

## **Deliverable 14:**

# **Regional Jellyfish Monitoring Program**

**National Marine Environmental Monitoring Center**

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## Abstract

“Jellyfish Monitoring and Network Establishment in the Yellow Sea” has been undertaken with special objectives of i) contributing in reporting “YSLME Jellyfish Monitoring Network” that should include monitoring methodology, data gathering and analysis, and recommendations for future studies, ii) performing jellyfish monitoring in the Yellow Sea and adjacent sea using ships of opportunity, iii) participating YSLME jellyfish regional committee for corporative research and establishment of jellyfish network, and iv) sharing information and data with relevant institution and Chinese partner.

Korean scientific and policy making programs were analyzed. Programs regarding jellyfish bloom started as basic scientific programs at National Institute of Fisheries Science (NIFS) in 2004, after bloom of *Nemopilema nomurai* in Korean waters. Since then central governments made policy making programs focusing on countermeasure to blooming jellyfish.

Through programs on jellyfish blooms undertaken by NIFS, Korea Institute of Ocean Science and Technology, Korea Marine Environment Management Corporation (KOEM), and Ministry of Ocean and Fisheries (MOF), bloom forming jellyfish were identified, their sources determined, advection paths proposed in Korean waters, their ecological and physiological characteristics elucidated, and mechanism of blooms suggested. However, in order to verify the sources of *N. nomurai* as well as the mechanism of its bloom, cooperative research and/or information and data sharing with Chinese scientists and institutions are absolutely required because it is mainly originated from Chinese coastal areas.

Sound and sufficient scientific knowledge on *Aurelia aurita* has been gathered through scientific programs to understand their blooming mechanism and impact on marine ecosystem as well as their ecological and physiological features. Based on this knowledge, direct polyp removal has been conducted and its efficiency on controlling *A. aurita*'s outgrowing population has been approved.

Central governments being aware of jellyfish blooms for their damages in fisheries, national key industries and summer regional economy, have established national wide monitoring network, prepared and executed jellyfish countermeasure plan, designated

responsible institutions for each program and funded for its achievement, and supported research cooperation with China and Japan. Removals of jellyfish medusa and polyp were the results of the research program closely connected with policy making program.

Nevertheless, it must be noted that the 5 eventual causes favoring jellyfish blooms (overfishing, eutrophication, climate change, translocation and habitat modification) were not properly tackled. Among the eventual causes, climate change is supposed to be the most threatening since it would change ecosystem structure and function, and entrain and/or favor jellyfish, highly venomous or blooming, invaders in Korean waters. Another note would be about highly venomous jellyfish such as *Cyanea nozakii*, *Carybdea brevipedalia* and others that would come with climate change. Studies for first aid against sting by these jellyfish as well as characterization and use of their venom would be highly recommended.

For better understanding of spatiotemporal distribution of jellyfish in the Yellow Sea and their variation in abundance, monitoring using ships of opportunity was performed.

Jellyfish were monitored in 11 sectors encompassing eastern Bohai Sea, Bohai Strait, and Yellow Sea. Three jellyfish species were observed: *N. nomurai* in the whole monitoring area; *C. nozakii* only in the inner Liaodong Bay; *Rhopilema esculentum* only in the eastern mid-Yellow Sea, indicating a source nearby for two latter species.

*N. nomurai* appeared from the beginning (July) to the end of monitoring (October) with decreasing trend along with monitoring time. Their peak was in the inner eastern coastal area of Liaodong Bay, indicating that that bay is effectively one of the sources of *N. nomurai*. Their size structure varied along with monitoring time and might imply that the source is not the innermost coastal area as suggested previously. Decrease of *N. nomurai* abundance in Liaodong Bay had been accompanied with increase of that in Bohai Strait. In this aspect spatiotemporal variation in abundance in the Bohai Strait was remarkable; *N. nomurai* were only in the center of the strait in July, extended into the whole Bohai Strait in August, and reduced in the succeeding months. This may indicate that population of *N. nomurai* advects out of the Liaodong Bay, passes through Bohai Strait, and circumvents northern Shandong peninsula, as suggested by Yoon et al. (2018). Variation in size structures in these areas supports this assumption.

However, neither the exact source of *N. nomurai* nor the amount of *N. nomurai* population out of the Liaodong Bay, or the area of convergence with population coming from off-Changjiang River could be estimated or determined because of limited spatial coverage of monitoring area; whole Bohai Sea including Bohai and Laizhou bays, and southern Yellow Sea such as off-Changjiang River, area between Shanghai and Lianyungang, and between southwestern Korean peninsula and Shanghai should be covered in future study to get better understanding on and more appropriate countermeasure plans to blooms of *N. nomurai*. Furthermore their blooming mechanism, population dynamics in the source area(s), drifting paths in the Yellow Sea, and their yearly abundance fluctuation are vaguely understood, therefore, require systematic and multidisciplinary future studies.

Drifting path, one of the above mentioned ‘must-do’s on *N. nomurai*, is an absolutely required research subject to reduce or prevent damages due to their blooms, and sighting method using ship of opportunity is at present the best among existing monitoring methods, for it is the most available and easiest method requiring short time, and less personnel and budget than any other conventional monitoring methods. This method is strongly recommended to be adopted as standard one for YSLME jellyfish monitoring to uncover drifting paths *N. nomurai*, and regularly applied for other areas by Korean and Chinese scientists to get a bigger and more accurate map of *N. nomurai*’s spatiotemporal distribution.

The 5 eventual causes favoring jellyfish blooms were not properly tackled by Korean and/or Chinese government. Reduction and/or prevention of jellyfish blooms would only be possible if two countries government take actions against the jellyfish blooms causes. One of the immediate and feasible actions is direct polyp removal, for its immediate, direct and durable effect in controlling jellyfish bloom. To apply this method, exact source of *N. nomurai* should be determined, which could be assessed by jellyfish monitoring using ship of opportunity combined in close and successive manner with systematic survey on the area where juveniles are massively appeared. Once the exact source determined, their polyps could be removed by the method of ‘underwater jet’ developed by Korean researchers. Climate change is likely the most threatening causation of jellyfish blooms since it would change ecosystem structure and function entraining and/or favoring jellyfish species of highly venomous or blooming invaders in Korean and Chinese waters. This invasion and drifting could be also monitored by using of ship of opportunity if they are of distinguishable by naked eyes.

Korean and Chinese scientists and governments should work together to cope with the jellyfish blooms; sharing data and information would be the first step to go further, and joint jellyfish monitoring cruise the second, and making a joint report and countermeasure plan based on each country's and joint cruise the third, and adoption of that countermeasure plan by two countries' government the fourth and final. In this process, YSLME would be the most appropriate program and should play its important role as an intermediate between scientist and policy makers of two countries.

Related to this process, the first step that YSLME should take in view of jellyfish bloom is establishment of a committee that is composed of jellyfish experts and related public officials of two countries. All information, data, and opinions should be directed to, discussed in, and concluded by this committee in order to take the best available policy to reduce and/or prevent damages due to jellyfish blooms. YSLME should provide space and fund to this committee to fulfill their role. The second step is to organize a joint jellyfish monitoring cruise and later, more systematic and multidisciplinary research cruise on areas that are suspected as sources of *N. nomurai*. The third step is, based on field multidisciplinary research cruise, to propose the best mean and way to control *N. nomurai* bloom.

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# 1. Introduction

Jellyfish is a free-swimming coelenterate that is the sexually reproducing form of a hydrozoan or scyphozoan (Fig. 1) and has a nearly transparent saucer-shaped body and extensible marginal tentacles studded with stinging cells ([www.merriam-webster.com/dictionary](http://www.merriam-webster.com/dictionary)).

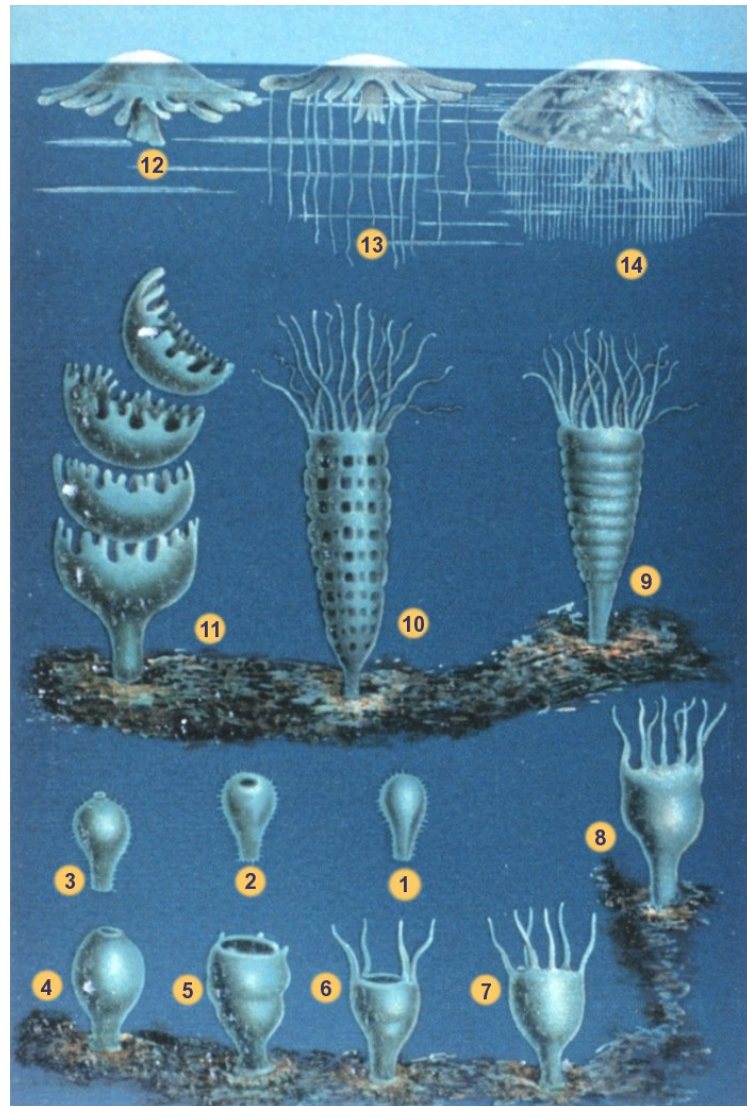


Figure 1. The developmental stages of scyphozoan jellyfish's life cycle: 1–3 Larva searches for site; 4–8 Polyp grows; 9–11 Polyp strobilates; 12–14 Medusa grow (Schleiden, 1869).

They are composed of Scyphozoa (true jellyfish), Cubozoa (box jellyfish), Staurozoa

(stalked jellyfish), and Hydrozoa (some, small jellyfish), and include in general comb-jelly (Ctenophora), and found all over the world, in marine as well as in freshwater, from surface waters to the deep sea. They are recognized as one of the biggest marine planktonic animals ranging from centimeters (Hydrozoa) to meters (Scyphozoa), often colorful, and common in coastal zones worldwide. The medusae of most species are fast growing, mature within a few months and die soon after breeding, but the polyp stage, attached to the seabed, may be much more long-lived. Jellyfish have been in existence for at least 500 million years (Cartwright et al., 2007) and possibly 700 million years or more, making them the oldest multi-organ animal group (Angier, 2011).

Jellyfish can occur in dense aggregation or blooms around the world and examples are *Pelagia noctiluca* (Goy, 1989), *Aurelia aurita* (Malej et al., 2012), *Rhopilema nomadica* (Boero et al., 2013), cubozoan *Carybdea marsupialis* (Canepa, 2014) in the Mediterranean Sea; *A. aurita* and *Cyanea capillata* in the Irish Sea (Bastian et al., 2011); *Mnemiopsis leidyi* in the Black Sea (Boero et al., 2013); *C. capillata* (Xia et al., 2005) and *Nemopilema nomurai* (Kawahara et al., 2006; Yoon et al., 2008) in the East China Sea; *N. nomurai* in the Yellow Sea (Yoon et al., 2014; Sun et al., 2015; Zhang et al. 2012), Bohai Sea (Dong et al., 2018; Yoon et al., 2018), Korean southern waters (Yoon et al., 2014) and in the East Sea (Kitajima et al., 2015; Uye, 2008); *A. aurita* in the Seto Inland Sea, Japan; *Chrysaora melanaster* in the Bering Sea (Brodeur et al., 2002); *Phyllorhiza punctata* in the Gulf of Mexico (Graham et al., 2003); *Cephea cephea* in the Red Sea (Cruz-Rivera and El-Regal, 2015).

Damages due to blooming jellyfish are on fisheries, recreation, and national key industries. Jellyfish have impacts on human health (Burnett, 2001; Fenner, 2005; Fenner and Williamson, 1996; Mariottini and Pane, 2010), blooms interfere with coastal power plant operations (Galil, 2008; Dong et al., 2010). Effects on fisheries are the most frequently reported and arise because of the biological effects of jellyfish on food webs and because of interference with fishing operations. Fisheries damages are temporary complete prevention of fishing operations (Schiariti et al., 2008; Nagata et al., 2009), needs for extra hauls in areas more distant from landing ports (Nagata et al., 2009), clogging and bursting of nets (Graham et al., 2003; Nagata et al., 2009; Uye and Ueta, 2004); reduced fish catches (Graham et al., 2003; Kawahara et al., 2006; Nagata et al., 2009; Dong et al., 2010; Quiñones et al., 2013), increased fish catch sorting time (Uye, 2008; Kawahara et al., 2006), and painful stings to fishermen sorting fish catches

(Kawahara et al., 2006).

Economic damages are huge and some examples are 9.3  $10^6$  US\$ (8.2  $10^6$  EURO) per year for the Italian NA trawling fleet (Palmieri et al., 2014), up to 10  $10^6$  US\$ due to *P. punctatamaya* in the Gulf of Mexico (Graham et al., 2003), approximately 20  $10^6$  US\$ in just one of the 17 prefectures in the Japanese waters of the East Sea due to *N. nomurai* (Kawahara et al., 2006), more than 200,000 US\$ due to *Chrysoara plocamia* to the Peruvian purse seiners of Ilo in only 35 days of fishing (Quiñones et al., 2013), and between 68.2 and 204.6  $10^6$  US\$/year for fisheries (Kim et al., 2012), 97  $10^6$  US\$/year for recreation, and more than 337  $10^6$  US\$/year for national key industries in Korean waters due to *N. nomurai* and *A. aurita* (MOMAF, 2009).

The causes of jellyfish blooms are not clearly understood yet. Richardson et al (2009) suggested that human-induced stresses of overfishing, eutrophication, climate change, translocation and habitat modification are the causes of promoting jellyfish (pelagic cnidarian and ctenophore) blooms (see also Purcell, 2007; Uye, 2008; Boero et al., 2013 for further information).

Overfishing is for the predator-prey relationship and competition for common food, zooplankton. Many fish compete for the same zooplankton prey as jellyfish (Purcell & Arai, 2001) and fish are also predators of jellyfish, with benthic and reef fish species ingesting polyps, and pelagic fish species eating ephyrae and small individuals (Purcell & Arai, 2001). Bird and marine mammals are also jellyfish predators (Smolowitz et al., 2015; Thiebot et al., 2016, 2017; McInnes et al., 2017; Hays et al., 2018). However, the removal of such fish, and eventually decrease of biodiversity open up ecological space for jellyfish, and consequently lead jellyfish blooms (Richardson et al., 2009).

Coastal eutrophication due to addition of excessive nutrients from fertilizer runoff and sewage encourages phytoplankton blooms that can ultimately lead to jellyfish outbreaks (Purcell et al., 2001). Nutrients, rich in nitrogen and phosphorus but poor in silica, lead proliferation of non-siliceous phytoplankton, such as flagellates including harmful red-tide species, and replace diatoms, resulting in a reduction in the size of primary and secondary producers. Such a food web supports fewer fish, marine mammals, turtles and seabirds because of the smaller average food size and longer food chain, and is more favorable for jellyfish than

for fish (Parsons & Lalli, 2002). Jellyfish can survive in such environments for their ability to feed on a range of prey, and will thrive given the high total amount of food available. Phytoplankton blooms (HAB) resulting from nutrient enrichment can sometimes sink to the seafloor, where their bacterial degradation can cause localized hypoxia (Diaz & Rosenberg, 2008). The greater tolerance of polyps and medusae than of fish to low oxygen conditions ensures that jellyfish survive and even reproduce during hypoxic events, which fish are unable to do (Richardson et al., 2009; Miller & Graham, 2012).

Warming of the sea surface can enhance water column stratification, leading to nutrient-poor surface waters where flagellates, because of their ability to migrate vertically into nutrient-rich deeper waters, can outcompete diatoms (Cushing, 1989). Warmer temperatures also accelerate medusae growth and ephyrae production (Purcell et al., 2007). Warming could also expand the distribution of many of the tropical jellyfish species toward subtropical and temperate latitudes (Holst, 2012).

The human-assisted movement of species to new marine areas is most commonly caused by the exchange of ballast water (containing organisms) between regions and the transport of fouling biota (e.g. polyps) on ship hulls (Graham & Bayha, 2007). Presence of ctenophore *Mnemiopsis leidyi* in the Black Sea (Oguz et al., 2008), *Phyllorhiza punctata* in the Gulf of Mexico (Graham et al., 2003), *A. aurita* in the Suez Canal (El-Serehy & Al-Rasheid, 2011), and in the southern Korean peninsula (Ki et al., 2008) indicates this translocation as an important factor of jellyfish blooms.

Because cnidarian polyps require a hard substrate for attachment, an increase in the amount of suitable benthic habitat could theoretically lead to polyp proliferation. This habitat modification is suggested as a leading factor jellyfish blooms in Taiwan (Lo & Chen, 2008), Korean waters (Yoon et al., 2018), inland Sea of Japan (Makabe et al. 2014), western Baltic Sea (Janßen et al., 2013), and in the northwestern Mediterranean Sea (Marques et al., 2015).

Countermeasures for jellyfish blooms are diverse and several management measures are proposed (Boero et al., 2013): develop jellyfish products for food and medicine, use cutting nets to destroy the jellyfish, destroy the polyps, use of biocontrol agents, prevent any activity that might promote the spread of gelatinous plankters, design nets that are not clogged by gelatinous plankton, employ selective fishing gear, and set early warning system. Among these

measures, 3 countermeasures are established and installed: jellyfish warning and/or installation of net for beaches (JellyRisk, 2013; Park et al., 2015), medusa (Park et al., 2015) and polyp removal (Yoon et al., 2018).

In the Yellow Sea, as well as its adjacent seas, two jellyfishes bloom: *N. nomurai* and *A. aurita*. *N. nomurai*, the most abundant and most damaging jellyfish bloomed episodically in 1920, 1950 and 1995 (Kawahara et al., 2006), and continuously in 2003-2009 (Yoon et al., 2014). Since then the abundance decreased but always in non-negligible (www.nifs.go.kr). This jellyfish is endemic species and believed to be originated from Chinese waters: northeastern East China Sea (Toyokawa et al., 2012; Sun et al., 2015) and Liaodong Bay, Bohai Sea (Dong et al., 2018), and advects into the Yellow, northeastern East China (South Sea for Korean) and East Seas (Yoon et al., 2018). However the exact path is not established yet. *A. aurita* are coastal jellyfish species an invader in around 1950s, and bloom since 1980s in the southeastern Korean peninsula and in the end of 1990s, blooms occur in the western Korean peninsula. Since then blooms occur every year all around Korean peninsula (www.nifs.go.kr).

Yellow Sea is a semi-enclosed sea bordering with East China Sea from south and Bohai Sea from north, and these two adjacent seas affect Yellow Sea's physical, chemical and biological properties, and jellyfish is not an exception. Besides this interrelationship between seas, the two countries bordering Yellow Sea, Peoples Republic of China and Republic of Korea that are densely populated, heavily urbanized, and industrialized should affect in a fundamental manner the health of the Yellow Sea and threaten its sustainability. Being recognized as an opportunist and known to bloom as a consequence of anthropogenic activities, jellyfish is the most appropriate marine organism of the Yellow Sea to comprehend marine ecosystem which is changing because of anthropogenic activities, establish scientific and/or management network to reduce damages because two countries suffer from the same jellyfish species, and to demonstrate the feasibility of sustainable fisheries management and of reducing stress to the ecosystem.

Objectives of this work are then, i) to contribute in reporting "YSLME Jellyfish Monitoring Network" that should include monitoring methodology, data gathering and analysis, and recommendations for future studies, ii) to perform jellyfish monitoring in the Yellow Sea and adjacent sea using ships of opportunity, iii) participate YSLME jellyfish regional

committee for corporative research and establishment of jellyfish network, and iv) to share information and data with relevant institution and Chinese partner (Chinese National Marine Environmental Monitoring Center).

## 2. Overview on Jellyfish Studies

### 2.1. RO Korea

#### 2.1.1 Current status

Jellyfish identification has been initiated since 1997 (KSF, 1997) resulting in 42 scientifically proved and reported jellyfish species in Korean waters (Fig. 2, table 1).

