	Others	


Field Observation Log (Habitat Mapping Study)
Page: of
Date: 7/15
Station: SP
Latitude: N
Longitude: E
Sed. temp.: °C
Salinity:
Surface / Water cov. / Sand/Mud / Slope / Water / Shell cov / Ox-depth / Shell-depth
Algae (1 m² x 3, % Coverage)
Ripple
Epifauna/Burrow Counting (1 m² x 3 quadrats)
Quad 1 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 Total Remark
Mollusca (rake)
Quad 2
Quad 3
NOTE
Description between stations (0-1000 m)
0 1000 m
st. st.



8. 현장조사 야장

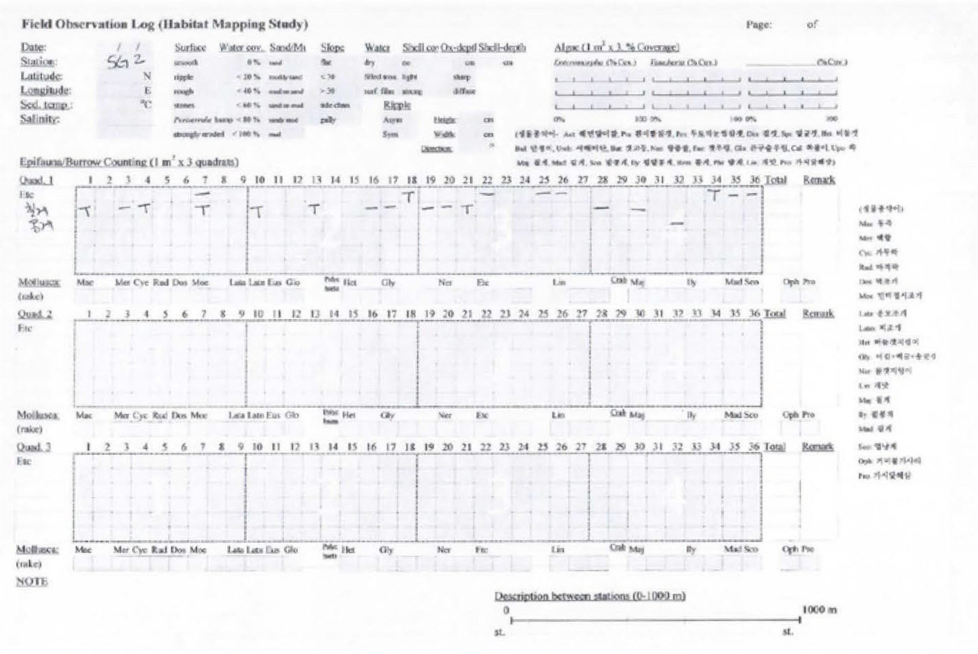
과제명: 서해연안조사				
정점번호: SD		조사일시: 2018년 7 월 15 일		
정점좌표	위도: ° ' "N 경도: ° ' "E 수심: m		도착시간 - 종료시간	9 시 50 분 - 10시 30분
기록자				
퇴적물 시료의 일반적 사항				
시료의 입도	Gravel ( )	Sand (○)	Mixed ( )	Mud ( )
시료의 색	Black ( )	Dark Gray ( )	Gray ( )	Olive Gray ( )
패각편 유무			시료의 냄새	
기타특이사항				
토양 시료의 일반적 사항				
시료의 입도	Gravel ( )	Sand ( )	Mixed ( )	Mud ( )
시료의 색	Black ( )	Dark Gray ( )	Gray ( )	Olive Gray ( )
패각편 유무			시료의 냄새	
기타특이사항				
채집시료 체크 리스트				
물시료			퇴적물시료	
4L 멸균채수병 (수질)	○		1L 락앤락	○
생물시료			토양시료	
			1L 락앤락	
군집조사			클로로필/규조류/중형동물	
기타 채집한 생물 시료 / 정점 특이사항				

코어 35cm까지.

[illegible]

21.65°C
31.25 Sal
90.0 DO(6.61)
7.47 pH

Yellow Sea Ecosystem Study					
Site-ID	SG2	Date	07/15/2018	Weather	Sunny
Location (GPS)	Latitude	37.07888 ° N		Arrival time	Departure time
	Longitude	126.85777 ° E		12:10 pm	1:10 pm
Recorded by	Junghyun Lee	Sampled by		Junsung Noh Junghyun Lee Seonju Kim Jooyeong Park	
In situ Measurement of Riverwater or Seawater quality (Mixed water)					
Color/odor					
Width/depth/velocity	Coastal area, outside of sea dike				
HACH 40d data	pH	Temp (°C)	DO (mg/L)	Salinity (mS/cm)	
	7.65	28.47	4.4	27.21	
Corresponding soil information					
Site location	Latitude	° N	Landuse	Agricultural	


Field Observation Log (Habitat Mapping Study)

Page: of

Date:
Station: SG2
Latitude: N
Longitude: E
Sed. temp.: °C
Salinity:

Epifauna/Burrow Counting (1 m² x 3 quadrats)

Quad. 1
Etc

Mollusca (rake)

Quad. 2
Etc

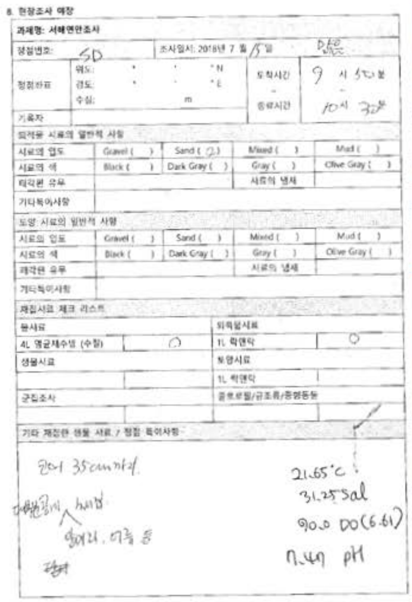
Mollusca (rake)

Quad. 3
Etc

Mollusca (rake)

NOTE

Description between stations (0-1000 m)



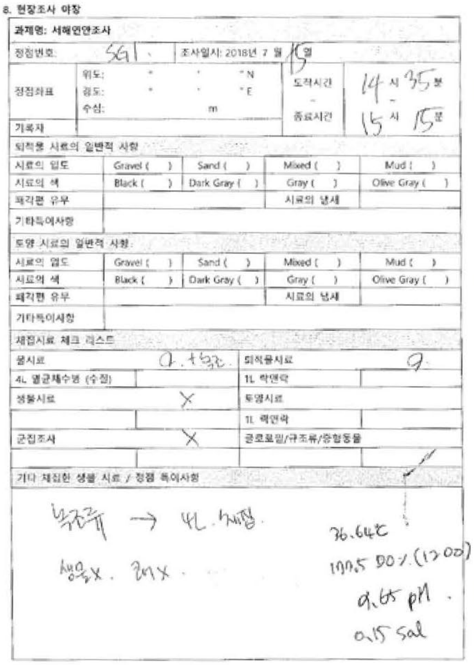
8. 현장조사 야장

과제명: 서해연안조사				
정점번호: SD	조사일시: 2018년 7 월 15 일			
정점좌표	위도: ° ′ ″N 경도: ° ′ ″E 수심: m		도착시간 - 종료시간	9 시 50 분 - 10시 32분
기록자				
퇴적물 시료의 일반적 사항				
시료의 입도	Gravel ( )	Sand (○)	Mixed ( )	Mud ( )
시료의 색	Black ( )	Dark Gray ( )	Gray ( )	Olive Gray ( )
패각편 유무			시료의 냄새	
기타특이사항				
토양 시료의 일반적 사항				
시료의 입도	Gravel ( )	Sand ( )	Mixed ( )	Mud ( )
시료의 색	Black ( )	Dark Gray ( )	Gray ( )	Olive Gray ( )
패각편 유무			시료의 냄새	
기타특이사항				
채집시료 체크 리스트				
물시료			퇴적물시료	
4L 멸균채수병 (수질)	○		1L 락앤락	○
생물시료			토양시료	
			1L 락앤락	
군집조사			클로로필/규조류/중형동물	
				✓
기타 채집한 생물 시료 / 정점 특이사항				

35cm까지

21.65°C
31.25 Sal
90.0 DO(6.61)
7.47 pH

Yellow Sea Ecosystem Study					
Site-ID	SG1	Date	07/15/2018	Weather	Sunny
Location (GPS)	Latitude	37.06888 ° N		Arrival time	Departure time
	Longitude	126.99250 ° E		2:35 pm	3:15 pm
Recorded by	Junghyun Lee	Sampled by		Junsung Noh Junghyun Lee Seonju Kim Jooyeong Park	
In situ Measurement of Riverwater or Seawater quality (Mixed water)					
Color/odor					
Width/depth/velocity	Inside of sea dike				
HACH 40d data	pH	Temp (°C)	DO (mg/L)	Salinity (mS/cm)	
	9.65	36.64	12	0.15	
Corresponding soil information					
Site location	Latitude	° N	Landuse	Agricultural	



8. 현장조사 야장

과제명: 서해연안조사

정점번호: SG1　조사일시: 2018년 7 월 15 일

정점좌표　위도: ° ' " N　경도: ° ' " E　수심: m　도착시간 14 시 35 분 ~ 종료시간 15 시 15 분

기록자

퇴적물 시료의 일반적 사항

시료의 입도	Gravel ( )	Sand ( )	Mixed ( )	Mud ( )
시료의 색	Black ( )	Dark Gray ( )	Gray ( )	Olive Gray ( )
패각편 유무			시료의 냄새	
기타특이사항				

토양 시료의 일반적 사항

시료의 입도	Gravel ( )	Sand ( )	Mixed ( )	Mud ( )
시료의 색	Black ( )	Dark Gray ( )	Gray ( )	Olive Gray ( )
패각편 유무			시료의 냄새	
기타특이사항				

채집시료 체크 리스트

물시료	[illegible]	퇴적물시료	[illegible]
4L 멸균채수병 (수질)		1L 약엔락	
생물시료	X	토양시료	
		1L 약엔락	
군집조사	X	균류포집/규조류/중형동물	

기타 채집한 생물 시료 / 정점 특이사항

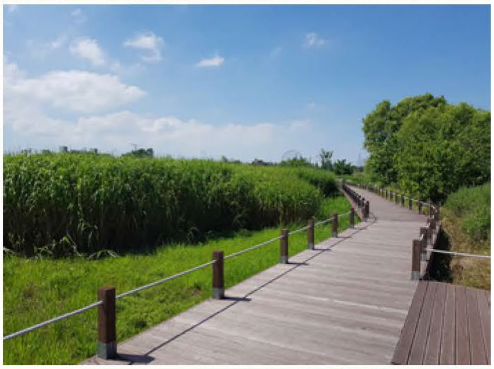
[illegible] → 4L 채집.

36.64℃

[illegible] DO%(12.00)

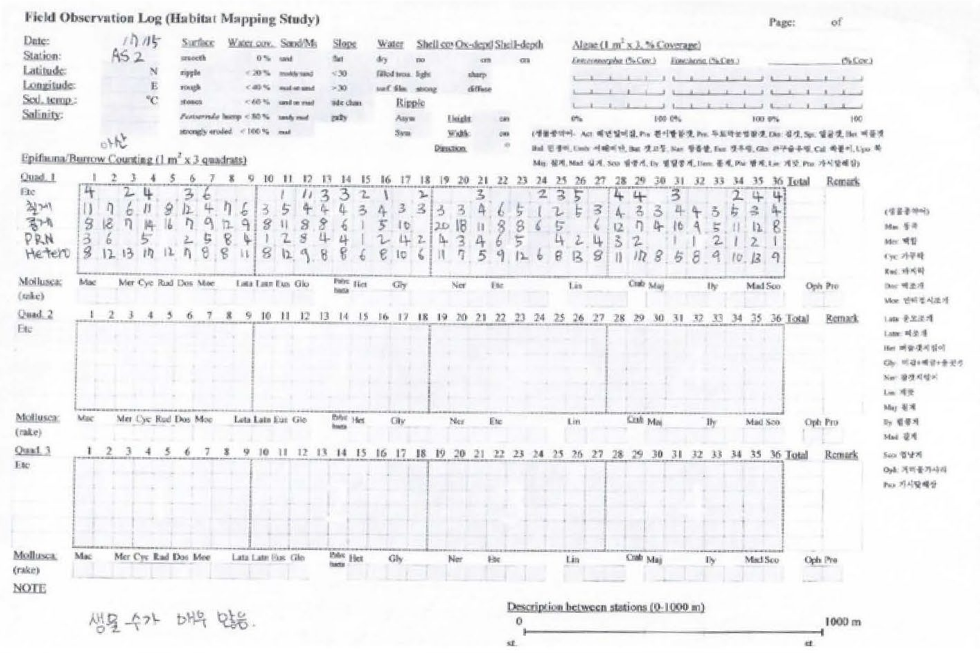
9.65 pH.

0.15 sal




Yellow Sea
2018. 6 June ~ 7 July
한중황해공동조사
中韓黃海共同調查
Joint Field Survey
서울대학교

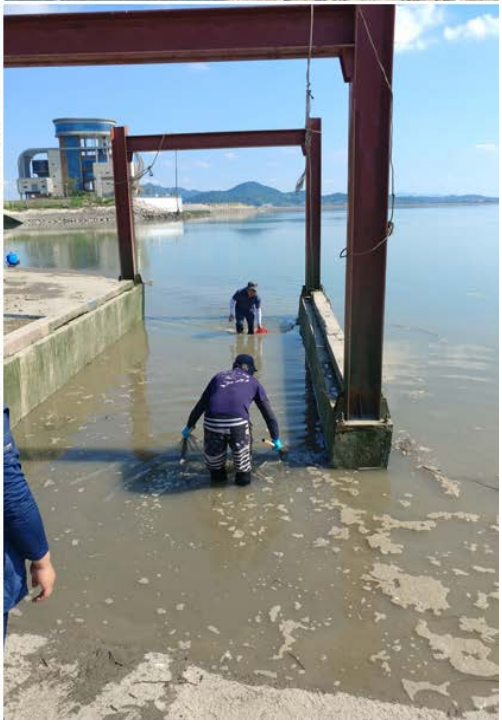
Yellow Sea Ecosystem Study					
Site-ID	AS2	Date	07/15/2018	Weather	Sunny
Location (GPS)	Latitude	37.15805 ° N		Arrival time	Departure time
	Longitude	126.98805 ° E		3:35 pm	4:35 pm
Recorded by	Junghyun Lee	Sampled by		Junsung Noh Junghyun Lee Seonju Kim Jooyeong Park	
In situ Measurement of Riverwater or Seawater quality (Mixed water)					
Color/odor					
Width/depth/velocity	Coastal area, outside of sea dike				
HACH 40d data	pH	Temp (°C)		DO (mg/L)	Salinity (mS/cm)
	7.84	29.45		4.2	24.9
Corresponding soil information					
Site location	Latitude	° N		Landuse	Agricultural