**Table 1. Jellyfish species officially recorded in Koran waters at present (Nov. 2018)**

No.	Species	No.	Species
1	<i>Sarsia tubulosa</i>	23	<i>Aegina citrea</i>
2	<i>Turritopsis nutricula</i>	24	<i>Pelagia noctiluca</i>
3	<i>Cladonema radiatum</i>	25	<i>Chrysaora pacifica</i>
4	<i>Rathkea octopunctata</i>	26	<i>Cyanea nozakii</i>
5	<i>Spirocodon saltatrix</i>	27	<i>Aurelia aurita (coerulea)</i>
6	<i>Liriope tetraphylla</i>	28	<i>Stenoscyphus inabai</i>
7	<i>Aglantha digitale</i>	29	<i>Nemopilema nomurai</i>
8	<i>Rhopalonema velatum</i>	30	<i>Diphyes chammisonis</i>
9	<i>Phialidium folleatum</i>	31	<i>Abylopsis eschscholtzi</i>
10	<i>Eirene menoni</i>	32	<i>Bougainvillia ramosa</i>
11	<i>Dipleurosoma typicum</i>	33	<i>Phialidium hemishaericum</i>
12	<i>Aequorea coerulescene</i>	34	<i>Aeguorea macrodactyla</i>
13	<i>Olinidias formosa</i>	35	<i>Diphyes dispar</i>
14	<i>Craspedacusta sowerbii</i>	36	<i>Abylopsis tetragona</i>

15	<i>Gonionemus vertens</i>	37	<i>Bathypphysa grimaldii</i>
16	<i>Proboscidactyla stellata</i>	38	<i>Agalma okenii</i>
17	<i>Proboscidactyla flavicirrata</i>	39	<i>Rhopilema esculentum</i>
18	<i>Porpita umbella</i>	40	<i>Aurelia limbata</i>
19	<i>Physalia physalis utriculus</i>	41	<i>Parumbrosa polylobata</i>
20	<i>Diphyes bojani</i>	42	<i>Carybdea brevipedalia</i>
21	<i>Muggiaea bargmannae</i>		
22	<i>Solmundella bitentaculata</i>		

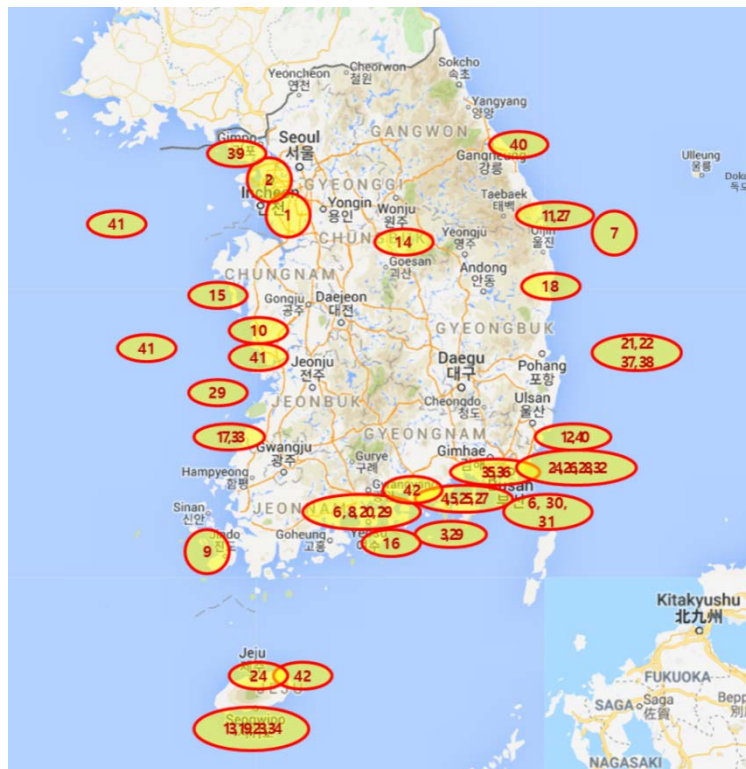


Figure 2. Location of sampling site of officially recorded jellyfish species in Korean waters. Number corresponds to those of table 1. Some sampling sites of several jellyfish (ex. *N. nomurai* and *C. brevipedalis*) were omitted due to too extended sampling areas.



Studies on blooming jellyfish had begun with the massive appearance of *N. nomurai* in the Yellow Sea in 2003. And in 2004, National Institute of Fisheries Science (NIFS) launched scientific research program that is still going on targeting principally blooming jellyfish: *Nemopilema nomurai*, *Aurelia aurita*. From that program, spatiotemporal distribution of *N. nomurai* in Korean waters (Yoon et al., 2014, Fig. 3), coastal appearance of jellyfish species (Fig. 4) including *N. nomurai* (Fig. 5) and *A. aurita* (Fig. 6) (NIFS, 2017), properties of venoms and natural products from *N. nomurai* (Kim et al., 2006, Liu et al., 2009, 2010; Kim et al., 2012; Fig. 7) *Cyanea nozakii*, *Chrysaora pacifica*, and *Carybdea brebipedalis* (Kang et al., 2009; Pyo et al., 2016; Fig. 8), field ecological characteristics such as target strength, vertical migration, and swimming speed (Lee et al., 2007, 2010; Fig. 9), forecasting jellyfish drifting path (Moon et al., 2010), DNA analysis (Ki et al., 2008; Heo et al., 2016; Lee et al., 2016), fishing gear development to reduce jellyfish bloom (NIFS, 2013; Park et al., 2015; Fig. 10, 11), and economic damages due to jellyfish blooms (Kim et al., 2012). Physio-ecological characteristics of blooming jellyfish were also studied (Lee et al., 2008, 2017; Han et al., 2012; Yoon et al., 2014).

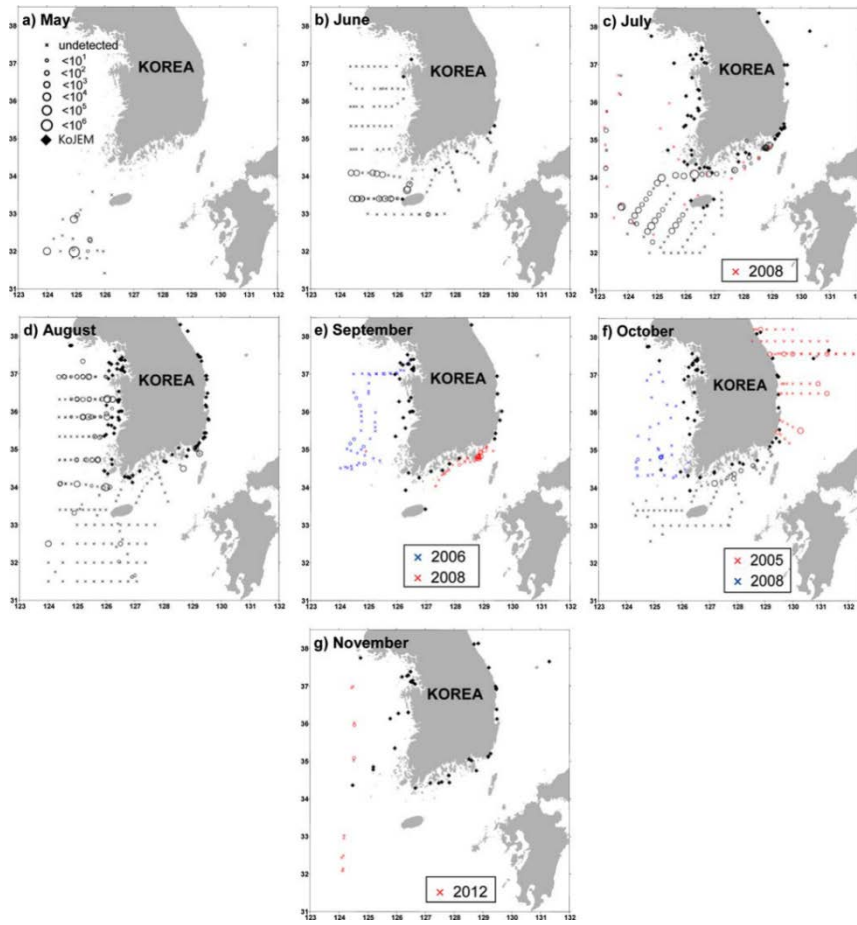


Figure 3. Spatiotemporal distribution of *N. nomurai* in Korean waters (from Yoon et al., 2014)

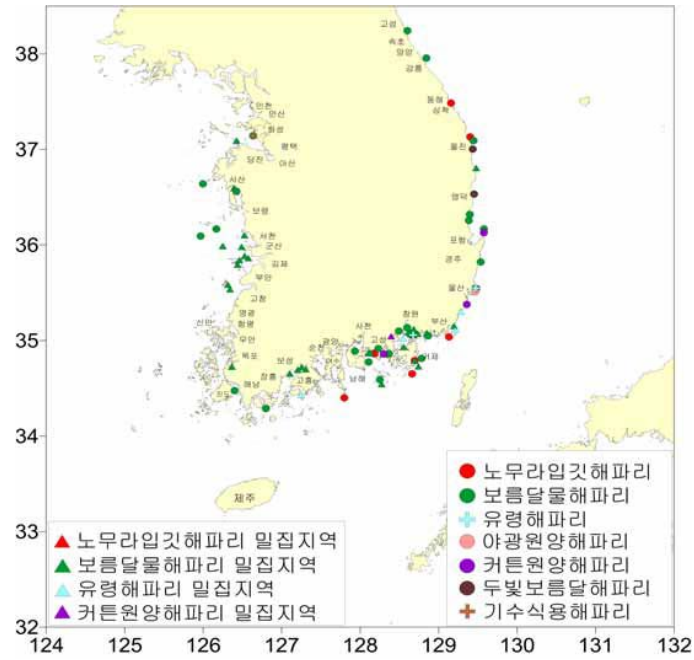


Figure 4. Jellyfish appearance in Korean waters at 20 June, 2017 (from NIFS, 2017)

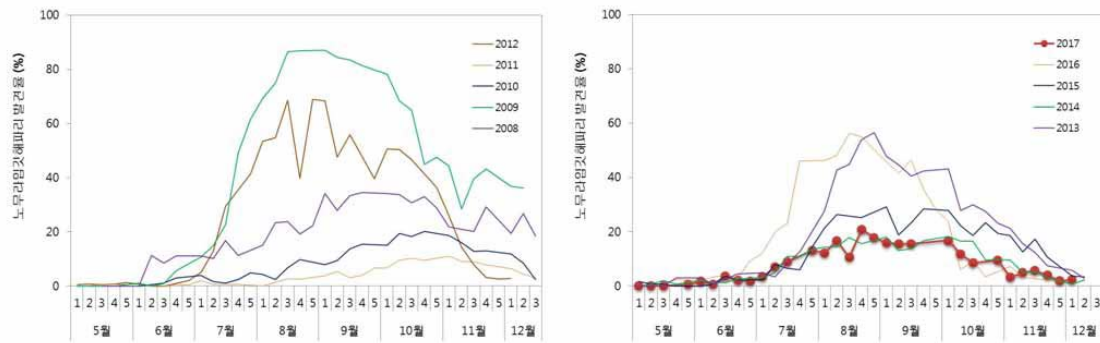


Figure 5. *N. nomurai*'s annual appearance (%) in Korean coastal waters for 2013-2017 (from NIFS, 2017).

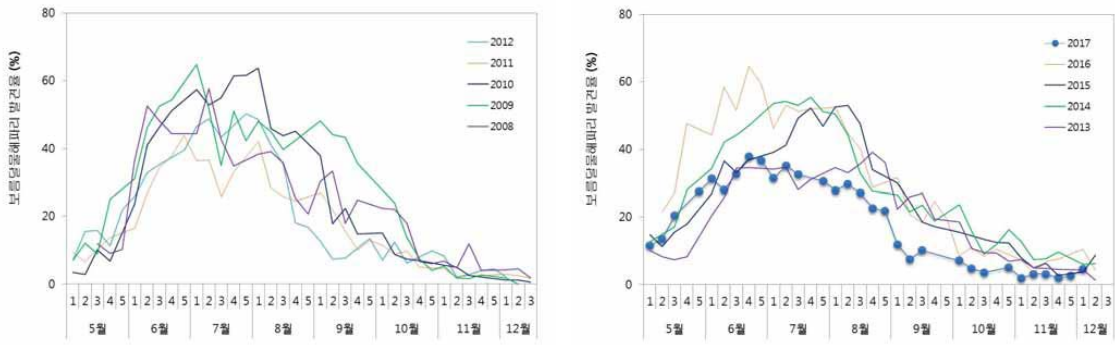


Figure 6. *A. aurita*'s annual appearance (%) in Korean coastal waters for 2013-2017 (from NIFS, 2017)

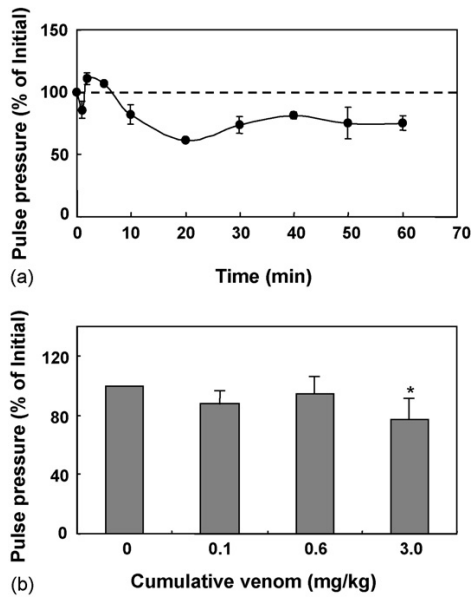


Figure 7. Effects of *N. nomurai* venom on arterial pulse pressure of rats (from Kim et al., 2006)

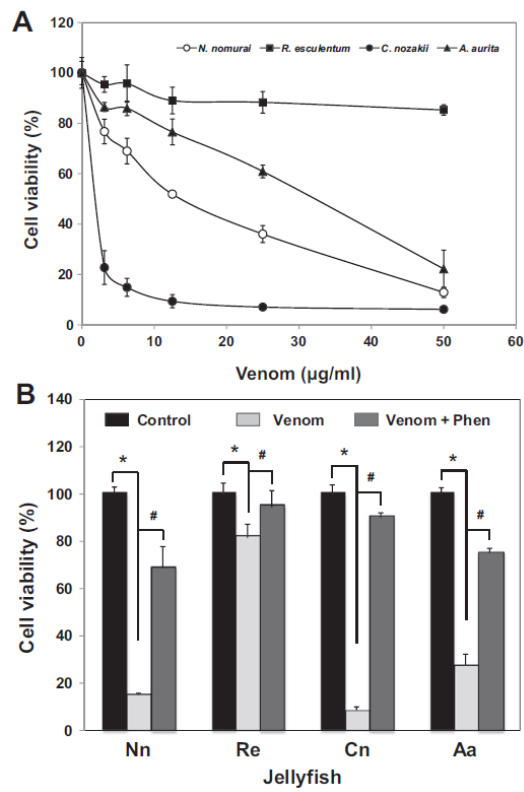


Figure 8. Inhibitory effects of a metalloproteinase inhibitor (1,10-phenanthroline) on the cytotoxicity of jellyfish venom (from Lee et al., 2011)

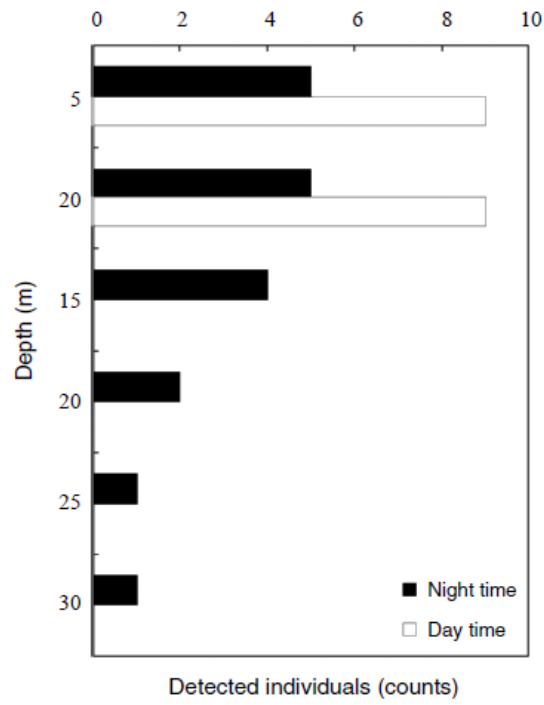


Figure 9. Vertical distribution of *N. nomurai* measured by optical method (from Lee et al., 2007).

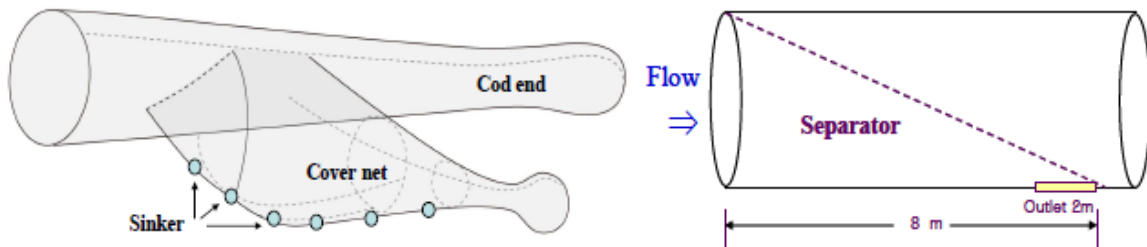


Figure 10. Trawl net development to reduce damages by jellyfish blooms (from NIFS, 2013)

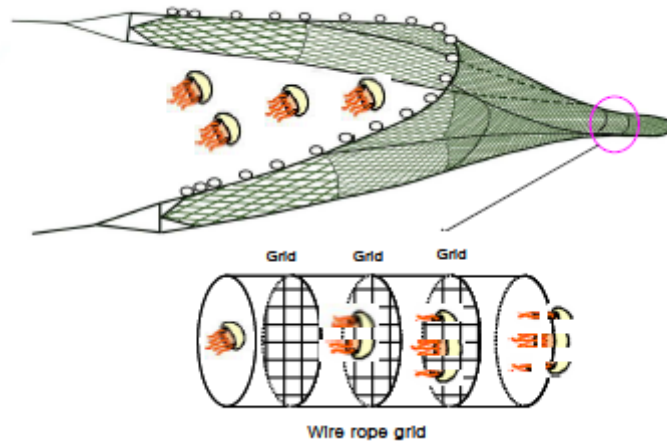


Figure 11. Trawl net used in jellyfish removal (from NIFS, 2013)

Korea Institute of Ocean Science and Technology had studied *A. aurita* in Masan Bay for 2004-2006 on mechanism of bloom in that bay, effect of temperature, salinity and dissolved oxygen concentration on settlement of planula and growth of polyps, physiological characteristics (ingestion rate, digestion time), biochemical composition, vertical distribution of polyps and medusa, and life cycle (MOMAF, 2007).

Ministry of Ocean and Fisheries (MOF) is undertaking “Development of the methods for controlling and managing marine ecological disturbance-causing and harmful organisms” since 2011. The program deals with blooming and non-blooming jellyfish, such as *N. nomurai*, *A. aurita*, cubomedusae *C. brebipedalis*, and hydromedusae *Blackfordia virginica*, and has elucidated bloom development of *A. aurita* in Gamak Bay, Yeosu, and impact of *Blackfordia virginica*'s bloom on zooplankton in Sihwa Lake, Gyeonggi-do. The program also studied energy and material transfer via food web, from phytoplankton to jellyfish *A. aurita* and *B. virginica* using stable isotope, and reported a newly named jellyfish species in Korean waters, *C. brebipedalia* (Chae et al., 2017). The program has analyzed *A. aurita*'s bloom mechanism, relation between habitat and its environmental characteristics, and provided rational of polyp removal in order to control jellyfish bloom. Genetic structures were defined and primers to quick detection from the environmental samples were developed for *N. nomurai*, *A. aurita*, *C. nozakii*, *C. pacifica*, *Rhopilema esculentum*, and *C. brebipedalia*.

## 2.1.2 Policy

Ministry dealing with jellyfish blooms is MOF since 2013, Ministry for Food, Agriculture, Forestry and Fisheries (MiFFAF) and Ministry of Land, Transport and Maritime Affairs (MLTM) in Feb. 2008-Mar. 2013, and Ministry of Maritime Affairs and Fisheries (MOMAF) before Feb. 2008.