8. 현장조사 야장

과제명: 서해연안조사				
정점번호: SD		조사일시: 2018년 7 월 15 일		
정점좌표	위도: ° ' " N 경도: ° ' " E 수심: m		도착시간 - 종료시간	9 시 50 분 - 10 시 30 분
기록자				
퇴적물 시료의 일반적 사항				
시료의 입도	Gravel ( )	Sand (○)	Mixed ( )	Mud ( )
시료의 색	Black ( )	Dark Gray ( )	Gray ( )	Olive Gray ( )
패각편 유무			시료의 냄새	
기타특이사항				
토양 시료의 일반적 사항				
시료의 입도	Gravel ( )	Sand ( )	Mixed ( )	Mud ( )
시료의 색	Black ( )	Dark Gray ( )	Gray ( )	Olive Gray ( )
패각편 유무			시료의 냄새	
기타특이사항				
채집시료 체크 리스트				
물시료		퇴적물시료		
4L 멸균채수병 (수질)	○	1L 락앤락	○	
생물시료		토양시료		
		1L 락앤락		
군집조사		클로로필/규조류/중형동물		
			✓	
기타 채집한 생물 시료 / 정점 특이사항				

21.65°C
31.25 Sal
90.0 DO(6.61)
7.47 pH



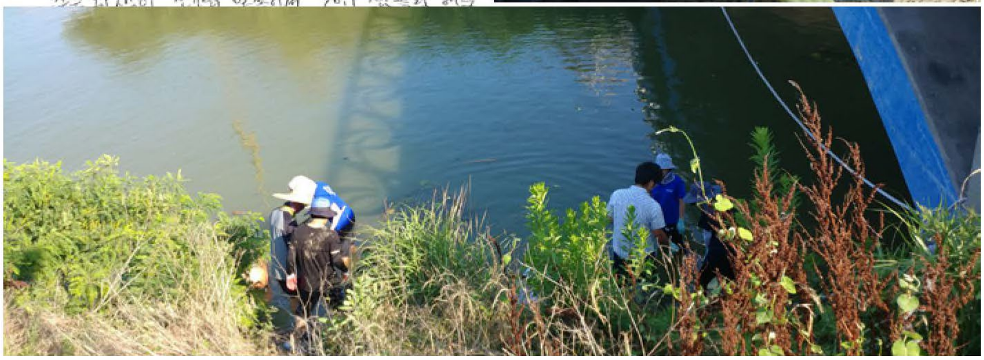
Yellow Sea Ecosystem Study					
Site-ID	AS1	Date	07/15/2018	Weather	Sunny
Location (GPS)	Latitude	37.05000 ° N		Arrival time	Departure time
	Longitude	127.10611 ° E		4:35 pm	5:30 pm
Recorded by	Junghyun Lee		Sampled by	Junsung Noh Junghyun Lee Seonju Kim Jooyeong Park	

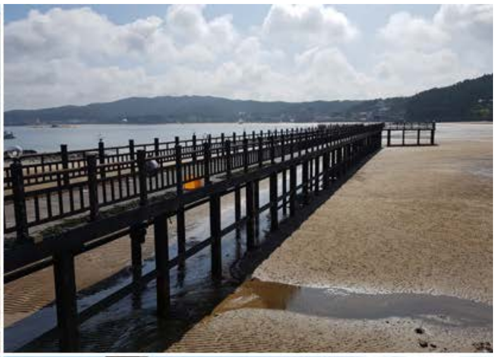
In situ Measurement of Riverwater or Seawater quality (Mixed water)				
Color/odor				
Width/depth/velocity	Inside of sea dike			
HACH 40d data	pH	Temp (°C)	DO (mg/L)	Salinity (mS/cm)
	9.07	32.83	10.09	0.17
Corresponding soil information				
Site location	Latitude	° N	Landuse	Agricultural

8. 현장조사 야장

과제명: 서해연안조사				
정점번호: AS1	조사일시: 2018년 7 월 15 日 [illegible]			
정점좌표	위도: ° ' " N 경도: ° ' " E 수심: m		도착시간 ~ 종료시간	시 분 ~ 11 시 30 분
기록자				
퇴적물 시료의 일반적 사항				
시료의 입도	Gravel ( )	Sand (a)	Mixed (a)	Mud ( )
시료의 색	Black ( )	Dark Gray ( )	Gray ( )	Olive Gray ( )
패각편 유무	X		시료의 냄새	X
기타특이사항				
토양 시료의 일반적 사항				
시료의 입도	Gravel ( )	Sand ( )	Mixed ( )	Mud ( )
시료의 색	Black ( )	Dark Gray ( )	Gray ( )	Olive Gray ( )
패각편 유무			시료의 냄새	
기타특이사항				
채집시료 체크 리스트				
물시료	a		퇴적물시료	a
4L 멸균채수병 (수질)			1L 약엔락	
생물시료	a		토양시료	a
			1L 약엔락	
군집조사	X		클로로필/규조류/중형동물	
기타 채집한 생물 시료 / 정점 특이사항				

다리밑에서 퇴적물 채집 — 경X
[illegible] 5cm — Chl.a X
망둥어 1마리. 4~5cm — 32.83°C
붕어 1마리 — 0.17sal
DO [illegible] %. (10.09)
둑쪽 산기슭에서 Soil — 9.07 pH
[illegible] 산기슭 [illegible] Soil [illegible]

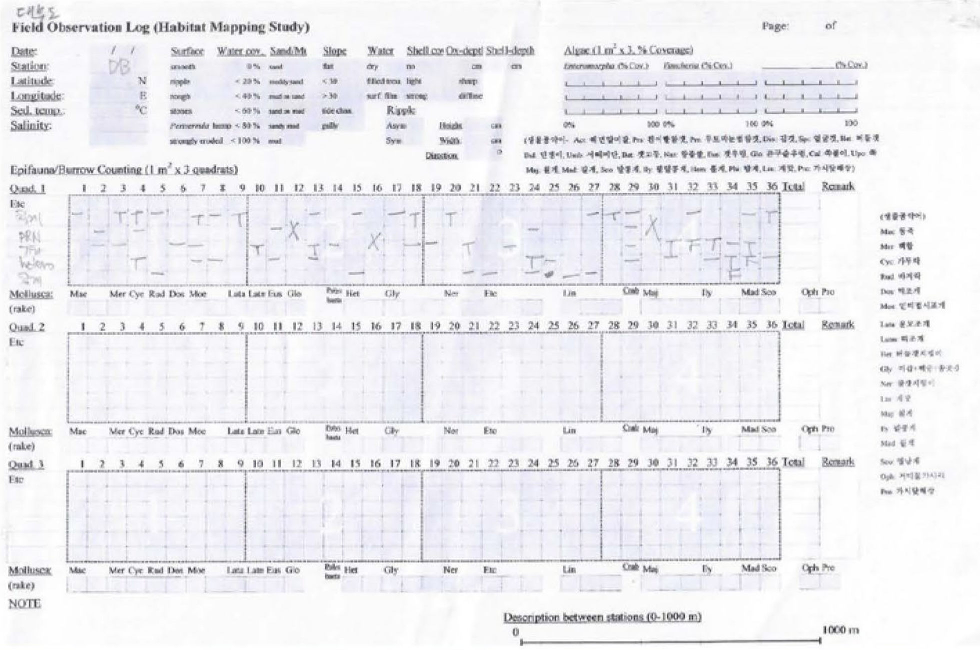


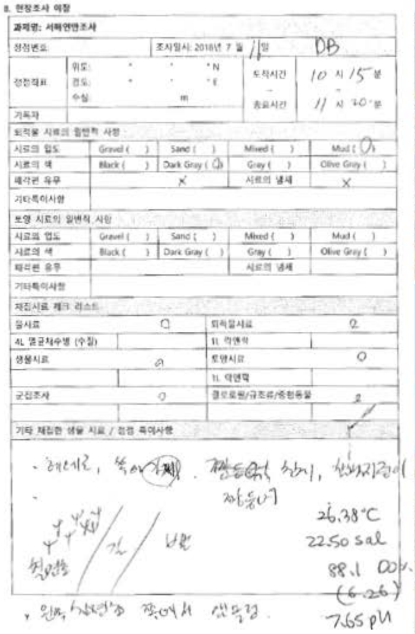







Yellow Sea Ecosystem Study						
Site-ID	DB	Date	07/16/2018		Weather	Sunny
Location (GPS)	Latitude	37.43694 ° N			Arrival time	Departure time
	Longitude	126.61944 ° E			10:15 am	11:20 am
Recorded by	Junghyun Lee		Sampled by		Junsung Noh Junghyun Lee Seonju Kim Jooyeong Park	
In situ Measurement of Riverwater or Seawater quality (Mixed water)						
Color/odor						
Width/depth/velocity						
HACH 40d data	pH	Temp (°C)		DO (mg/L)		Salinity (mS/cm)
	7.65	26.38		6.26		22.5
Corresponding soil information						
Site location	Latitude	° N		Landuse		



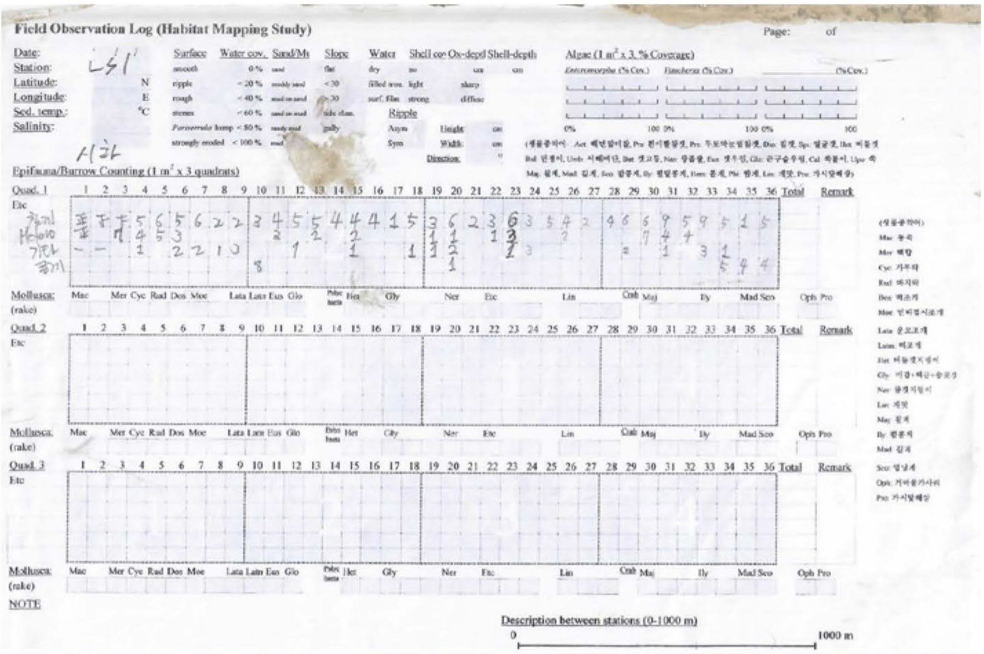


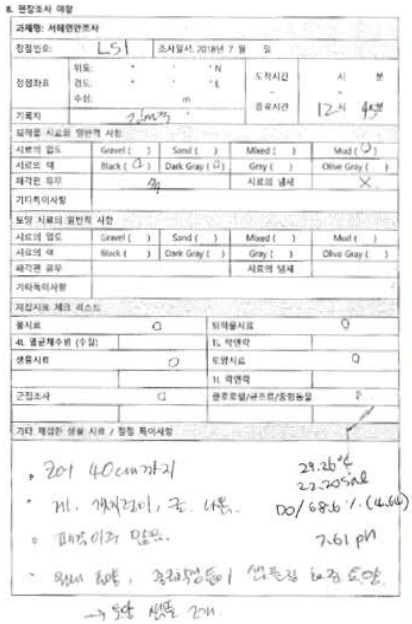
8. 현장조사 야장

과제명: 서해연안조사				
정점번호		조사일시: 2018년 7 월 11일 DB		
정점좌표	위도: ° ' " N 경도: ° ' " E 수심: m		도착시간 ~ 종료시간	10 시 15 분 ~ 11 시 20 분
기록자				
퇴적물 시료의 일반적 사항				
시료의 입도	Gravel ( )	Sand ( )	Mixed ( )	Mud (O)
시료의 색	Black ( )	Dark Gray (O)	Gray ( )	Olive Gray ( )
패각편 유무	×		시료의 냄새	×
기타특이사항				
토양 시료의 일반적 사항				
시료의 입도	Gravel ( )	Sand ( )	Mixed ( )	Mud ( )
시료의 색	Black ( )	Dark Gray ( )	Gray ( )	Olive Gray ( )
패각편 유무			시료의 냄새	
기타특이사항				
채집시료 체크 리스트				
물시료	O		퇴적물시료	O
4L 멸균채수병 (수질)			1L 각병	
생물시료	O		토양시료	O
			1L 약병	
군집조사	O		클로로필/규조류/중형동물	O
기타 채집한 생물 시료 / 정점 특이사항				