National policy against jellyfish had initiated since 2003 when *N. nomurai* had appeared in mass. In 2006 Fisheries Policy Office (FPO) of MOMAF established Korean Jellyfish Monitoring Network (KoJeM) and installed Jellyfish Monitoring Center (JMC) at NIFS (National Fisheries Research and Development Institute, NFRDI, before 2016) in charge of the network. The objectives of KoJeM was to i) gather regular data of jellyfish appearance in Korean waters, ii) disseminate information required for fisheries, iii) accumulate data and information for relevant policy making. In this KoJeM of the year of 2006, 271 volunteers of fishermen, 86 public officials and 20 researchers of NFRDI participated and covered entire coastal Korean waters (Fig. 12). Participants of KoJeM reported weekly appearance of jellyfish from May to December. JMC at NIFS gathered, analyzed, and disseminated information through fax, e-mail, and web (<http://www.nifs.go.kr/bbs?id=jellynews>, Fig. 13) and published yearly “Report on the jellyfish appearance in Korean waters”(Fig. 14). In 2010, after reoccurrence of *N. nomurai*'s bloom in 2009, MiFFAF reinforced KoJeM adding more jellyfish monitoring peoples (294 fishermen, 67 public officials, 60 researchers) and ships (29 ships) (Fig. 15). A structure for countermeasure jellyfish bloom was installed in MOF and in relevant institution and organization including related central ministries, regional governments, NFRDI, Korea Marine Environment Management Corporation (KOEM), National federation of Fisheries Cooperatives, Korea Fisheries Infrastructure Public Agency, etc. Main ideas of establishing such structure to countermeasure jellyfish blooms were i) prevention of areal expansion of jellyfish, ii) reinforcement of monitoring, iii) early and effective removal of jellyfish medusa, and iv) follow-up management through forecasting, information dissemination to mass media. In 2015, 146 autonomous fishermen's associations were involved into KoJeM. Based on the jellyfish appearance information, NIFS issues jellyfish warning signal (Fig. 16) depending on jellyfish species (*A. aurita* or *N. nomurai*) and density or



appearance rate: attention, caution, alert, serious. Based on warning signals, regional governments undertakes jellyfish removal (Fig. 17) using specially designed net (Fig. 11) with fund provided by MOF. Besides this works, JMC at NIFS issue printed document, pamphlet (Fig. 18), brochure, and leaflet to provide information about venomous jellyfish and first aid to general public.

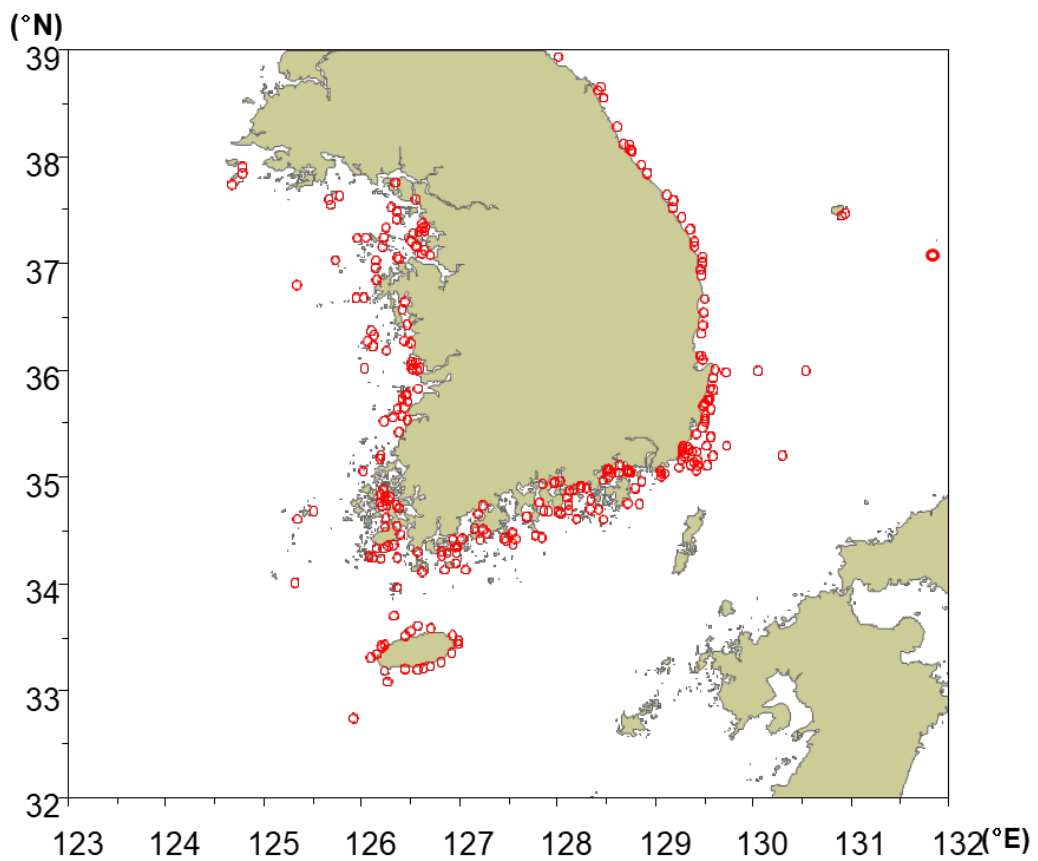


Figure 12. Jellyfish monitoring sites of KoJeM in 2006

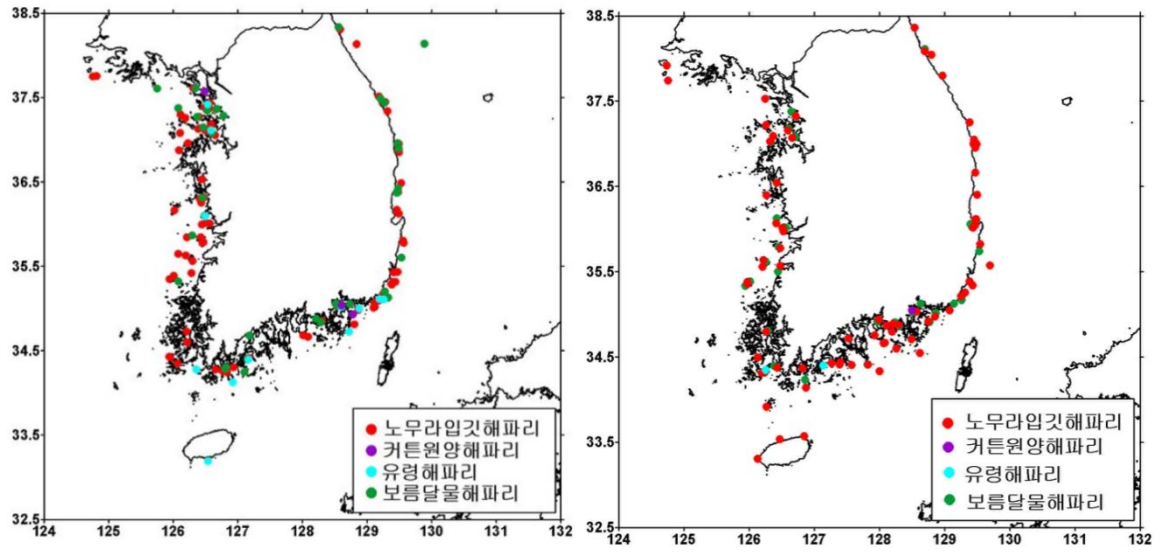


Figure 13. Jellyfish appearance in Korean waters in August of 2007 (left) and 2009 (right)



Figure 14. An example of “Report on the Jellyfish Appearance in Korean Waters” by NIFS

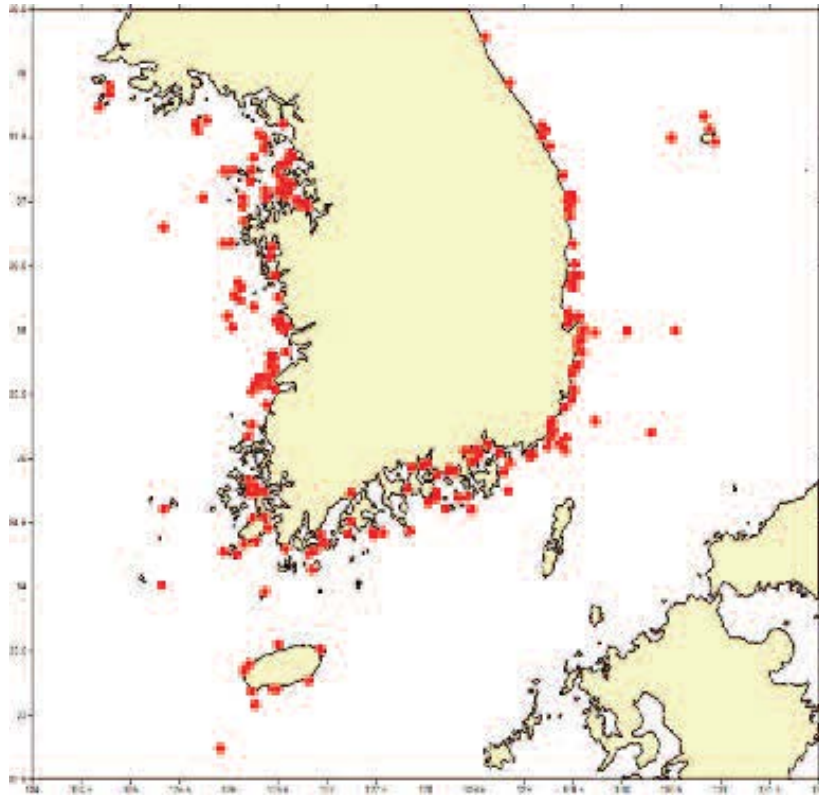


Figure 15. Jellyfish monitoring sites of KoJeM in 2010

The screenshot shows the website of the National Institute of Fisheries Science (NIFS). The top navigation bar includes links for '정보공개' (Information Disclosure), '국민소통' (Public Communication), '알림마당' (Notice Board), '예보·속보' (Forecast/Breaking News), '국립수산과학원소개' (Introduction to NIFS), '소속기관' (Affiliated Institutions), and '해양수산자료실' (Marine and Fisheries Data Room). The main content area is titled '해파리속보' (Jellyfish Breaking News) and features a warning about the mass appearance of *Aurelia aurita* (moon jellyfish) in the southern part of the Korean peninsula. The warning includes the date '2018-07-31' and the number of views '338'. It also provides a link to a PDF report and a list of related news items.

Figure 16. Jellyfish warning on mass appearance of *A. aurita* in July 2018



Figure 17. Jellyfish removal by a fishing boat



**국립해양과학관 해파리대처반**  
해파리 피해 예방을 위한 1차원적 대응을 위한  
국립해양과학관 해파리대처반은 해파리 피해 예방을  
위하여 2014년 11월 17일 '해파리 피해  
예방 및 대응 지침서'를 발간했다.

**문의처**  
국립해양과학관 해양조사팀

**국립해양과학관**  
해양조사팀 | Tel: 02-5200-1111  
Marine Science Museum  
Tel: 02-5200-1111  
www.nmsm.go.kr

**우리 바다 출현 독성해파리 접촉피해 응급대처법**




**국립해양과학관**

**익하게 쓰인 경우**

1. 쓰인 즉시 물 밖으로 내움
2. 화상부위에 남아있는 독소는 신속히 제거하고, 해당물질 다량 흡수 방지 세척
3. 통증이 심하면 얼음 또는 냉해빙 또는 온해빙 (45℃ 내외)을 하여 통증을 완화시킨다
4. 상처부위의 상처가 심하면 진정제 복용 확인

**심각한 증상이 나타나는 경우**

1. 쓰인 즉시 물 밖으로 내움
2. 호흡곤란·의식불명·면역 반응 등 심각한 증상을 보일 경우 즉시 의료진의 도움을 요청 (의료진에 경우 심폐소생술 실시)
3. 병원으로 이송하여 응급처치와 병동 치료 받도록 함

**노랑머리 해파리**

노랑머리 해파리(Physalia physalis)는 해파리목 노랑머리과에 속하는 해파리이다. 노랑머리 해파리는 노랑머리 해파리목에 속하는 해파리이다. 노랑머리 해파리는 노랑머리 해파리목에 속하는 해파리이다. 노랑머리 해파리는 노랑머리 해파리목에 속하는 해파리이다.

**산호초 해파리**

산호초 해파리(Physalia physalis)는 해파리목 산호초과에 속하는 해파리이다. 산호초 해파리는 산호초 해파리목에 속하는 해파리이다. 산호초 해파리는 산호초 해파리목에 속하는 해파리이다.

**우리 바다 출현 독성해파리**

**노랑머리 해파리**

노랑머리 해파리(Physalia physalis)는 해파리목 노랑머리과에 속하는 해파리이다. 노랑머리 해파리는 노랑머리 해파리목에 속하는 해파리이다. 노랑머리 해파리는 노랑머리 해파리목에 속하는 해파리이다.

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Figure 18. First aid for venomous jellyfish sting issued by NIFS

In 2009 Marine Policy Office (MPO) of MLTM before 2013 and MOF after 2013 launched a program entitled “Planning of Damage Prevention due to Harmful Marine Organism, Jellyfish”. In that program, current status of Korea and other country’s countermeasure were analyzed and compared, economic damages due to jellyfish blooms assessed, and future direction to reduce or prevent damages due to jellyfish blooms proposed.

According to that report, fisheries damages were between US\$ 69 10<sup>6</sup> and 206 10<sup>6</sup>, national key industries (National Power Plant) a little more than US\$ 53 10<sup>6</sup>, and regional economy in summer up to US\$ 14 10<sup>6</sup> (MLTM, 2009). As recommendations, the report listed i) establishment of monitoring system, ii) establishment of jellyfish identification and information sharing system, iii) basic scientific program to elucidate mechanism of jellyfish bloom, iv) jellyfish venom, v) forecasting jellyfish bloom, and vi) use of jellyfish for natural or rare substances. This planning program was developed as program to monitor, forecast, and prevent damages due to bloom forming jellyfish (MLTM, 2011, 2012), and to search bloom forming jellyfish polyps in Chungcheongnam-do and Jeollabuk-do in 2011, Sihwa Lake, Gyeonggi-do in 2012, Gyeongsangnam-do in 2012, and Jeollanam-do in 2014. Methods of polyp eradication, such as Sodium hypochlorite, supply of substrate for polyp settlement and taking back, installation of fine nets for ephyra confinement, covering polyps with yellow loess, underwater jet, etc., were tested in laboratory and in field through 2011-2012 MLTM’s program by NIFS; underwater jet to remove polyps was the most efficient, eco-friendly, and of the lowest cost. Polyp removal was tested at great scale at electric power transmission towers at Sihwa Lake in 2012 and 2013, and at Dangjing port, Chungcheongnam-do (Fig. 19, 20)

In 2013 MPO of MOF launched program that is specially targeting search and removal of bloom forming jellyfish, *A. aurita*, in Korean coastal areas and designated KOEM as managing institution. Since then 1374 areas were surveyed for polyp existence: 236 in the western, 160 in the eastern, 978 in the southern coast (Fig. 21). The survey revealed hot spot of *A. aurita* polyps at floating docks, fish-farm barges, submerging pillars, ripraps of breakwater, dock walls, artificial reefs, natural rock beds and other underwater hard substrates. Once the survey ended and the abundance at areas was more



than  $10^7$  polyps, they were removed (Fig. 22). Recently cost evaluation was made and compared between polyp and medusa removals, and revealed that the former was of 0.78-3.14% of the latter (Yoon et al., 2018). Through this program of searching and removing jellyfish polyps, removal methods were refined and developed to be more eco-friendly, e.g. polyp suction (Fig. 23), cost effective, e.g. semi-automatic brush (Fig. 24) and safer.



Figure 19. Underwater jet machine and its use in jellyfish polyp removal

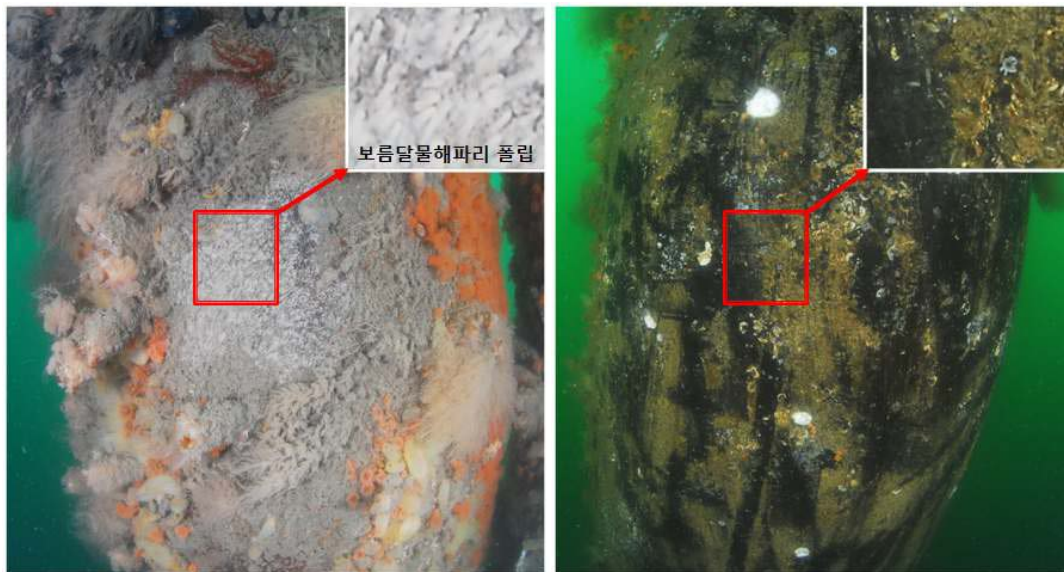


Figure 20. Polyps on mussel shell before (left) and after appliance of underwater jet.  
Boxes indicate *A. aurita*'s polyps (left) and removed by underwater jet (right)

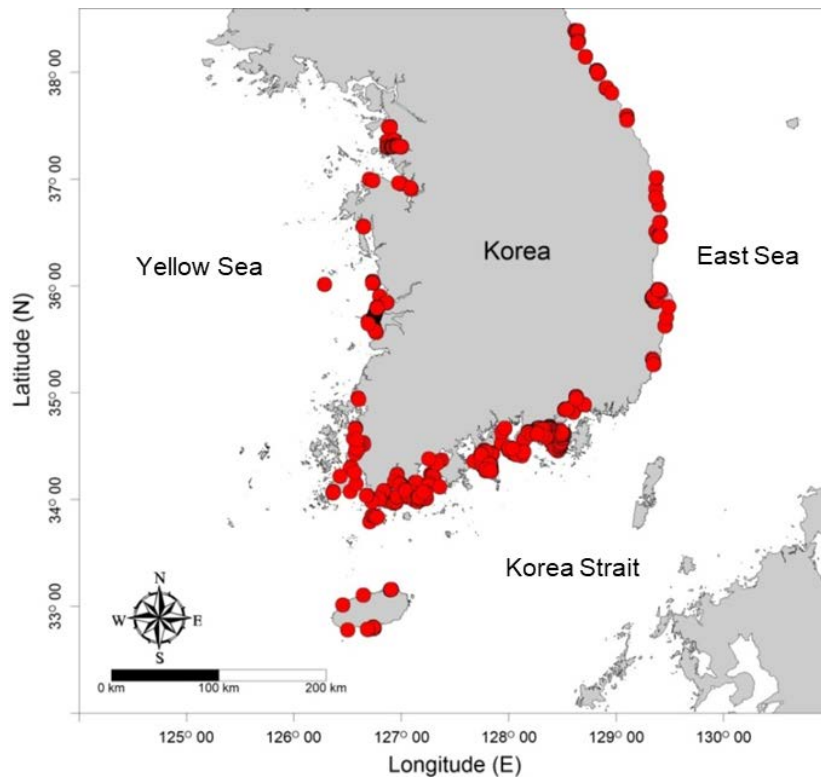


Figure 21. Sites of polyp survey

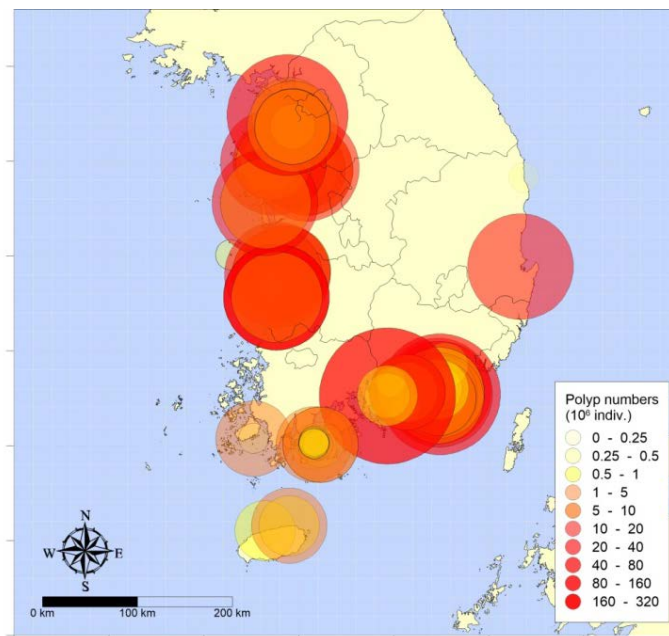


Figure 22. Abundance of polyps in Korean coastal area

When it is  $> 10^7$  polyps, polyps were removed.