26.38°C
22.50 sal
88.1 DO%
(6.26)
7.65 pH

Yellow Sea Ecosystem Study					
Site-ID	LS1	Date	07/16/2018	Weather	Sunny
Location (GPS)	Latitude	37.43694 ° N		Arrival time	Departure time
	Longitude	126.61944 ° E		12:10 pm	12:45 pm
Recorded by	Junghyun Lee	Sampled by		Junsung Noh Junghyun Lee Seonju Kim Jooyeong Park	
In situ Measurement of Riverwater or Seawater quality (Mixed water)					
Color/odor					
Width/depth/velocity	Coastal area, outside of sea dike				
HACH 40d data	pH	Temp (°C)	DO (mg/L)	Salinity (mS/cm)	
	7.61	29.26	4.64	22.2	
Corresponding soil information					
Site location	Latitude	° N	Landuse	Industrial, Municipal	





8. 현장조사 야장

과제명: 서해연안조사				
정점번호: LS1		조사일시: 2018년 7 월 일		
정점좌표	위도: ° ' " N 경도: ° ' " E 수심: m		도착시간 - 종료시간	시 분 - 12시 45분
기록자	[illegible]			
퇴적물 시료의 일반적 사항				
시료의 입도	Gravel ( )	Sand ( )	Mixed ( )	Mud (O)
시료의 색	Black (O)	Dark Gray (O)	Gray ( )	Olive Gray ( )
패각편 유무	유		시료의 냄새	X
기타특이사항				
토양 시료의 일반적 사항				
시료의 입도	Gravel ( )	Sand ( )	Mixed ( )	Mud ( )
시료의 색	Black ( )	Dark Gray ( )	Gray ( )	Olive Gray ( )
패각편 유무			시료의 냄새	
기타특이사항				
채집시료 체크 리스트				
물시료	O		퇴적물시료	O
4L 멸균채수병 (수질)			1L [illegible]	
생물시료	O		토양시료	O
			1L [illegible]	
군집조사	O		클로로필/규조류/중형동물	O
기타 채집한 생물 시료 / 정점 특이사항				

• 깊이 40cm까지 29.26°C 22.20 sal

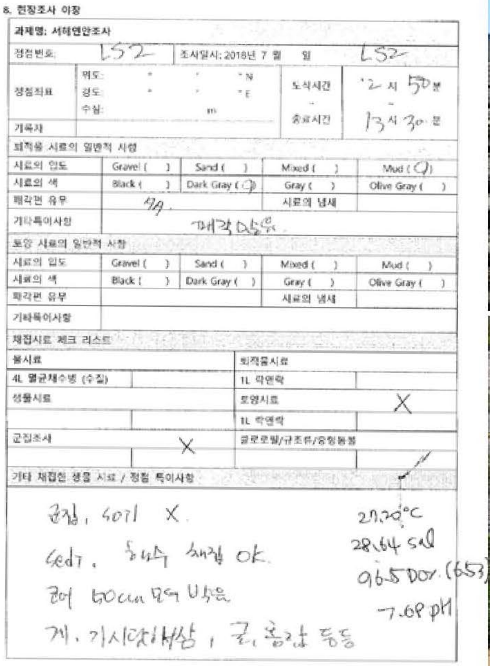
• 게, 개지렁이, 굴, [illegible] DO/ 68.6% (4.64)

• 패각이 많음. 7.61 pH

• [illegible]

→ [illegible]

Site-ID	LS2	Date	07/16/2018	Weather	Sunny
Location (GPS)	Latitude	37.46750 ° N		Arrival time	Departure time
	Longitude	126.76861 ° E		12:50 pm	1:30 pm
Recorded by	Junghyun Lee	Sampled by		Junsung Noh Junghyun Lee Seonju Kim Jooyeong Park	
In situ Measurement of Riverwater or Seawater quality (Mixed water)					
Color/odor					
Width/depth/velocity	Coastal area, outside of sea dike				
HACH 40d data	pH	Temp (°C)	DO (mg/L)	Salinity (mS/cm)	
	7.69	27.2	6.53	28.64	
Corresponding soil information					
Site location	Latitude	° N	Landuse	Industrial, Municipal	



8. 현장조사 야장

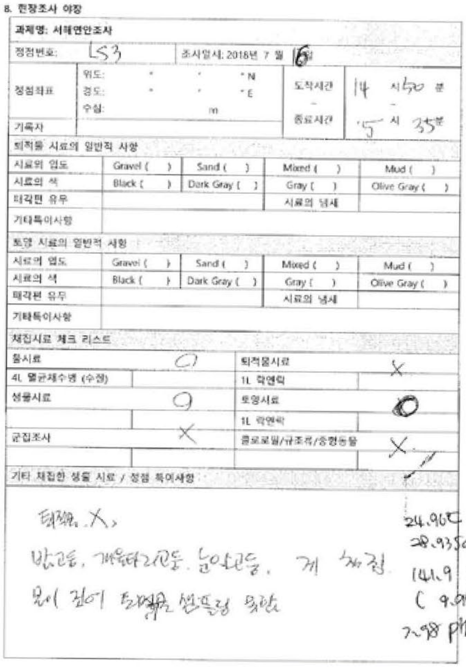
과제명: 서해연안조사				
정점번호: LS2	조사일시: 2018년 7 월 일 LS2			
정점좌표	위도: ° ' " N 경도: ° ' " E 수심: m		도착시간 ~ 종료시간	12시 50분 ~ 13시 30분
기록자				
퇴적물 시료의 일반적 사항				
시료의 입도	Gravel ( )	Sand ( )	Mixed ( )	Mud (○)
시료의 색	Black ( )	Dark Gray (○)	Gray ( )	Olive Gray ( )
패각편 유무	있음.		시료의 냄새	
기타특이사항	패각 다수.			
토양 시료의 일반적 사항				
시료의 입도	Gravel ( )	Sand ( )	Mixed ( )	Mud ( )
시료의 색	Black ( )	Dark Gray ( )	Gray ( )	Olive Gray ( )
패각편 유무			시료의 냄새	
기타특이사항				
채집시료 체크 리스트				
물시료			퇴적물시료	
4L 멸균채수병 (수질)			1L 락앤락	
생물시료			토양시료	X
			1L 락앤락	
군집조사	X		클로로필/규조류/중형동물	
				✓
기타 채집한 생물 시료 / 정점 특이사항				

군집, 607l X.
sed., 동식 채집 OK.
굴이 50cm 모여 있음
게, 가시닻해삼, 굴, 총알고둥 등등

27.20°C
28.64 sal
96.5 DO%.(6.53)
7.68 pH


556 MPS

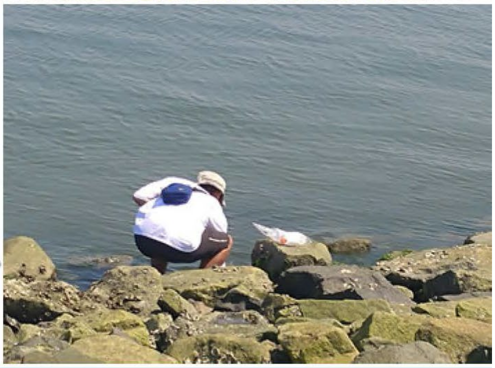
Yellow Sea Ecosystem Study					
Site-ID	LS3	Date	07/16/2018	Weather	Sunny
Location (GPS)	Latitude	37.48250 ° N		Arrival time	Departure time
	Longitude	126.77166 ° E		2:50 pm	3:35 pm
Recorded by	Junghyun Lee	Sampled by		Junsung Noh Junghyun Lee Seonju Kim Jooyeong Park	
In situ Measurement of Riverwater or Seawater quality (Mixed water)					
Color/odor					
Width/depth/velocity	Inside of sea dike				
HACH 40d data	pH	Temp (°C)	DO (mg/L)	Salinity (mS/cm)	
	7.98	24.96	9.96	28.93	
Corresponding soil information					
Site location	Latitude	° N	Landuse	Industrial, Municipal	


8. 현장조사 야장

과제명: 서해연안조사				
정점번호: LS3	조사일시: 2018년 7 월 16일			
정점좌표	위도: ° ' " N 경도: ° ' " E 수심: m		도착시간 - 종료시간	14 시 50 분 - 15 시 35분
기록자				
퇴적물 시료의 일반적 사항				
시료의 입도	Gravel ( )	Sand ( )	Mixed ( )	Mud ( )
시료의 색	Black ( )	Dark Gray ( )	Gray ( )	Olive Gray ( )
패각편 유무			시료의 냄새	
기타특이사항				
토양 시료의 일반적 사항				
시료의 입도	Gravel ( )	Sand ( )	Mixed ( )	Mud ( )
시료의 색	Black ( )	Dark Gray ( )	Gray ( )	Olive Gray ( )
패각편 유무			시료의 냄새	
기타특이사항				
채집시료 체크 리스트				
물시료	O	퇴적물시료	X	
4L 멸균채수병 (수질)		1L 광엔릭		
생물시료	O	토양시료	O	
		1L 광엔릭		
군집조사	X	클로로필/규조류/중형동물	X	
기타 채집한 생물 시료 / 정점 특이사항				

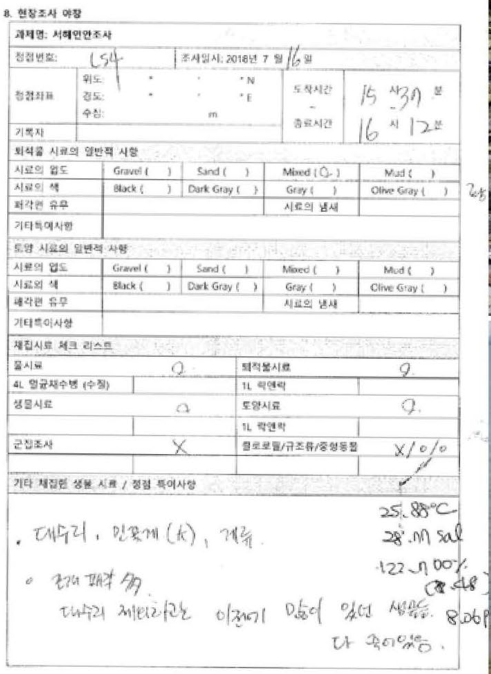
퇴적물 X,
밤고둥, 개울타리고둥, 눈알고둥, 게 채집
물이 깊어 토양은 샘플링 못함

24.96C
28.93ms
141.9 DO
(9.96)
7.98 pH




556 MPS

Yellow Sea Ecosystem Study					
Site-ID	LS4	Date	07/16/2018	Weather	Sunny
Location (GPS)	Latitude	37.45388 ° N		Arrival time	Departure time
	Longitude	126.74444 ° E		3:37 pm	4:12 pm
Recorded by	Junghyun Lee		Sampled by	Junsung Noh Junghyun Lee Seonju Kim Jooyeong Park	
In situ Measurement of Riverwater or Seawater quality (Mixed water)					
Color/odor					
Width/depth/velocity	Inside of sea dike				
HACH 40d data	pH	Temp (°C)	DO (mg/L)	Salinity (mS/cm)	
	8.06	25.88	8.48	28.77	
Corresponding soil information					
Site location	Latitude	° N	Landuse	Industrial, Municipal	



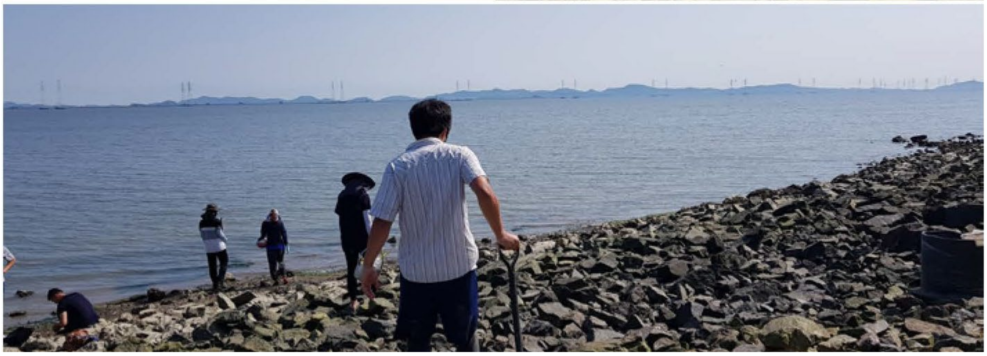
8. 현장조사 야장

과제명: 서해연안조사				
정점번호: LS4	조사일시: 2018년 7 월 16 일			
정점좌표	위도: ° ' " N 경도: ° ' " E 수심: m		도착시간 ~ 종료시간	15 시 37 분 16 시 12 분
기록자				
퇴적물 시료의 일반적 사항				
시료의 입도	Gravel ( )	Sand ( )	Mixed (O)	Mud ( )
시료의 색	Black ( )	Dark Gray ( )	Gray ( )	Olive Gray ( )
패각편 유무			시료의 냄새	
기타특이사항				
토양 시료의 일반적 사항				
시료의 입도	Gravel ( )	Sand ( )	Mixed ( )	Mud ( )
시료의 색	Black ( )	Dark Gray ( )	Gray ( )	Olive Gray ( )
패각편 유무			시료의 냄새	
기타특이사항				
채집시료 체크 리스트				
물시료	O		퇴적물시료	O
4L 멸균채수병 (수질)			1L 락앤락	
생물시료	O		토양시료	O
			1L 락앤락	
군집조사	X		클로로필/규조류/중형동물	X/O/O
기타 채집된 생물 시료 / 정점 특이사항				

25.88°C
28.77 sal
122.7 00%
(8.48)
8.06p

. 대수리, 민꽃게 (k), 게류.

° 갯가 패각 多.
대수리 제비리고둥 이전에 많이 있던 생물들.
다 죽어있음.