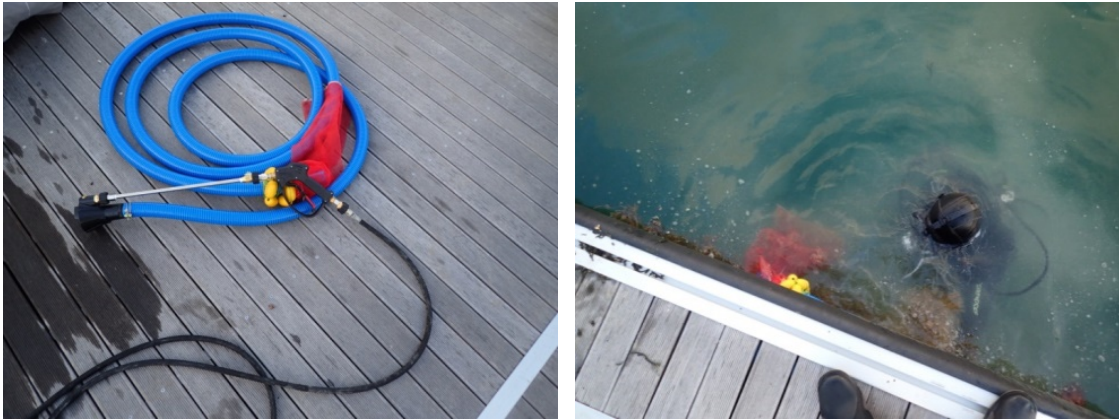


Figure 23. Polyp suction device tested and approved its eco-friendly feature

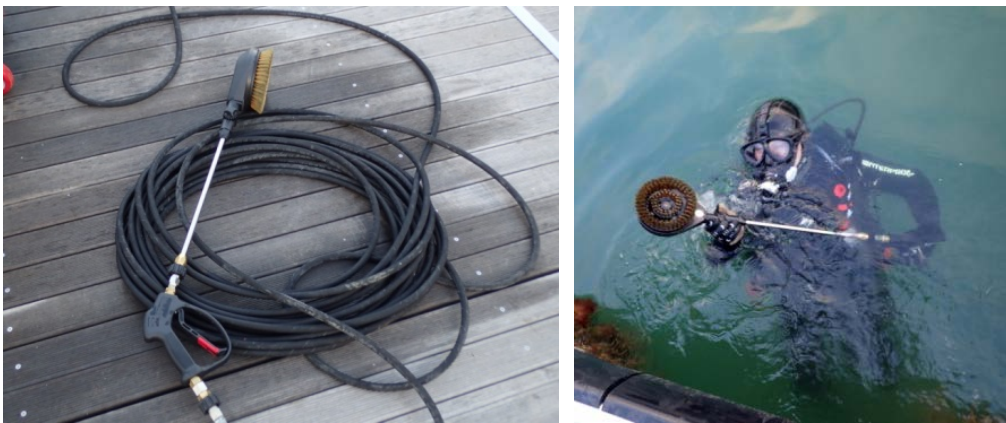


Figure 24. Tested and approved semi-automatic polyp removal device

### 2.1.3 Conclusion

Programs regarding jellyfish bloom have started 2004 as scientific program at NIFS, after bloom of *N. nomurai* in Korean waters. Since then central governments made scientific as well as policy making programs.

Through these programs, bloom forming jellyfish were identified, their sources determined, advection paths proposed in Korean waters, their ecological and physiological characteristics elucidated, and mechanism of blooms were suggested. However, for *N. nomurai* is from Chinese coastal areas, their sources as well as mechanism of bloom are to be verified, and for this reason, cooperative research and/or information and data sharing with Chinese scientists and institution are absolutely required.



Sound and sufficient scientific knowledge on *A. aurita* was gathered to understand their blooming mechanism and its impact on marine ecosystem as well as their ecological and physiological features. Based on this knowledge, polyp removal was initiated and its efficiency approved in controlling *A. aurita*'s outgrowing population.

Central governments being aware of jellyfish blooms for their damages in fisheries, national key industries and summer regional economy, have established national wide monitoring network, prepared and executed jellyfish countermeasure plan, designated responsible institutions for each program and funded for its achievement, and supported research cooperation with China and Japan. Removals of jellyfish medusa and polyp were the results of the research program closely connected with policy making program.

Nevertheless, it must be noted that the 5 eventual causes favoring jellyfish blooms (overfishing, eutrophication, climate change, translocation and habitat modification) were not properly tackled. Among the eventual causes, climate change is the most threatening since it would change ecosystem structure and function, and entrain and/or favor jellyfish, highly venomous or blooming, invaders in Korean waters. Another note would be about highly venomous jellyfish such as *C. nozakii*, *C. brebipedalia* and others that would come with climate change. Studies for first aid against sting by these jellyfish as well as characterization and use of their venom would be highly recommended.

## **2.2. PR China**

### **2.2.1 Current Status**

In recent years, the frequency and categories of marine ecological disasters have been increasing. Jellyfish blooms have become a new type of marine ecological disaster after red tide, green tide and other ecological disasters globally. Jellyfish disasters were formed by an abnormal increasing number of jellyfish in local waters, which undermined the safety of outdoor bathing place, and impacted the normal intake of industrial water and fishing seriously. Jellyfish bloom is a natural phenomenon, which blooms about every 40 years in history. However, the outbreak frequency is higher and higher, even to an alarming rate of once every year in recent years.

Jellyfish bloom used to bloom occasionally and failed to attract the attention of researchers before the middle of 1990s. Since offshore ecosystems have changed a lot in China under the pressure of the global temperature change, the increasing intensity of human activities and the overfishing of fishery resources, jellyfish blooms have become more frequent, with large outbreaks in Bohai Sea, the northern East China Sea and the southern Yellow Sea. The frequency of jellyfish blooms in northern China is significantly higher than that in southern China. In recent years, the density of jellyfish in Bohai Sea has been increasing, and the local waters have seen significant increase in jellyfish blooms (Table 2).

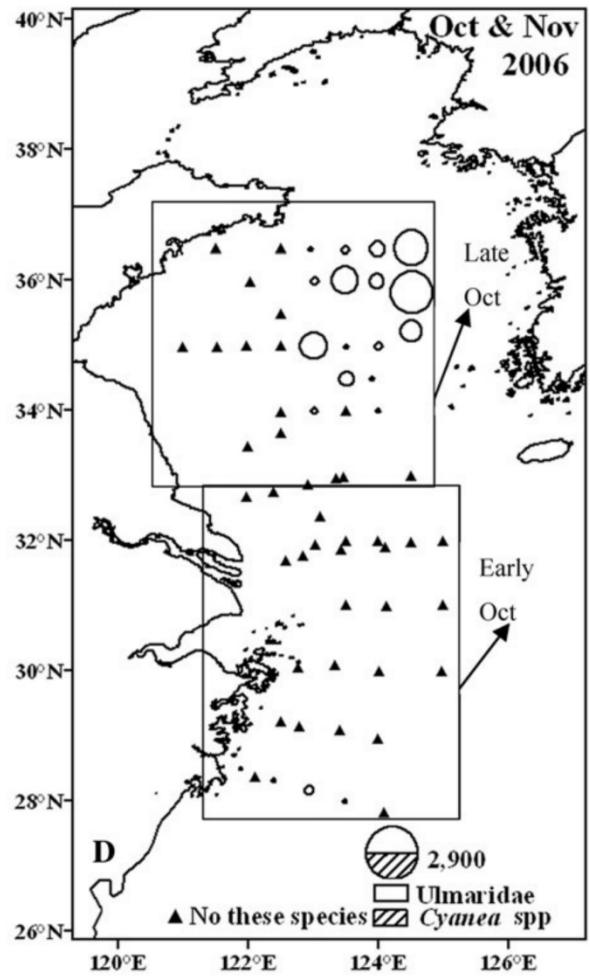
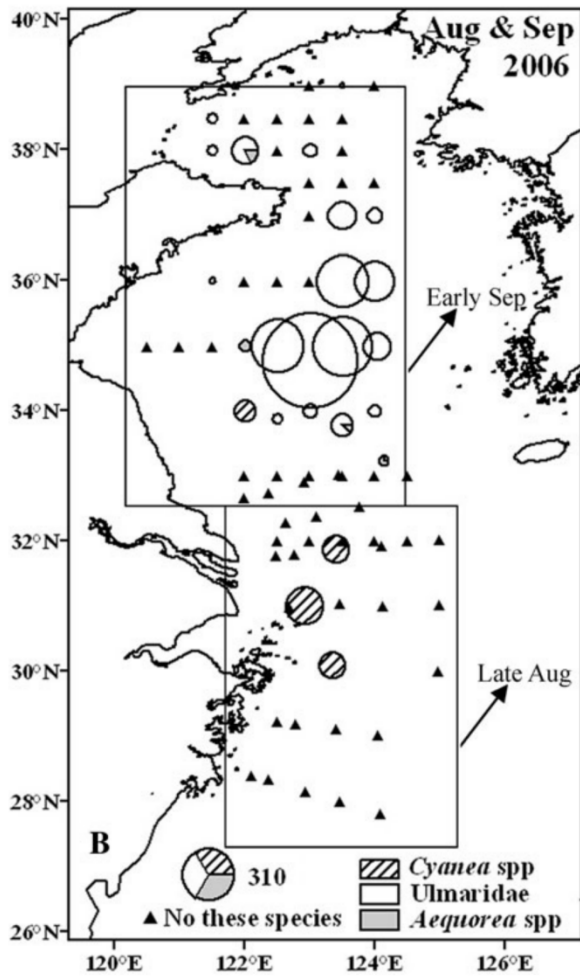
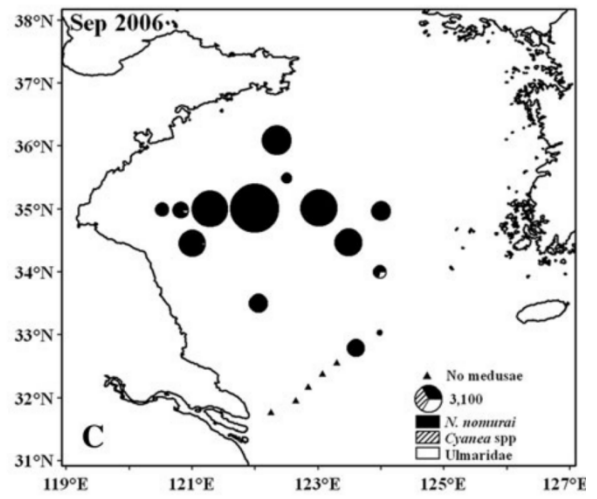
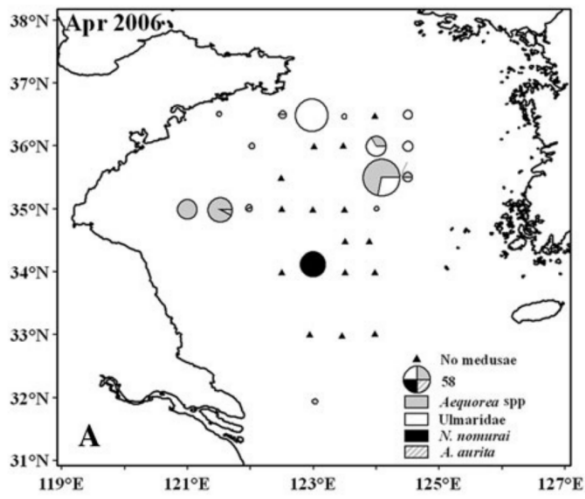
**Table 2.** Published accounts of jellyfish blooms in Chinese seas and their negative impacts on human enterprises (Dong et al., 2010).

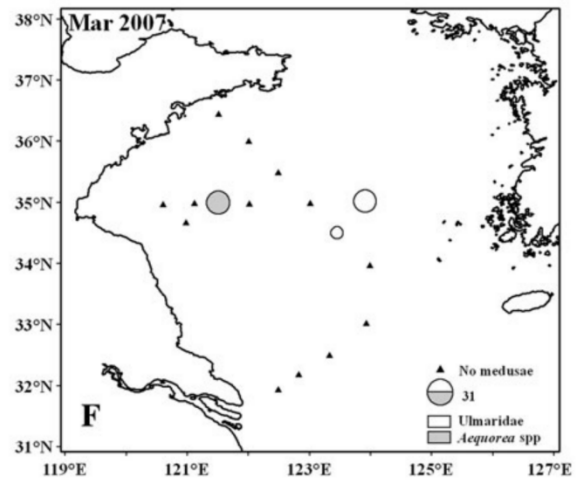
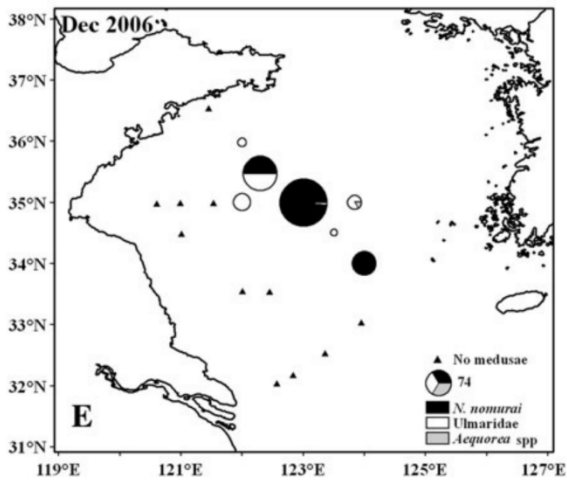
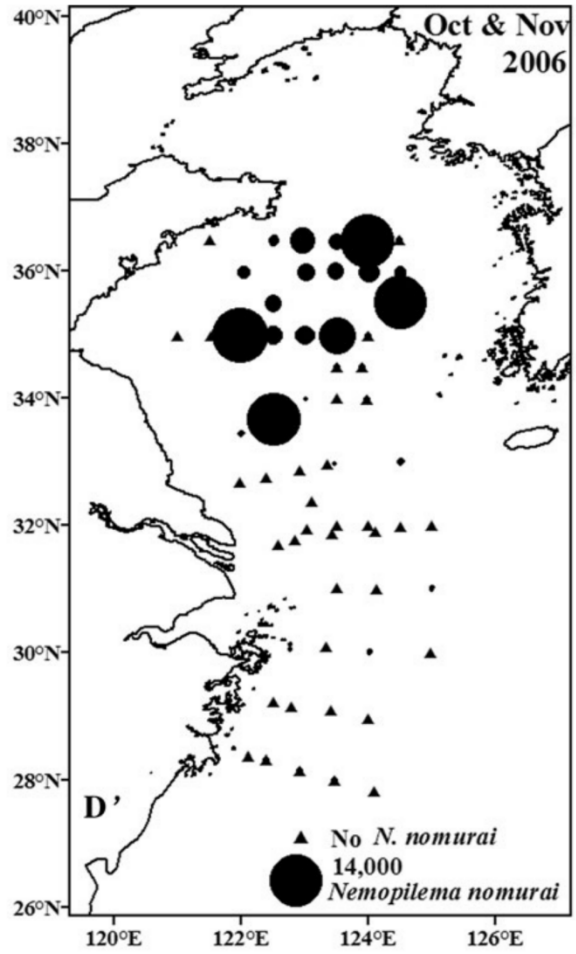
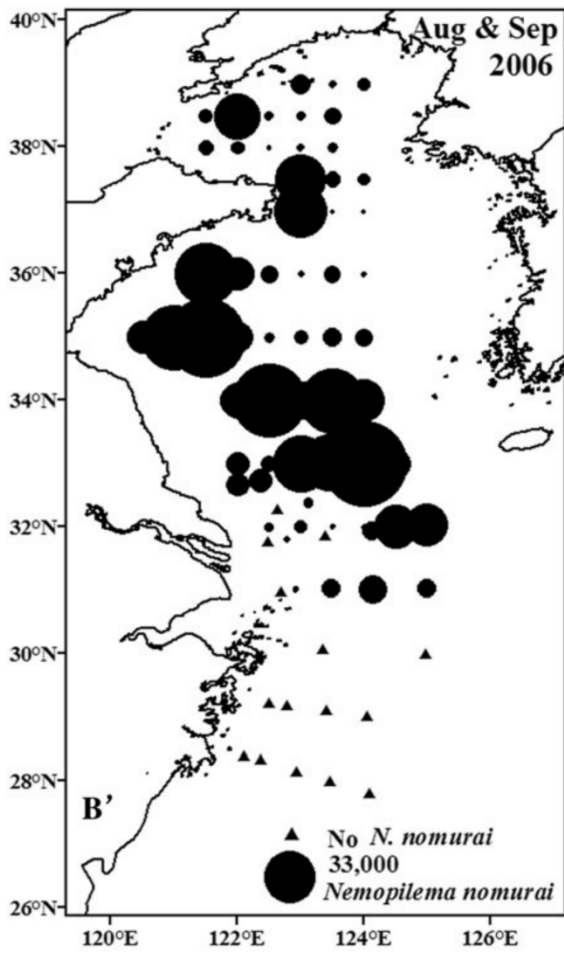
Species	Year	Location	Direct consequences
<i>Aurelia aurita</i>	2004; 2008	Qinhuangdao, Hebei province	Over 4000 tons of <i>A. aurita</i> were cleaned up in July 2008
<i>A. aurita</i>	2007	Yantai, Shandong province	Interference with aquaculture
<i>A. aurita</i>	2008	Weihai, Shandong province	20–50 tons of <i>A. aurita</i> were cleaned up each day
<i>A. aurita</i>	2009	Qingdao, Shandong province	Over 10 tons of <i>A. aurita</i> were cleaned up for two days
<i>Cyanea</i> sp.; <i>Nemopilema nomurai</i>	1999	Middle South Zhejiang province	Interference with fisheries
<i>Cyanea nozakii</i>	2004	Liaodong Bay	Sharp decline of edible jellyfish <i>Rhopilema esculentum</i>
<i>Cyanea</i> sp.	2003; 2004	Yangtze Estuary	Comprised 85.47% of the total catch of fisheries in November 2003 and 98.44% in May 2004
<i>Nemopilema nomurai</i>	2003–2005	East China sea	Mean biomass in monitoring sites 608–7144 kg/h
<i>N. nomurai</i>	2005; 2007	Huludao, Liaoning province	Interference with fisheries

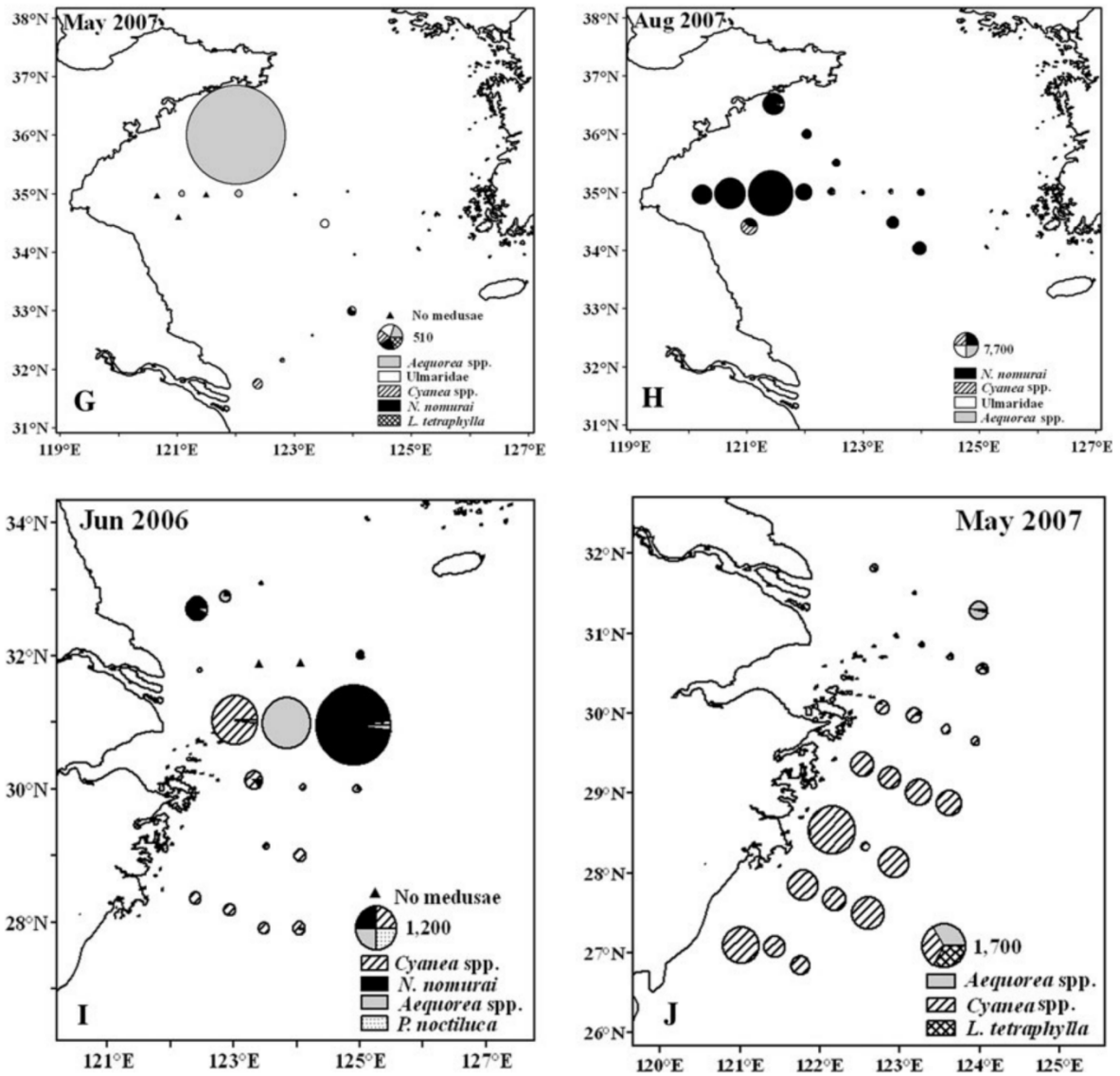
From 2003 to 2014, there were several incidents of jellyfish blooms, causing blockages in the water intake of power plants, loss of offshore catches and injuries on beaches. In 2004, the abnormal proliferation of *Cyanea nozakii* in Liaodong Bay of Bohai Sea was particularly significant, which resulted in the reduction of *Rhopilema esculentum* and fishing industry. From June to September 2007, a very rare bloom of *Aurelia aurita* occurred in the coastal areas in Yantai and Weihai, Shandong province. Since 2008, the coastal power plants in the north areas of Qingdao and Longkou have suffered from jellyfish boom for many years. In July 2009, the jellyfish bloom hit power plant in Qingdao and hampered the safe operation. In late July 2013, a high-density jellyfish population formed in the waters around the Hongyanhe nuclear power plant in Liaoning province. On July 21, 2014, the Hongyanhe nuclear power plant

suffered an outage because *Aurelia aurita* blocked the cold water intake system. In the south of China, jellyfish invaded the cold water system of nuclear power in Daya Bay from February to March 2017. From 2003 to 2016, the average number of people stung by jellyfish on the beach was up to 1,400 per year, and the total number of deaths was 21. An eight-year-old boy was stung by *Nemopilema nomurai*, which caused acute pulmonary edema, and he died in rescue on August 2, 2013.

Blooms of giant jellyfish have formed increasingly in the southern Yellow Sea (YS) and northern East China Sea (ECS) during summer and fall since the end of the 1990s. The distribution of giant jellyfish varies with seasons, temperature, salinity and other hydrological conditions throughout the coastal waters in the southern YS and northern ECS. The distribution was mainly in the Yangtze Estuary and Subei shoal. Zhang et al. (2012) sampled giant jellyfishes using bottom trawl surveys during 2006–2007 in the YS and ECS. Bottom trawl surveys provided the first opportunity to sample giant jellyfish in the YS and ECS to assess population biomass and abundance over large area and in different season. Distribution, biomass, and biomass composition of the jellyfish assemblage during April 2006 to August 2007 surveys in Chinese waters were shown in Figure 25. Wei et al. (2015) described the observation of distribution of *N. nomurai* made on R/V Beidou from July 29 to August 7, 2009 (Figure 26). Most medusae were observed gathering between the 30 m and 50 m isobaths near the tidal front to the south of the Shandong Peninsular. All stations with *N. nomurai* abundance exceeding  $1.0 \times 10^4$  ind./km<sup>2</sup> were located in the tidal front area.

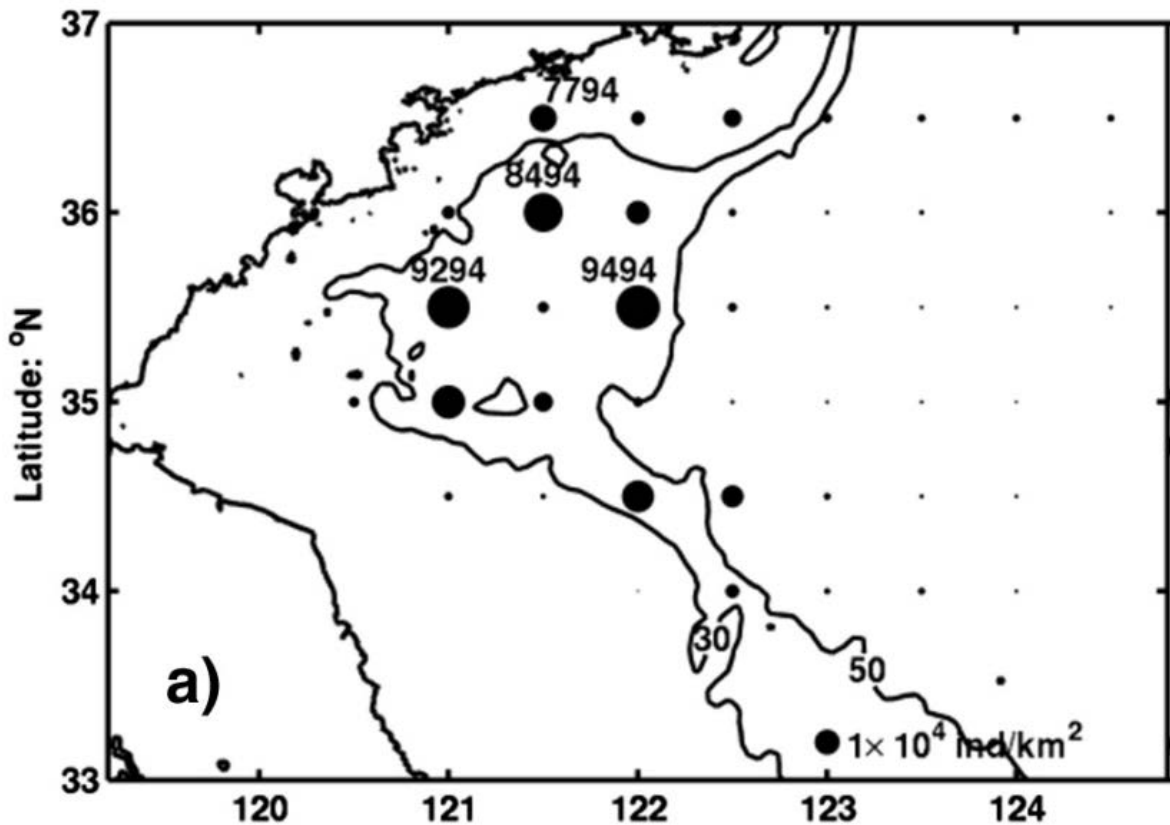






**Figure 25.** Distribution, biomass, and biomass composition of the jellyfish assemblage during April 2006 to August 2007 surveys in Chinese waters.

A–J Pies indicated total jellyfish biomass (pie size: biomass,  $\text{kg km}^{-2}$ . Biomass increased linearly with the pie area at each station), different shadings indicated different jellyfish species, with proportions as percentages of the pie area. Note that in (B) and (D), biomass of *Nemopilema nomurai* was excluded to show biomasses of other species, which otherwise would be masked by *N. nomurai* due to their huge biomass. The biomass of *N. nomurai* was shown instead in (B') and (D'). Different scale bars used for different surveys. *A. aurita* = *Aurelia aurita*; *L. tetraphylla* = *Liriope tetraphylla*; *P. noctiluca* = *Pelagia noctiluca*.



**Figure 26.** Observed distributions of *N. nomurai* in early August, 2009. Observations were made from July 29 to August 7. The station numbers of observations are denoted. Contour lines are water depth. Solid dots represent the abundance.

### (1) Characters of main species

At present, the main giant species of jellyfish blooms in China are *Aurelia aurita*, *Nemopilema nomurai*, and *Cyanea nozakii*. The biomass of small jellyfish (below 2cm), such as *Pleurobrachia globosa*, also increased.

*Aurelia aurita* is a widely studied species of the genus *Aurelia*. All species in the genus are closely related, and it is difficult to identify *Aurelia* medusae without genetic sampling; most of what follows applies equally to all species of the genus. The most common method used to identify the species consists of selecting a jellyfish from a harbour using a device, usually a drinking glass and then photographing the subject. This means that they can be



released into the harbour shortly afterwards and return to their natural habitat. The jellyfish is translucent, usually about 25–40 cm (10–16 in) in diameter, and can be recognized by its four horseshoe-shaped gonads, easily seen through the top of the bell. It is distributed in Dalian, Yantai, Weihai and Qingdao.

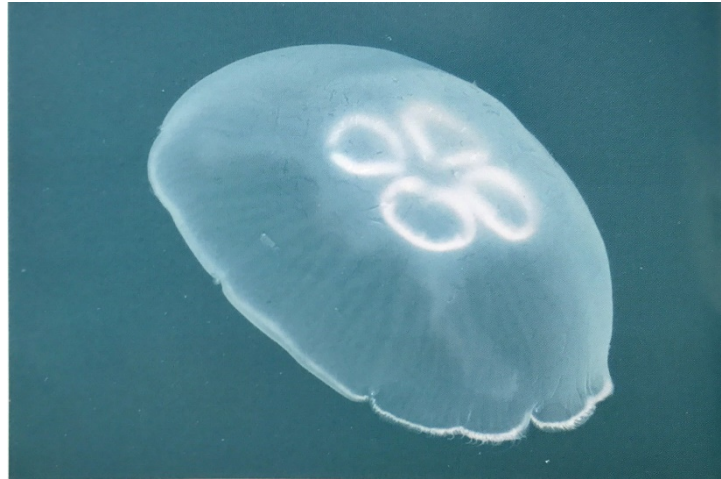


Figure 27. *Aurelia aurita* (picture from book named “最新クラゲ図鑑—110種クラゲの不思議な生態”)

*Nemopilema nomurai* is a very large rhizostomae jellyfish, in the same size class as the lion’s mane jellyfish, the largest cnidarian in the world. It is edible but not considered high quality. It is the only species in the monotypic genus *Nemopilema*.



Figure 28. *Nemopilema nomurai* (picture from book named “最新クラゲ図鑑—110種クラゲの不思議な生態”)



*Cyanea nozakii*, commonly known as the ghost jellyfish, is a species of jellyfish found in the northern Pacific Ocean near the coasts of China and Japan. Along with other species of giant jellyfish, it is showing a greater tendency to appear in large numbers and cause blooms. The medusa stage of *Cyanea nozaki* has a distinctive flat-topped bell which can grow to a diameter of 50 centimetres (20 in). The bell is usually cream or pale yellow in colour with a dark centre and a translucent rim. It has eight large marginal lobes and eight bundles of thread-like marginal tentacles. There may be a hundred or more tentacles in each bundle which are either translucent or a reddish colour, and can extend for 10 metres (33 ft). Under the centre of the bell is the manubrium, the mouth being surrounded by a tangled mass of rusty-brown or orange oral tentacles. They can live for thousands of years.



Figure 29 *Cyanea nozakii* (picture from book named “最新クラゲ図鑑—110種クラゲの不思議な生態”)

*Pleurobrachia globosa*, the species live in a wide range of temperature and salinity. The optimum temperature is about 23°C, and the optimum salinity is about 32. The density of this jellyfish is relatively high in spring and autumn, with the height of about 7~12mm and width of about 5~10mm. This jellyfish has a strong luminescence ability and can ingest zooplankton, thus they harm the fishing industry and pose a serious threat to the breeding industry indirectly.



Figure 30. *Pleurobrachia globosa* (by Chunjiang Guan, 2017)

## (2) Medusa monitoring methodologies

Currently, there is no unified method for the abundance or biomass estimation of the giant jellyfish, and it is generally believed that the quantification of giant jellyfish is difficult. The common problem is that giant jellyfish have large water content, large volume, and patch distribution, which all lead to inaccurate biomass estimation. Among traditional methods of netting, acoustics, optics and imaging systems, imaging systems are more widely used. The traditional investigation method using plankton trawl was to evaluate the bottom trawl fisheries resource.

When evaluating the biomass and abundance of jellyfish species, although the current method was semi-quantitative method in some extent, the method of relative indexes as quantitative biomass of inter-annual comparison was of practical significance according to the use of historical data of jellyfish abundance. The use of netting tools, such as bottom trawling, may lead to underestimation of biomass or abundance. One reason is that the opening widths of the nets will change under variable water pressure, making it difficult to quantify. Another is the vertical and horizontal distribution of patches on jellyfish. For example, Barz *et al.* reported that the distribution of jellyfish in the south of the North Sea was mainly in the range of 5-25m, which was not evenly distributed in the vertical direction. In the normal investigation of the Yellow sea in China, large amounts of jellyfish were also found in the surface or subsurface of many stations, and the sand jellyfish in the southern part of Japan Sea mainly accumulated in the water layer above 40m. Thirdly, the type of netting, including middle net or bottom trawl, cannot fully capture all of jellyfish except the target water layer set by the

netting. Therefore, it is necessary to estimate the capture efficiency or catch rate.

Including the traditional netting method for measuring jellyfish abundance, the method called sight survey for visually counting giant jellyfish abundance on the ship's deck has been also used by many scientists. Since 2006, the research group of professor Uye of Hiroshima University has been carrying out sight survey on ferry boats from the surrounding cities of Japan Sea to the surrounding cities of the East China Sea to number the distribution and abundance of giant jellyfish in the surface of Yellow Sea and Japan Sea by sighting. The advantage of the sight survey method is that it is easy to operate, economical and labor-saving. The disadvantage is that the abundance of jellyfish can only be observed on the surface of water or in the upper water. The use of this method is affected by weather, hydrological conditions, vertical movement behavior of jellyfish, etc. Therefore, quantitative monitoring by this method is not entirely accurate. Sight survey was rarely reported and was only done by research ships rather than by ferry boats in China. Wang Yantao *et al.* observed a bloom of jellyfish (*Aequorea* spp.) during a comprehensive investigation in the Yellow and East China Seas in April 2011.

In order to illustrate the geographical variations in abundance, size, and biomass, sight survey by naked eyes was carried out at each station. A plankton net was used to collect jellyfish samples and calculate their abundance. The researchers stood on the back deck when the ship stopped. Their eyes were about 4m above the sea surface, the furthest distance of observation was about 10m, the observation was maintained 30 minutes, and the number of surface multi-tube jellyfish within their visual range was measured and recorded. The results showed that the occurrence frequency of the dark green multi-tube jellyfish was 16% in all stations, mainly in the south coast of the East China Sea. During August 1 to September 30, 2011, the population abundances and distributions of three scyphozoan jellyfish species *Nemopelima nomurai*, *Cyanea nozakii* and *Aurelia aurita* were examined by visual observation twice per week by Wang Shiwei *et al.* The researchers divided the observers into two groups, standing on both sides of the bow of the survey ship, the speed of which was 6 knots. During the course of the voyage, a unit of time was set at 5 minutes, the total number of jellyfish observed in the field of vision was counted, and longitude and latitude were recorded synchronously.

The specific calculation method of average abundance of jellyfish was as follows: During the period of stopping for related visual verification, the results showed that in the visual range

of bow standing,  $W_0$  which could distinguish the jellyfish's biggest observed distance was 20m (10m each side). Assuming that the total voyage distance was  $D$ , then the total observed area was  $A = W_0D$ . If the total number of giant jellyfish observed was  $N_0$ , and the average abundance of this species during observation was  $M = N_0/A = N_0/(W_0D)$ . Because each observation route covered most of the water in the bay,  $M$  was used to represent the average abundance of jellyfish in the bay. According to the results, *Aurelia aurita* showed a trend of gradual decline.

The populations of both *Nemopelima nomurai* and *Cyanea nozakii* reached their peak on August 11, and declined successively at the end of August and the middle of September. At the end of September, three kinds of jellyfish had basically disappeared. At present, there are only two reports about using visual method to monitor jellyfish, which is still not widely used, possibly because the marine survey in China is mainly carried out by research ships. Most jellyfish surveys do not use visual methods because of its time limitations. Future studies are expected to be carried out on more ferry voyages and use visual methods to monitor giant jellyfish in a wider area of the ocean in order to collect more data.

Yang Dongfang *et al.* analyzed the application of new technologies (underwater photography, sonar imaging and aerial imaging) of jellyfish monitoring methods in recent years, and compared the advantages and disadvantages of various monitoring methods, which made a useful supplement for the comprehensive understanding of jellyfish monitoring methods. The advantage of underwater camera monitoring method was that it had high resolution and could reflect the movement behavior of jellyfish, and the temporal and spatial distribution, movement process and behavior performance of jellyfish could be recorded by underwater camera. Its disadvantage was that the field of vision was limited. In recent years, the underwater camera technology had been constantly improved in the process of development with the resolution and the scope of monitoring constantly expanding.

The advantages of the sonar imaging monitoring method included wide monitoring range, the ability to monitor both the horizontal and vertical distribution of jellyfish, and the ability to monitor in muddy or dim water. The disadvantages lie in low resolution, the inability to distinguish species from species, and the inability to reflect the movement of jellyfish. In recent years, a combination of acoustic and optical image has been developed for the quantitative detection of jellyfish. Aerial images, on the surface or near surface, can observe the distribution,

movement and behavior of giant jellyfish. Another advantage of aerial surveillance was that it could make these observations without disturbing the jellyfish.

### **(3) Jellyfish larva monitoring methodologies**

The above methods were basically for monitoring. For early larva of monitoring, especially the monitoring of fertilized eggs, larva, scyphistoma, ephyra and other small individuals, it was more difficult. The traditional method mainly collected samples through the nets or water samples, and then have these samples classified by morphology identification.

However, the early stage of jellyfish was small, and it was difficult to identify species under the microscope, so molecular biological biomarkers are being developed to identify the early stage of jellyfish in recent years. For example, molecular methods for early detection of *Aurelia aurita* have gradually been established and perfected. Wang Jianyan *et al.* chose specific molecular markers and designed specific primers to establish a molecular probe test method of *Aurelia aurita* which could test a large number of network or samples attached to the substrate directly, quickly and conveniently. However, this method was limited to the qualitative and semi-quantitative research of *Aurelia aurita*. If we combined it with real-time fluorescent quantitative PCR technology, a new method of rapid qualitative and quantitative analysis for *Aurelia aurita* to study the behavior of *Aurelia aurita* in the early growth stage can be established. Liu *et al.* also reported the rapid detection of several development stages of cyanobacteria by the method of strong specificity and sensitive ring mediated isothermal amplification. Zhang Fang *et al.* have established the combination of quantitative PCR, the ribosome/mitochondrial gene PCR amplification high-throughput sequencing (metabarcoding), FISH and other molecular biology technology and diving in situ observation, quadrat investigation, training experiment and other basic biological methods to develop and establish a reliable method for the detection of tiny jellyfish. They have acquired several data. In addition, the outdoor habitat of giant jellyfish can be studied and monitored, and the seasonal and inter-annual changes of polyp population dynamics in the found habitat can be monitored using Scuba diving, underwater robot and other methods.

The number of jellyfish in coastal waters has increased under the comprehensive influence of global warming and eutrophication of seawater, and jellyfish blooms are showing an upward trend. Jellyfish blooms can not only cause serious losses to the local economy and ecology, but

also has a serious impact on coastal tourism. The frequent outbreaks of jellyfish disasters have seriously threatened the service functions of marine ecosystems and are alarming for our offshore ecosystems. In-depth study of jellyfish disasters, mastering the law of its occurrence, exploring the conditions for its formation, and establishing an early warning and forecasting system for jellyfish disasters are conducive to preventing the occurrence of jellyfish disasters and providing effective technical support during disaster emergency response.

### **2.2.2 Relevant Policy**

“The specification for marine monitoring Part 6: Organism analysis” and “Specifications for oceanographic survey Part 6: Marine biological survey” are two criteria for monitoring in China. “Contingency plan of jellyfish disaster: Qinhuang Island bathing beach”, “Contingency plan of jellyfish disaster: coastal waters in Qingdao”, “contingency plan of jellyfish disaster -- Xiamen bathing beach” were carried out. Several programs: “Operational application of monitoring and warning technology of jellyfish disaster and demonstration research in the typical waters”, “Progress on studying jellyfish bloom, and mechanical and ecological environmental effects”, “Formation mechanism, monitoring and prediction, and technology of evaluation and prevention of jellyfish disaster in China” were started.