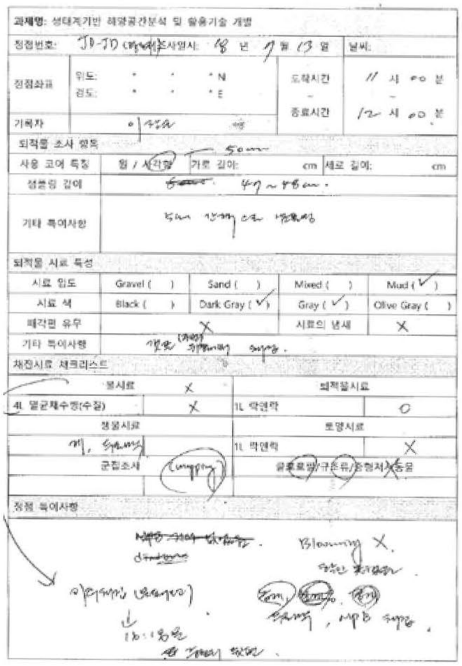






180716
LS4

Yellow Sea Ecosystem Study					
Site-ID	JD	Date	07/13/2018	Weather	Sunny
Location (GPS)	Latitude	35.00472 ° N		Arrival time	Departure time
	Longitude	126.42083 ° E		11:00 am	12:00 pm
Recorded by	Changkeun Lee	Sampled by		Hanna Bae Inok Lee Hosang Kim Kyuwon Hwang	
In situ Measurement of Riverwater or Seawater quality (Mixed water)					
Color/odor					
Width/depth/velocity	Coastal area				
HACH 40d data	pH	Temp (°C)	DO (mg/L)	Salinity (mS/cm)	
Corresponding soil information					
Site location	Latitude	° N	Landuse	Agricultural	



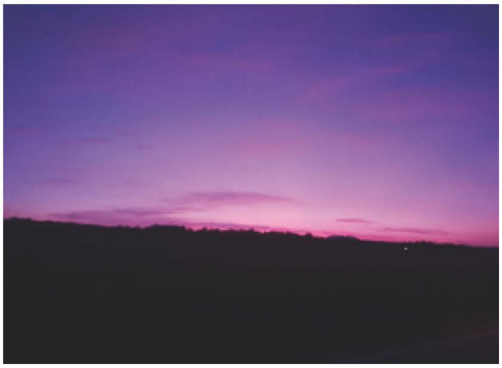
과제명: 생태계기반 해양공간분석 및 활용기술 개발

정점번호: JD-JD	조사일시: 18 년 7 월 13 일		날씨:	
정점좌표	위도: ° ' " N 경도: ° ' " E		도착시간 ~ 종료시간	11 시 00 분 ~ 12 시 00 분
기록자	이			
퇴적물 조사 항목				
사용 코어 특징	원 / 사각형	가로 길이: cm	세로 길이: cm	
샘플링 깊이	47~48cm.			
기타 특이사항				
퇴적물 시료 특성				
시료 입도	Gravel ( )	Sand ( )	Mixed ( )	Mud (✓)
시료 색	Black ( )	Dark Gray (✓)	Gray (✓)	Olive Gray ( )
패각편 유무	X		시료의 냄새	X
기타 특이사항				
채집시료 체크리스트				
물시료	X	퇴적물시료		
4L 멸균채수병(수질)	X	1L 락앤락	O	
생물시료		토양시료		
		1L 락앤락	X	
군집조사		플랑크톤/규조류/중형저서동물		
정점 특이사항				

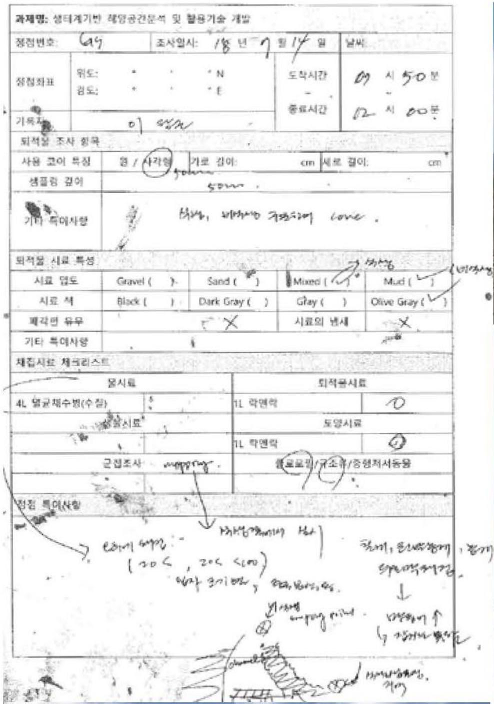
Blooming X.







Yellow Sea Ecosystem Study					
Site-ID	GS	Date	07/14/2018	Weather	Sunny
Location (GPS)	Latitude	35.74305 ° N		Arrival time	Departure time
	Longitude	126.87694 ° E		9:50 am	12:00 pm
Recorded by	Changkeun Lee	Sampled by		Hanna Bae Inok Lee Hosang Kim Kyuwon Hwang	
In situ Measurement of Riverwater or Seawater quality (Mixed water)					
Color/odor					
Width/depth/velocity					
HACH 40d data	pH	Temp (^oC)	DO (mg/L)	Salinity (mS/cm)	
	7.89	33.37	7.25	24.94	
Corresponding soil information					
Site location	Latitude	° N	Landuse		



과제명: 생태계기반 해양공간분석 및 활용기술 개발

정점번호: G4	조사일시: 18 년 7 월 14 일	날씨:	
정점좌표	위도: ° ' " N 경도: ° ' " E	도착시간 - 종료시간	09 시 50 분 - 12 시 00 분
기록자	이		

퇴적물 조사 항목

사용 코어 특징	원 / 사각형	가로 길이: cm	세로 길이: cm
샘플링 길이	50cm		
기타 특이사항			

퇴적물 시료 특성

시료 입도	Gravel ( )	Sand ( )	Mixed (✓)	Mud (✓)
시료 색	Black ( )	Dark Gray ( )	Gray ( )	Olive Gray (✓)
패각편 유무	X		시료의 냄새	X
기타 특이사항				

채집시료 체크리스트

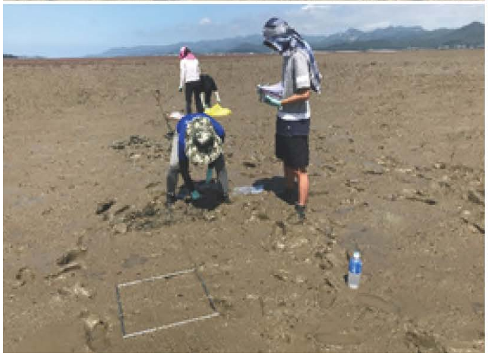
물시료		퇴적물시료	
4L 멸균채수병(수질)		1L 락앤락	O
생물시료		토양시료	
		1L 락앤락	O
군집조사	mapping.	미세조류/규조류/중형저서동물	