# 3. Jellyfish Monitoring using Ferry Boat in the Yellow and Bohai Seas

## 3.1. RO Korea

### 3.1.1. Introduction

Since the bloom of *Nemopilema nomurai* in 2003 in the Yellow Sea, intensive monitoring in Korean waters were undertaken and their source were suggested to be off Changjiang River, northwestern East China Sea (ECS), and advected into the southeastern Yellow Sea (YS) and Southern Sea of Korean peninsula, and, passing through Korea/Tsushima Strait, into the East Sea (Kawahara et al., 2006; Yoon et al., 2008; Yoon et al., 2014). Collections of early developmental stages of *N. nomurai* at southwestern YS (Toyokawa et al., 2012; Sun et al., 2015) had proved off Changjiang River as source of *N. nomurai*.

In 2007, a set of trawl data at a transect from the South YS to near the tip of Shandong Peninsula was gathered and analyzed (Chang, 2018) and revealed that individuals of *N. nomurai* from the South YS were bigger than ones from near SP. Similar observation was made by Sun et al (2015). Later, Dong (2018) reported capture of metaephyrae of *N. nomurai* in the inner coastal area of Liaodong Bay (LiB), Bohai Sea (BS) in May, 2005, providing that LiB was one of the sources. They postulated in addition that *N. nomurai* population in LiB accomplished their life cycle there, and that a very small portion of them advected into the YS.

Abundance and distribution of *N. nomurai* in the BS and North YS were studied previously by Uye et al. (2010) and Takao et al. (2012) by sighting method onboard of ships of opportunity, and Zhang et al. (2012), Wang et al. (2013) and Dong et al. (2018) by fishing net. Yoon et al. (2014) and Sun et al. (2015) analyzed *N. nomurai*'s population structure of the YS, and suspected advection of *N. nomurai*'s population of the BS into the YS. Such advection is likely taking place considering previously reported water currents in those seas (Guan, 1994; Naimie et al., 2001; Xia et al., 2006; Chen, 2009): entering current into the BS through northern Bohai Strait (BoS), exiting current from BS through middle and southern BoS into northwestern South YS, seasonally varying their direction and intensity.

This current should affect *N. nomurai*'s spatiotemporal distribution in the BS and induce advection into the YS. And, this advection, if exist, should increase population size of *N. nomurai* of the YS as a result of mixing with population produced at off Changjiang River mouth. Such advection due to water current was previously reported for population of *N. nomurai* of the northern ECS (Yoon et al., 2008); Changjiang Diluted Water entrained *N. nomurai* produced at off Changjiang River mouth into the waters of the southwest coast of the Korean peninsula, and then into the Yellow and East/Japan Seas. Such advection of jellyfish by water current was not studied yet for jellyfish produced in the BS.

Therefore, we undertook monitoring of *N. nomurai* from July to October, 2018 in the BS and northern YS using sighting method onboard of ships of opportunities to follow their monthly geographical distribution, and to test a hypothetical advection from BS into YS, taking into account of previously described current patterns in those seas.

### 3.1.2. Materials and Method

Monitoring of *N. nomurai* using sighting method onboard of cargo-ferry boat was made 5 times from July to October, 2018 for an area expanding from northern YS to BS. Regular cargo-ferry boats were used: from Incheon, Korea Yantai, China and from Bayuquan, China to Incheon, and from Incheon, Korea to Qingdao, China. A Chinese domestic ferry boat from Yantai to Dalian was also used (Tab. 3). Southeastern YS was also visited.

Sighting was performed for 10 m width of sea surface (Fig. 27). The width was evaluated with trigonometric function (Fig. 28). Before cargo-ferry boat left dock, best spot as nearest as possible to the bow was selected, and height of the spot from sea surface (h) was measured with laser rangefinder (GLM 50C Professional, Bosch, Germany, Fig. 29). After boat set sail at a constant speed, angle (a) from the spot to the edge of foam (fw) was measured with digital goniometer (Fig. 28) that gave  $fw = \tan(a) \times h$ . Considering fw plus 10 m of jellyfish monitoring width (mw),  $\tan(b)$  was calculated, and used to estimate the mw with goniometer. This foam and monitoring widths were checked 2 or 3 times during cruise.

From sunrise to sunset or from departure to arrival at port, every distinguishable *N. nomurai* were counted at every 5 min. and their size were estimated and grouped at 4 categories (<30 cm, 30-60 cm, 60-90 cm, and >90 cm). Pieces of *N. nomurai*'s umbrella were also counted.



On occasion, *C. nozakii* and *R. esculentum* were counted. Transparency, which is one of the most restraining factors of sighting method, could not be measured, but was likely varied from ca. 15 m in offshore to ca. 0.5 m in the coastal area of LiB. GPS logger (Garmin Montana, USA, Fig. 29) was used to record geographical position and GMT every 30 sec., and later used in calculating distance covered by boat for 5 min. The distance between positions was calculated with “Approximate Formula II” of “Geographical Distance Calculations (<https://www.scribd.com/document/37837953/Distance>)”, and with mw, surface and abundance of *N. nomurai* (inds. ha<sup>-2</sup>) were calculated.

Table 3. Itinerary and date of jellyfish monitoring

Itinerary	Date			
	July	August	September	October
Incheon-Yantai	19-20	2-3/25-26	13-14	7-8
Yantai-Dalian	21	4/27	15	9
Bayuquan-Incheon	23-24	6-7/30-31	17-18	11-12
Incheon-Qingdao	25-27	7-9/26-28	11-13	10-12

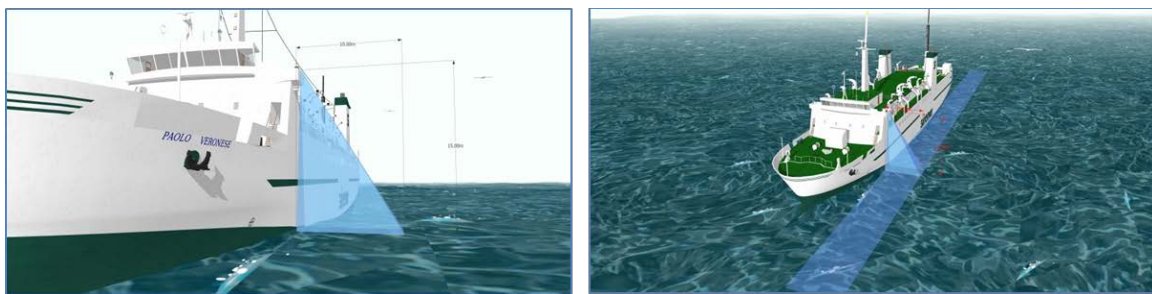


Figure 31. Measurements of height, angle and width of jellyfish monitoring

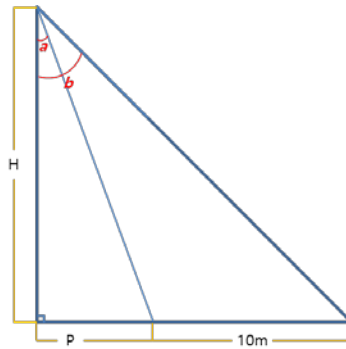


Figure 32. Trigonometric function that was used in calculating jellyfish monitoring width



Figure 33. From left to right, rangefinder, GPS and goniometer

### 3.1.3. Results and Discussion

Monitoring lines were divided into 11 sectors (Fig. 28) taking into account of geographic location and current systems to follow monthly geographical distribution and temporal density variation of *N. nomurai*: Korean coastal sector (Sec. 1), northeastern South YS (Sec. 2), northern South YS (Sec. 3), southwestern North YS (Sec. 4, composed of 2 lines), Bohai Strait (BoS, Sec. 5-1 for southern, 5-2 for middle, and 5-3 for northern BoS), outer eastern LiB (Sec. 6), inner eastern LiB (Sec. 7), central northern YS (cnYS, Sec. 8), central northwestern YS (Sec. 9), and Chinese coastal sector (Sec. 10). Sectors of BoS were designated as an area between a line from the southernmost end of the Liaodong Peninsula to northernmost end of the Shandong Peninsula, and ferry line from Yantai to Dalian (Tab. 3). Final sector 11 was southeastern YS (Mokpo-Heugsan do-Hatae do-Gageo do).

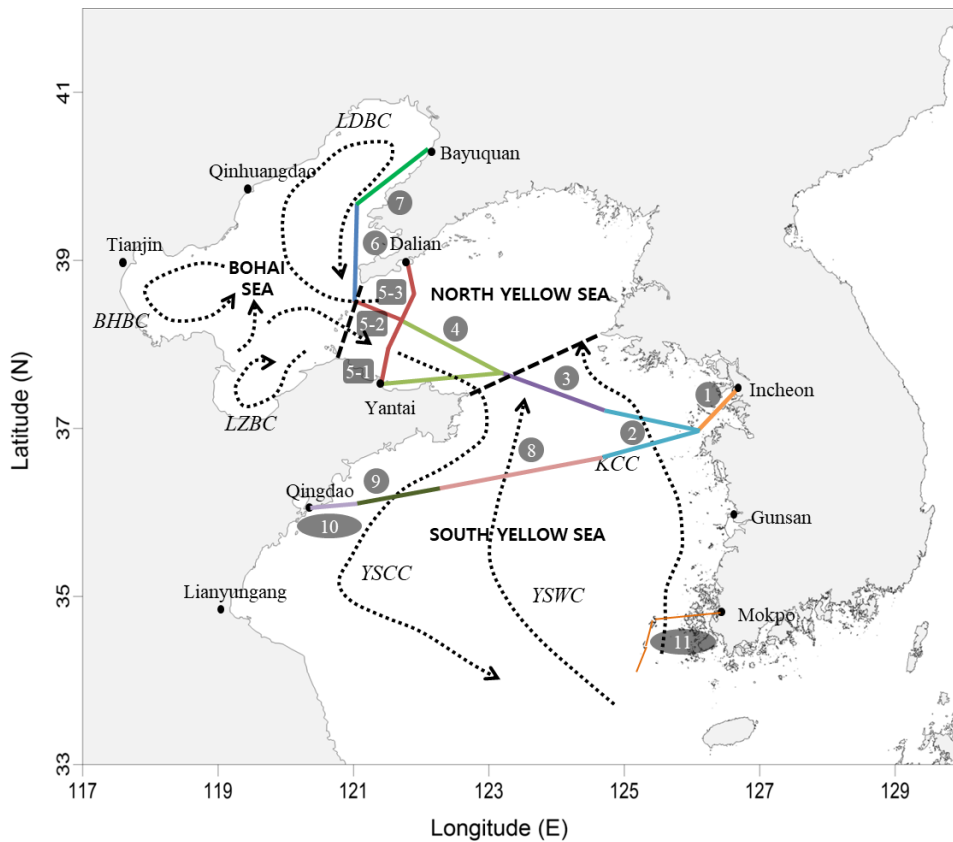


Figure 34. Jellyfish monitoring area with sectors represented by colored lines. Broken lines indicate boundaries between North and South YS, and between YS and BS. Dotted lines represent current in summer in the BS (redrawn from Zhao et al., 1995) and YS (redrawn from Hwang et al., 2014): LDBC, Liaodong Bay Circulation Current; BHBC, Bohai Bay Circulation Current; LZBC, Laizhou Bay Circulation Current; KCC, Korean Coastal Current; YSCC, YS Coastal Current; YSWC, YS Warm Current (in winter).

### 3.1.3.1 Abundance and size structure of *N. nomurai*

In July, *N. nomurai* were most abundant in the Sec. 7 followed by Sec. 5-2 and Sec. 7 (Fig. 31). This spatial abundance pattern indicates i) source of *N. nomurai* is inner Liaodong Bay (Sec. 7), ii) they advect into the YS through central area of BoS (Sec. 5-2), and iii) other population of *N. nomurai*, presumably from off Changjiang River, advect into the off Qingdao.

Size structures at these 3 sectors were depicted in figure 30, and reveals that those of Secs. 7 and 5-2 are similar but different from that of Sec. 10. Sec. 7 was divided equidistantly into 7 sub-sectors, more deeply analyzed and depicted in figure 31. It is likely that size structure

divided into two at Sec. 7-4 where individual < 30 cm were the least abundant, whereas toward the inner (Sec. 7-1) and outer LiB (Sec. 7-7) portion of the small individuals is increasing. This might indicate that the source of *N. nomurai* found in the LiB is not the inner coastal area (Dong et al., 2018) but outer LiB. This speculation needs to be verified with more rigorous dataset of jellyfish monitoring in the whole LiB. No dead *N. nomurai* were observed.

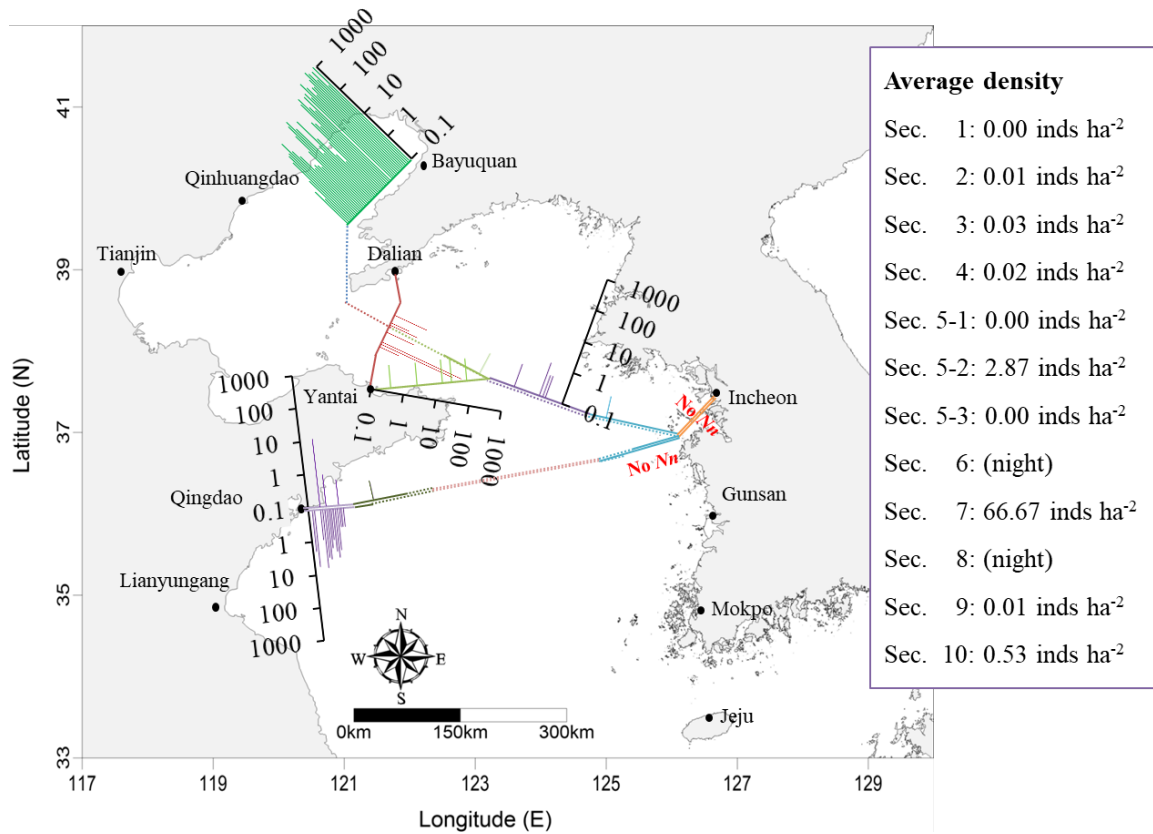


Figure 35. *N. nomurai*'s abundance in the northern YS and BS in July.

Solid cruise lines indicate daytime visit and dotted line nighttime visit.

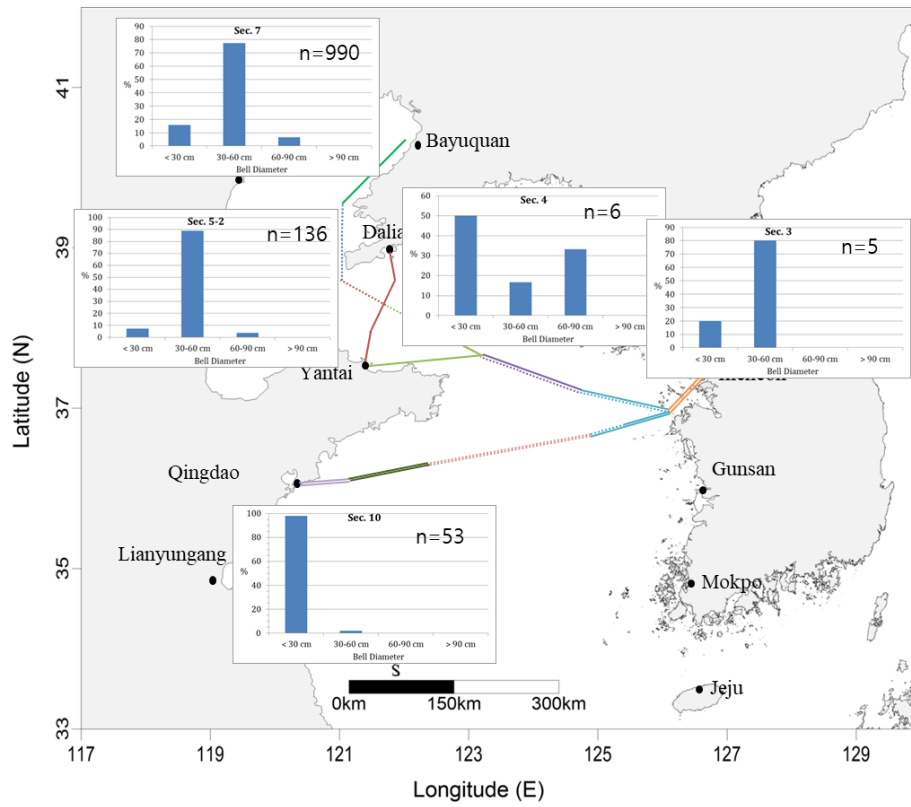


Figure 36. *N. nomurai*'s size structure in the northern YS and BS in July.

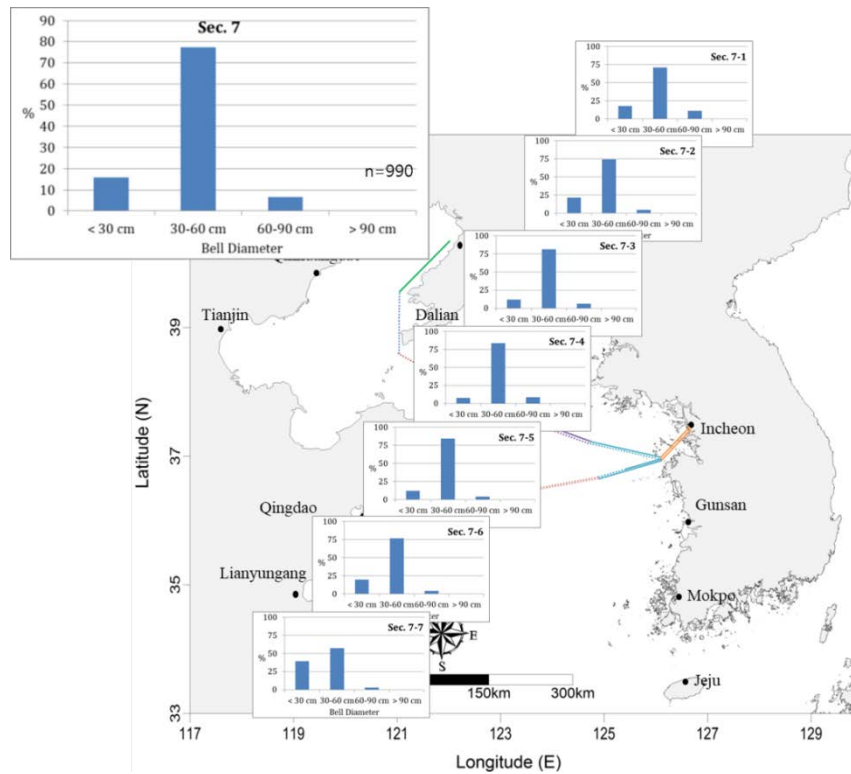


Figure 37. *N. nomurai*'s size structure at Sec. 7 (inner eastern Liaodong Bay) in July.

In the beginning of August, highest abundance of *N. nomurai* was at Sec. 7, which was decreased about 60% compared to that of July. Decreases were also observed at Secs. 10 and 3. Increase, however, was recorded at BoS (Secs. 5-1, 5-2, 5-3, 4, 2, and 1. Increase was remarkable at Sec. 5-2, about 200%, and at Sec. 4 about 3600 %, compared to that of July. (Fig. 34). This might indicate that population of *N. nomurai* in the LiB was already in decreasing state in this period, and that the decrease was in part due to advection of a portion of the population through BoS (Sec. 5-2) and northern SP (Sec. 4). Appearance of *N. nomurai* in the eastern YS (Secs. 1 and 2) should be due to northward drifting of a population issued from Changjiang River (Yoon et al., 2018).

Size structure of *N. nomurai* of this cruise was depicted in figure 35. It showed that individuals at Sec. 7 were small and medium-sized, whereas individuals in the outer LiB (Sec. 6), BoS (Secs. 4) and northern SP (Sec. 5-2) were larger than 30 cm. This finding reinforces that *N. nomurai* population of the LiB advects into the YS through BoS and circumvents SP. However, it shows no indication about how many individual or portion of the population of *N. nomurai* of the BS enter into the YS. This should be considered in future study to clarify the

impact of *N. nomurai* bloom of the BS to the YS. Size structure at 3 subsectors of Sec. 7 (Fig. 36) also indicated difference among subareas that should be clarified in future studies. Dead *N. nomurai* were observed only at 2 sectors with non-negligible abundance (Fig. 37).

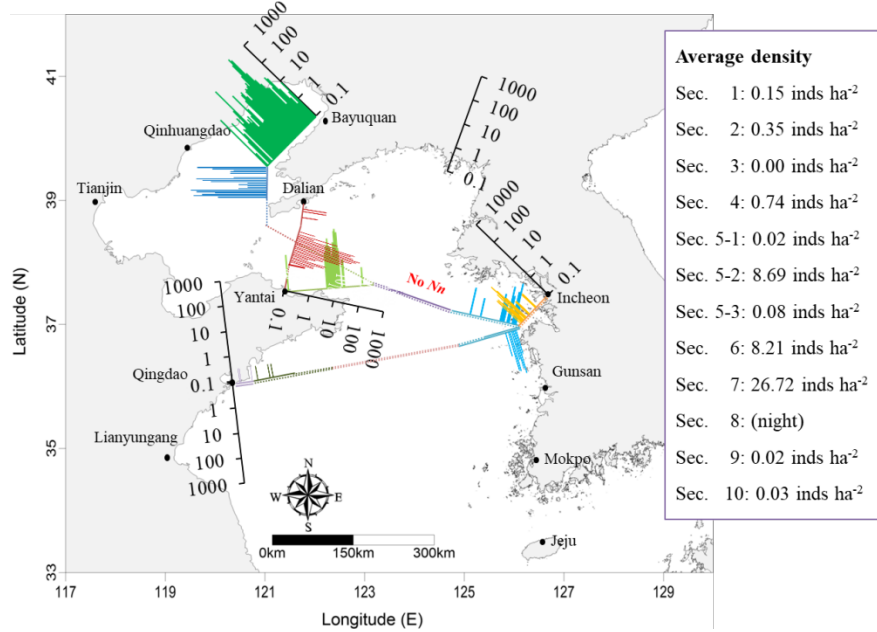


Figure 38. *N. nomurai*'s abundance in the northern YS and BS in the beginning of August

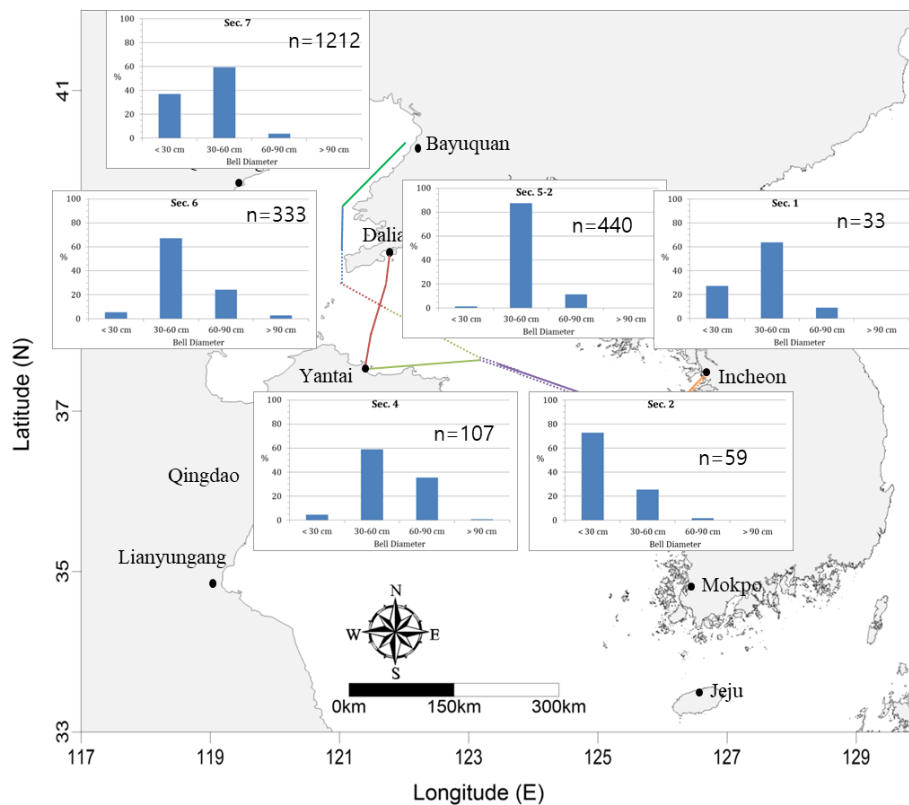


Figure 39. *N. nomurai*'s size structure in the northern YS and BS in the beginning of August

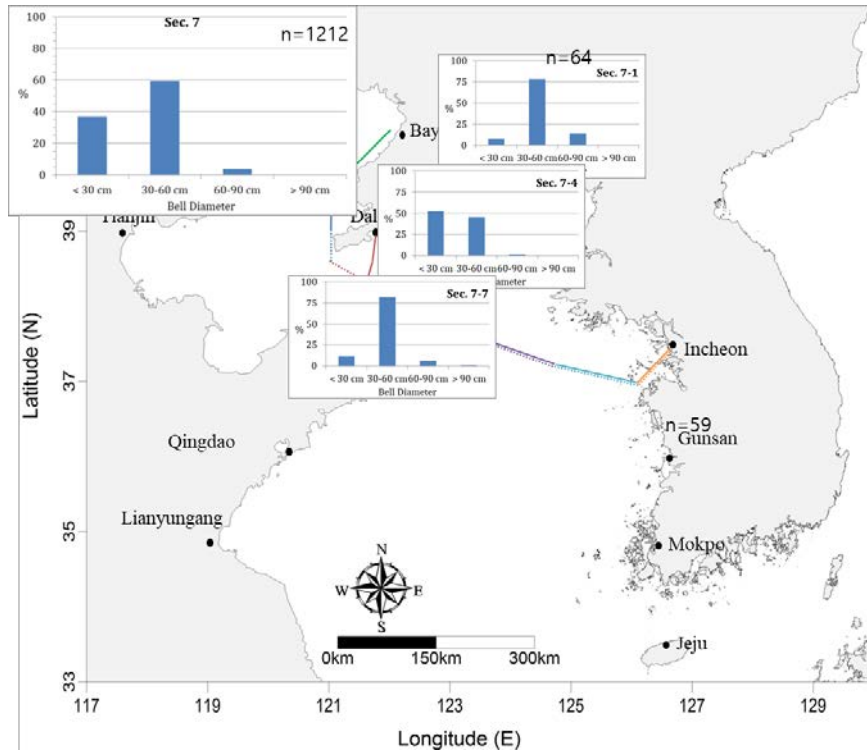


Figure 40. *N. nomurai*'s size structure at Sec. 7 in the beginning of August



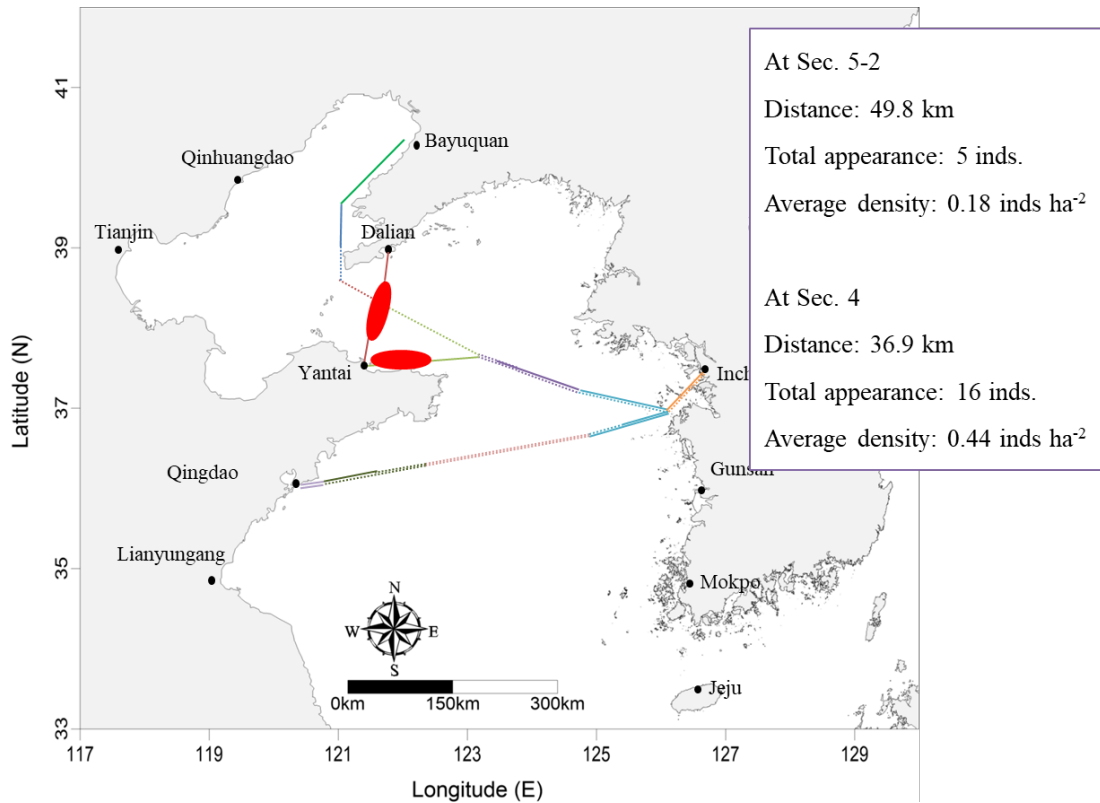


Figure 41. Dead *N. nomurai*'s abundance in the beginning of August

In the end of August, abundance of *N. nomurai* at Sec. 7 was the highest (Fig. 38), followed by Sec. 4 and Sec. 5-3. Compared to abundance at the beginning of August (Fig. 34), increase of abundance in the latter two sectors was remarkable, being 347 % and 3912 %, respectively for Sec. 4 and Sec. 5-3; decrease was recorded only at Sec. 5-2. It is also noted that *N. nomurai* were occurred in the whole BoS, which was not observed in the previous monitoring cruise.

*N. nomurai*'s size in the end of August was all bigger than 30 cm (Fig. 39). Only in 2 areas (southern BoS, Sec. 5-1; eastern YS, Secs. 1, 2) individuals smaller than 30 cm appeared.

Dead individuals were recorded at 3 sectors (Fig. 40). It is noteworthy that they are only found in the innermost eastern coastal are of LiB (inner half of Sec. 7), and in the whole BoS, and in the northern SP.

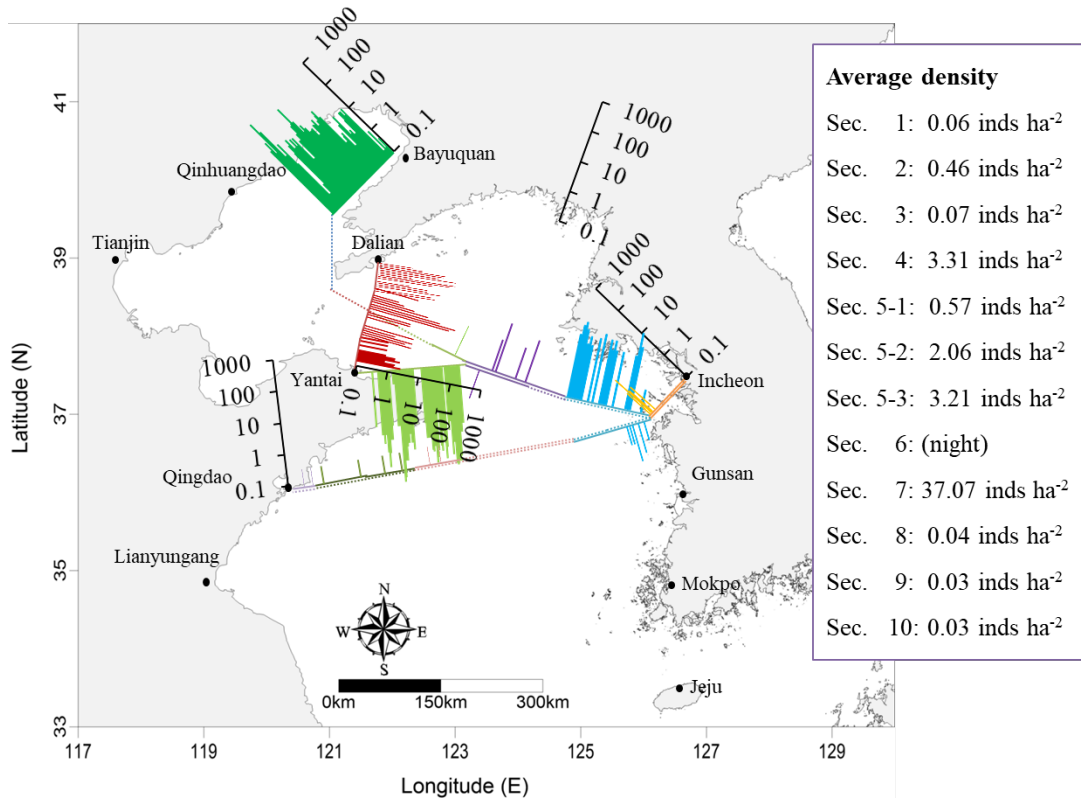


Figure 42. *N. nomurai*'s abundance in the northern YS and BS in the end of August

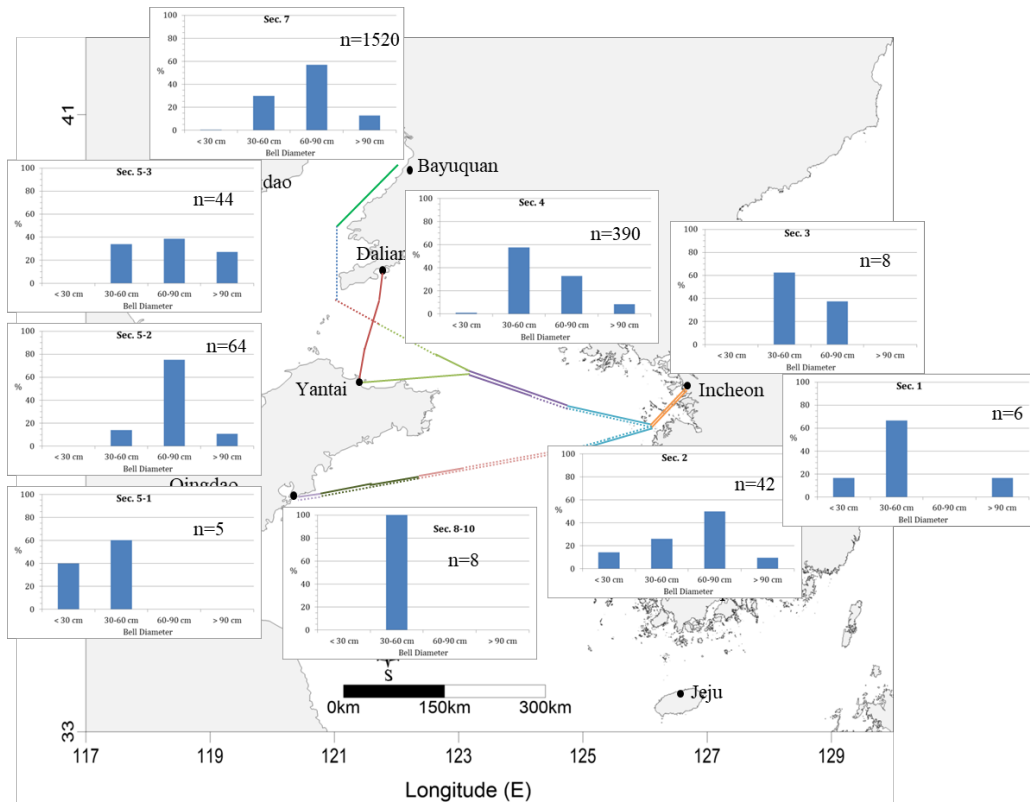


Figure 43. *N. nomurai*'s size structure in the northern YS and BS in the end of August.

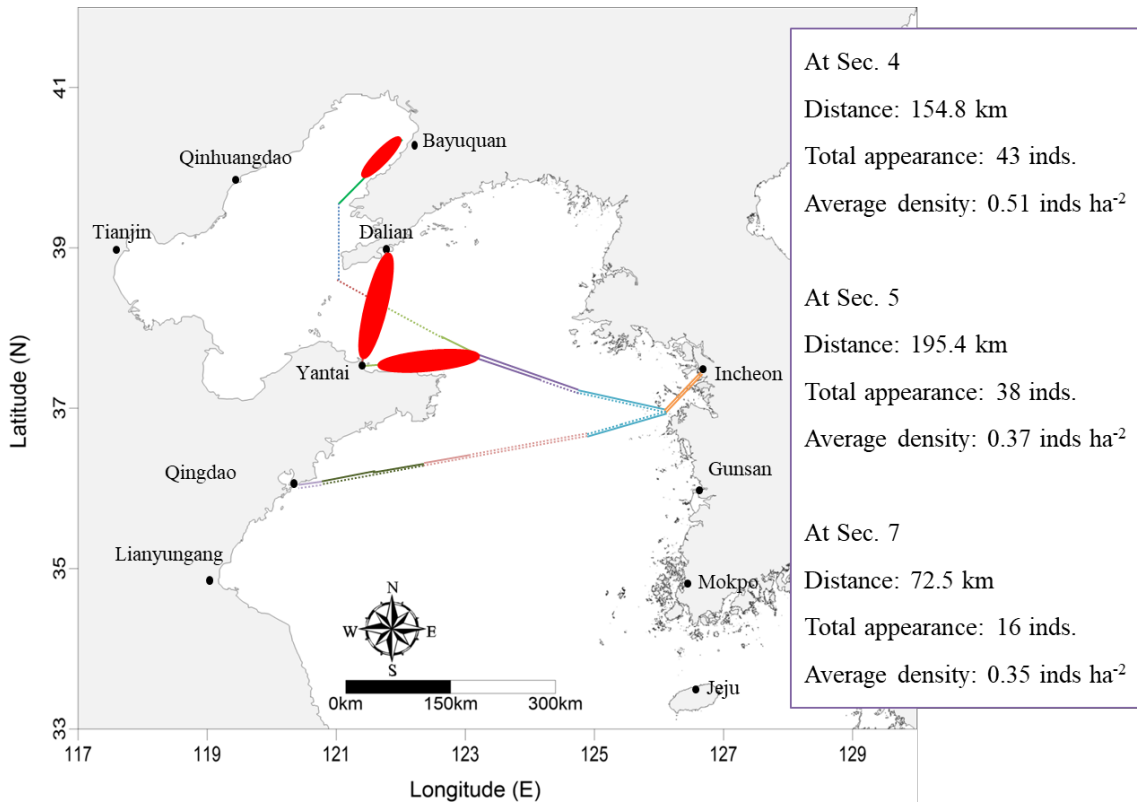


Figure 44. Dead *N. nomurai*'s abundance in the end of August

In September, *N. nomurai* were observed in all monitoring areas (Fig. 41) but with decreased abundance, compared to that of August, notably in areas of BS (Secs. 5, 7) and southwestern North YS (Sec. 4). Increases were recorded in the eastern (Secs. 1, 2), central (Sec. 8), and western YS (Sec. 9). Appearance area in the BoS was shrunken into the center (Sec. 5-2).

Size of *N. nomurai* was all >30 cm except that of Sec. 7 (Fig. 42). Dead *N. nomurai* was observed in areas of BS and southwestern North YS (Fig. 43). Compared to the end of August, appearance area was shrunken at Sec. 4 and 7.