정점 특이사항

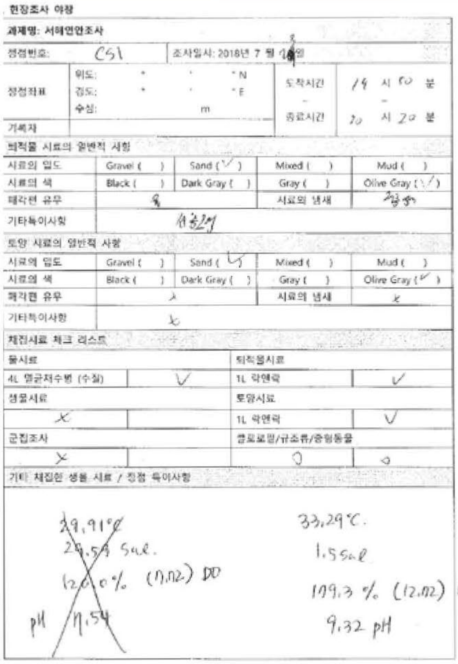









Yellow Sea Ecosystem Study						
Site-ID	CS1	Date	07/23/2018		Weather	Sunny
Location (GPS)	Latitude	° N			Arrival time	Departure time
	Longitude	° E			7:50 pm	8:20 pm
Recorded by	Seo Joon Yoon		Sampled by		Changkeun Lee Yunqiao Zhou	
In situ Measurement of Riverwater or Seawater quality (Mixed water)						
Color/odor						
Width/depth/velocity						
HACH 40d data	pH		Temp (°C)		DO (mg/L)	Salinity (mS/cm)
	9.32		33.29		12.72	1.5
Corresponding soil information						
Site location	Latitude		° N		Landuse	

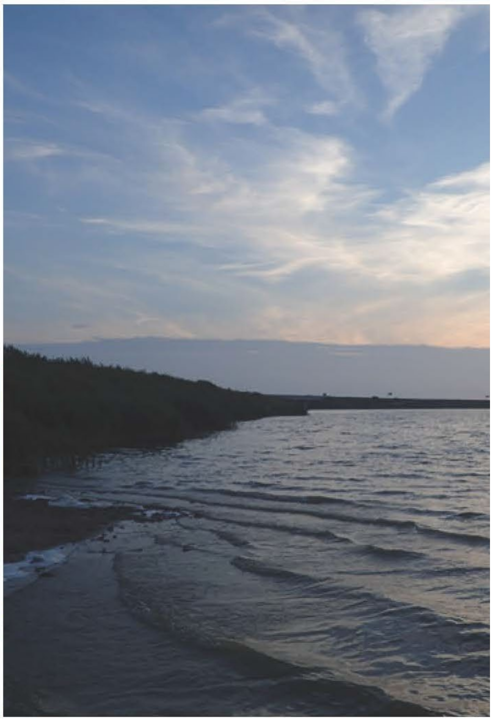


현장조사 야장

과제명: 서해연안조사				
정점번호: CS1		조사일시: 2018년 7월 일		
정점좌표	위도: ° ' " N 경도: ° ' " E 수심: m		도착시간 – 종료시간	19 시 50 분 – 20 시 20 분
기록자				
퇴적물 시료의 일반적 사항				
시료의 입도	Gravel ( )	Sand (✓)	Mixed ( )	Mud ( )
시료의 색	Black ( )	Dark Gray ( )	Gray ( )	Olive Gray (✓)
패각편 유무	유		시료의 냄새	정상
기타특이사항	서울2억			
토양 시료의 일반적 사항				
시료의 입도	Gravel ( )	Sand (✓)	Mixed ( )	Mud ( )
시료의 색	Black ( )	Dark Gray ( )	Gray ( )	Olive Gray (✓)
패각편 유무	X		시료의 냄새	X
기타특이사항	X			
채집시료 체크 리스트				
물시료		퇴적물시료		
4L 멸균채수병 (수질)	✓	1L 락앤락	✓	
생물시료		토양시료		
X		1L 락앤락	✓	
군집조사		클로로필/규조류/중형동물		
X		O	O	
기타 채집한 생물 시료 / 정점 특이사항				

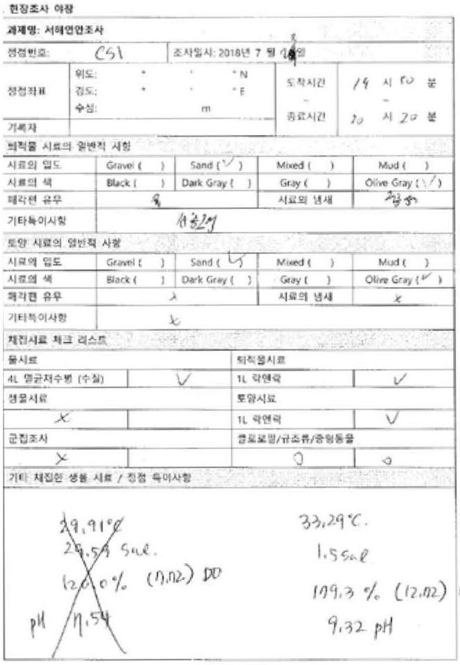
~~29.91°C~~
~~29.54 Sal.~~
~~120.0% (7.02) DO~~
~~pH 7.54~~

33.29°C.
1.5 Sal
179.3 % (12.72) DO
9.32 pH





Yellow Sea Ecosystem Study					
Site-ID	CS2	Date	07/23/2018	Weather	Sunny
Location (GPS)	Latitude	° N		Arrival time	Departure time
	Longitude	° E		6:30 pm	7:40 pm
Recorded by	Seo Joon Yoon	Sampled by		Changkeun Lee Yunqiao Zhou	
In situ Measurement of Riverwater or Seawater quality (Mixed water)					
Color/odor					
Width/depth/velocity					
HACH 40d data	pH	Temp (°C)	DO (mg/L)	Salinity (mS/cm)	
	7.54	29.91	7.72	29.59	
Corresponding soil information					
Site location	Latitude	° N	Landuse		



현장조사 야장

과제명: 서해연안조사

정점번호: CS1		조사일시: 2018년 7 월 18일		
정점좌표	위도: ° ' " N 경도: ° ' " E 수심: m	도착시간 - 종료시간	19 시 50 분 - 20 시 20 분	
기록자				
퇴적물 시료의 일반적 사항				
시료의 입도	Gravel ( )	Sand (√)	Mixed ( )	Mud ( )
시료의 색	Black ( )	Dark Gray ( )	Gray ( )	Olive Gray (√)
패각편 유무	[illegible]		시료의 냄새	[illegible]
기타특이사항	[illegible]			
토양 시료의 일반적 사항				
시료의 입도	Gravel ( )	Sand (√)	Mixed ( )	Mud ( )
시료의 색	Black ( )	Dark Gray ( )	Gray ( )	Olive Gray (√)
패각편 유무	X		시료의 냄새	X
기타특이사항	X			

채집시료 체크 리스트

물시료		퇴적물시료	
4L 멸균채수병 (수질)	√	1L 락앤락	√
생물시료		토양시료	
X		1L 락앤락	√
군집조사		클로로필/규조류/중형동물	
X		O	O

기타 채집한 생물 시료 / 정점 특이사항

~~29.91°C~~
~~29.59 Sal.~~
~~120.0% (7.72) DO~~
~~pH 7.54~~

33.29°C.
1.5 Sal
179.3 % (12.72) DO
9.32 pH