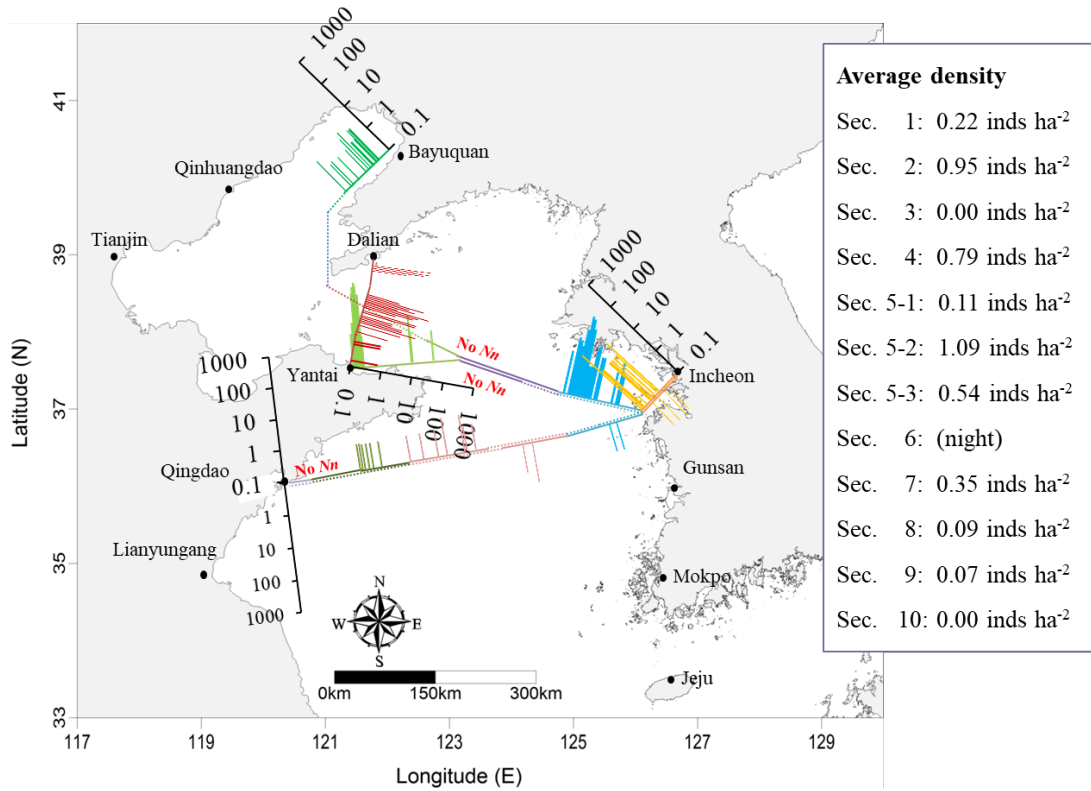


Figure 45. *N. nomurai*'s abundance in the northern YS and BS in September

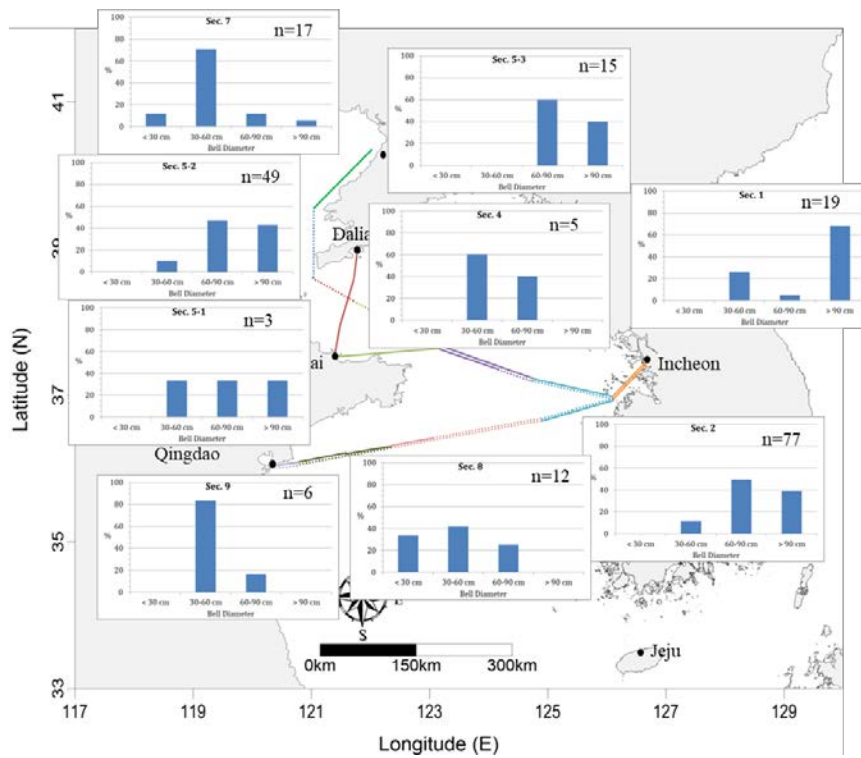


Figure 46. *N. nomurai*'s size structure in the northern YS and BS in September.

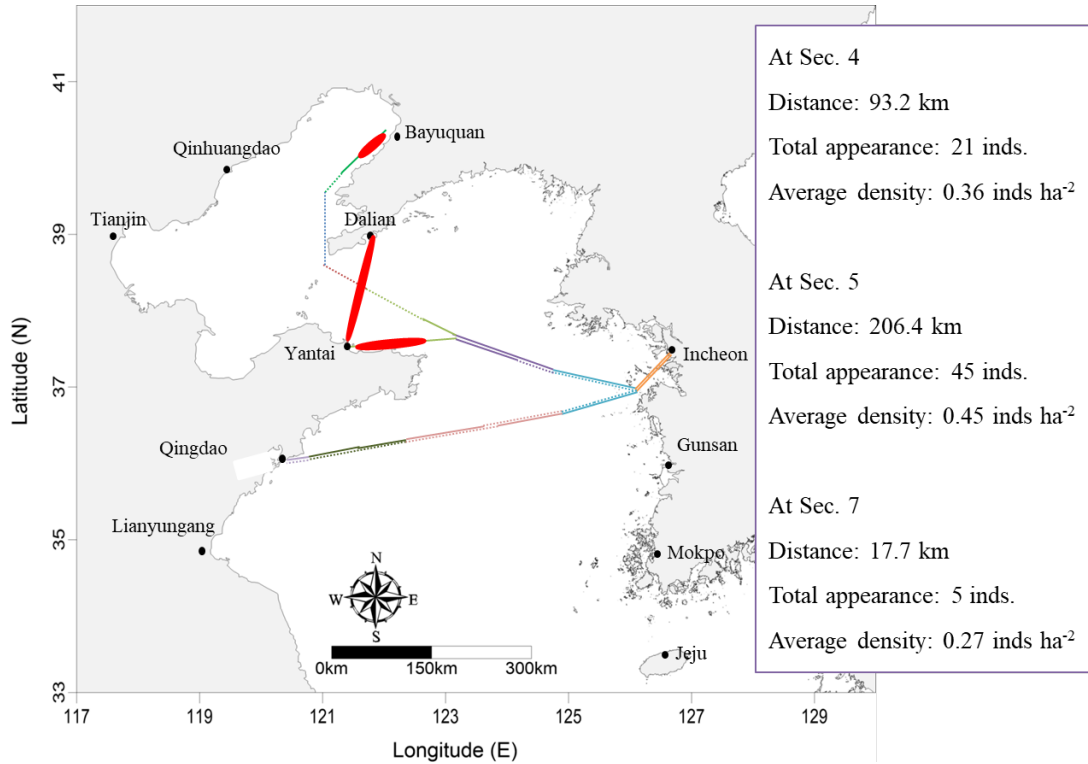


Figure 47. Dead *N. nomurai*'s abundance in September

*N. nomurai* in the monitoring areas in October were nearly disappeared with density always  $<0.1$  inds. ha<sup>-1</sup> (Fig. 44). Densities at the boundary between South and North YS (Sec. 3), and northern BoS (Sec. 5-3) were relatively high compared to other areas. An area of southeastern YS, Mokpo, Heugsan do, Hatae do, and Gageo do line was monitored in mid-October and at the beginning of November for *N. nomurai*'s appearance but revealed none of them. Dead *N. nomurai* were observed only at the innermost coastal area of LiB (Sec. 7) and in the middle of BoS (Sec. 5-2) in small quantity (Fig. 45).

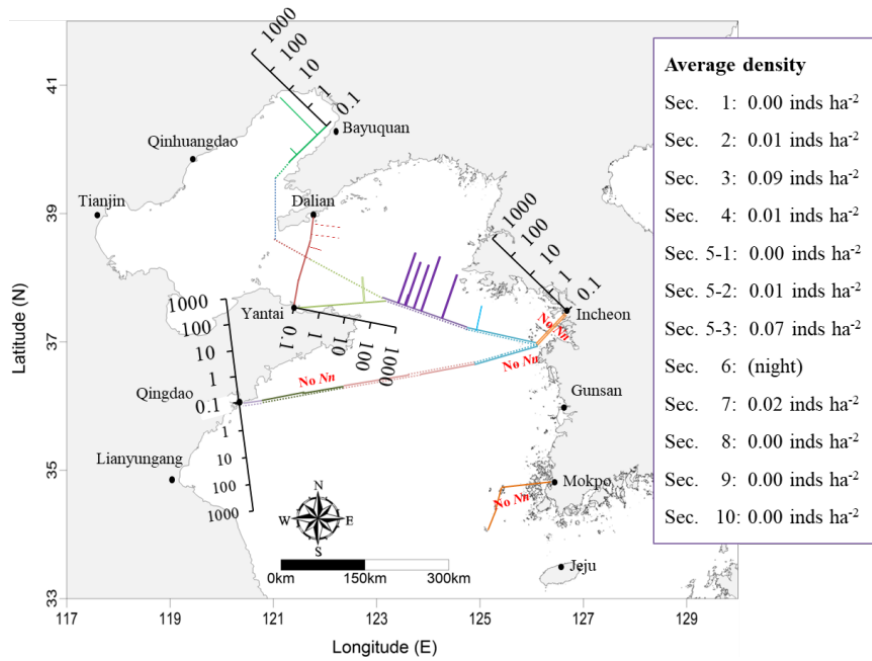


Figure 48. *N. nomurai*'s abundance in the northern YS and BS in October

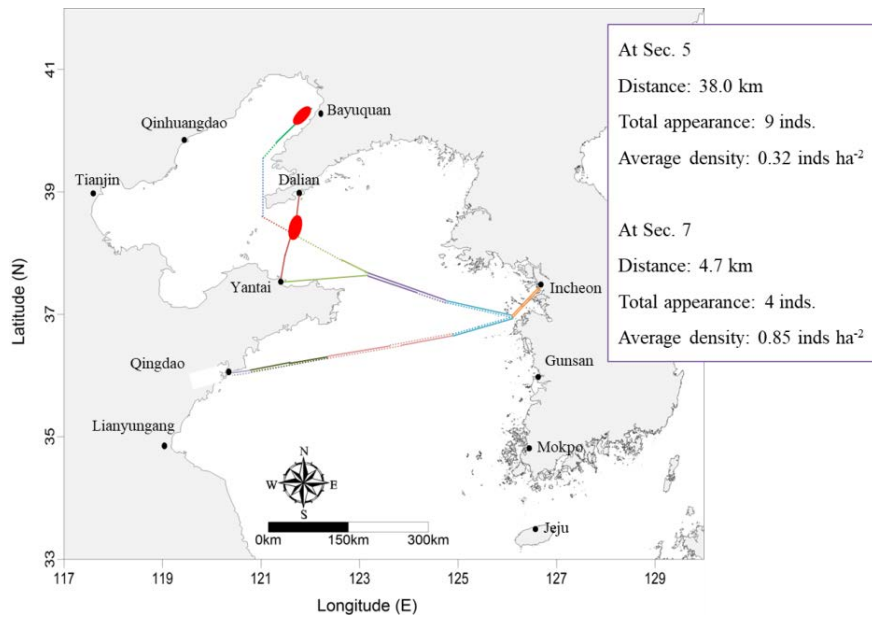
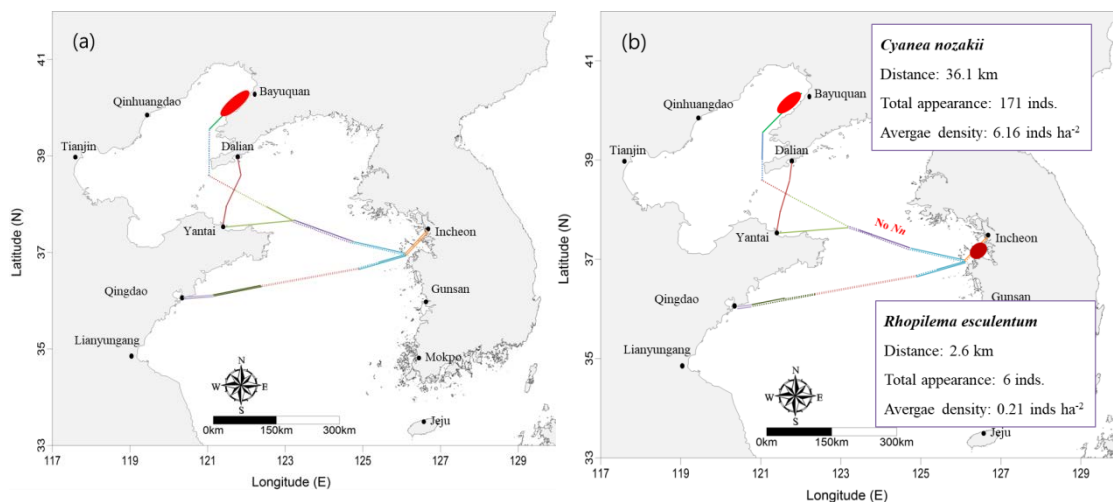


Figure 49. Dead *N. nomurai*'s abundance in October

### 3.1.3.2 Abundance of *Cyanea nozakii* and *Rhopilema esculentum*

Highly venomous and famous jellyfish predator, *C. nozakii* appeared in the inner eastern coastal area of LiB (Sec. 7) since from the beginning until the end of jellyfish monitoring (Fig. 46). It was noted that their abundance was restricted in that sector and was not found at all in other sectors, and that in area occupied by *Cyanea*, *N. nomurai* were rare. This might indicate a predator-prey relation between them, which should be taken into account if population dynamics of *N. nomurai* as well as its cause of disappearance are to be investigated. For this species' highly venomous feature, attention should be paid for their eventual advection into YS and into the Korean coastal waters.

On the contrary to *C. nozakii*'s distribution, *R. esculentum*'s distribution was totally restricted to the eastern coastal area of mid-YS (Sec. 1) from July to August. Its abundance was very low, up to 0.27 inds. ha<sup>-1</sup>.





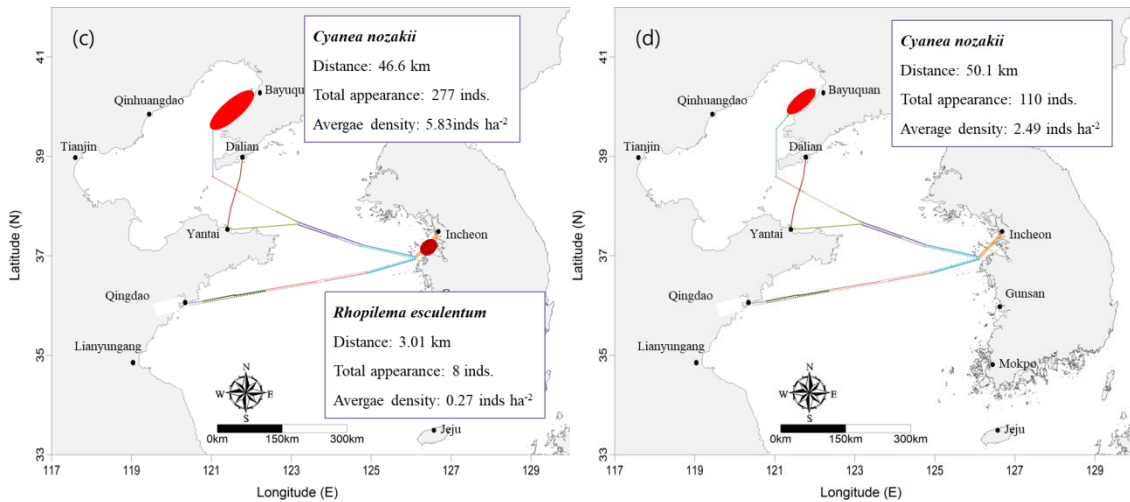


Figure 50. *C. nozakii* and *R. esculentum*'s appearance in July (a), beginning of August (b), September (c), and October (d)

### 3.1.4. Conclusion

Jellyfish abundance was monitored in 11 sectors encompassing eastern Bohai Sea, Bohai Strait, and Yellow Sea. *N. nomurai* appeared since the beginning to the end of monitoring with decreasing trend along with monitoring time. Their peak was in the inner eastern coastal area of Liaodong Bay, indicating that that bay is one of the sources of *N. nomurai*. Their size structure varied along with monitoring time and might imply that the source is not the innermost coastal area as suggested previously. Decrease of Liaodong Bay's *N. nomurai* abundance accompanied with increase of that in Bohai Strait. In this aspect spatiotemporal variation in abundance in the Bohai Strait was remarkable; *N. nomurai* were only in the center of the strait in July, extended their appearance area into the whole Bohai Strait in August, and reduced in the succeeding months. This is likely indicate that population of *N. nomurai* advects out of the Liaodong Bay, passes through Bohai Strait, and circumvent northern Shandong peninsula, as suggested by Yoon et al. (2018). Variation in size structures in these areas supports this view.

However, neither the exact source of *N. nomurai* nor the amount of *N. nomurai* population out of the Liaodong Bay, or the area of convergence with population coming from off Changjiang River could be estimated or determined because of limited spatial coverage of monitoring area; whole Bohai Sea including Bohai Bay and Laizhou Bay, and southern Yellow Sea should be covered in future study to make the objectives possible.

*C. nozakii* were only appeared in the inner Liaodong Bay, and their abundance might be related with that of *N. nomurai*. *R. esculentum* were only observed in the eastern mid-Yellow Sea, indicating a source nearby.

Sighting method onboard of ferry boat is at present the best candidate among monitoring methods, for it is most available and easiest method requiring short time, and less personnel and budget than any other conventional monitoring methods. With regular jellyfish monitoring and with more accurate estimation of size, dynamics of *N. nomurai* population in the Yellow Sea as well as in Bohai Sea could be clearly understood. Model study is strongly required to elucidate path and evaluate impact of *N. nomurai* bloom in those seas.

## 3.2. PR China

### 3.2.1 Introduction

Sight survey was rarely reported and was only done by research ships rather than by ferry boats in China. Wang Yantao *et al.* observed a bloom of jellyfish (*Aequorea* spp.) during a comprehensive investigation in the Yellow and East China Seas in April 2011. In order to illustrate the geographical variations in abundance, size, and biomass, sight survey by naked eyes was carried out at each station. A plankton net was used to collect jellyfish samples and calculate their abundance. The researchers stood on the back deck when the ship stopped. Their eyes were about 4m above the sea surface, the furthest distance of observation was about 10 meters, the observation was maintained 30 minutes, and the number of surface multi-tube jellyfish within their visual range was measured and recorded. The results showed that the occurrence frequency of the dark green multi-tube jellyfish was 16% in all stations, mainly in the south coast of the East China Sea.

During August 1 to September 30, 2011, the population abundances and distributions of three scyphozoan jellyfish species *Nemopelima nomurai*, *Cyanea nozakii* and *Aurelia aurita* were examined by visual observation twice per week by Wang Shiwei *et al.* The researchers divided the observers into two groups, standing on both sides of the bow of the survey ship, the speed of which was 6 knots. During the course of the voyage, a unit of time was set at 5 minutes, the total number of jellyfish observed in the field of vision was counted, and longitude

and latitude were recorded synchronously. The specific calculation method of average abundance of jellyfish was as follows: During the period of stopping for related visual verification, the results showed that in the visual range of bow standing,  $W_0$  which could distinguish the jellyfish's biggest observed distance was 20m (10m each side). Assuming that the total voyage distance was  $D$ , then the total observed area was  $A = W_0D$ . If the total number of giant jellyfish observed was  $N_0$ , and the average abundance of this species during observation was  $M = N_0/A = N_0/(W_0D)$ . Because each observation route covered most of the water in the bay,  $M$  was used to represent the average abundance of jellyfish in the bay. According to the results, *Aurelia aurita* showed a trend of gradual decline. The populations of both *Nemopelima nomurai* and *Cyanea nozakii* reached their peak on August 11, and declined successively at the end of August and the middle of September. At the end of September, three kinds of jellyfish had basically disappeared. At present, there are only two reports about using visual method to monitor jellyfish, which is still not widely used, possibly because the marine survey in China is mainly carried out by research ships. Most jellyfish surveys do not use visual methods because of the time limitations of visual methods. Future studies are expected to be carried out on more ferry voyages and using visual methods to monitor giant jellyfish in a wider area of the ocean in order to accumulate more data. In order to make up for the vacancy of related research in China, we carried out the sight survey on jellyfish monitoring experiment on the ferry boat, and discussed the variation of jellyfish abundance in the monitoring area and the feasibility of the method.

### 3.2.2 Materials and method

Two experimental studies on visual jellyfish monitoring were conducted on the ferry boat from Dalian to Yantai on 14 and 15 August 2018. Our method was modified from sight survey using ship according to Yoon *et al* (2018). We chose a place of jellyfish monitoring and measured the height ( $H$ ) from the sea surface to the place of monitoring using laser rangefinder or tapeline, or string with marked meters. After setting sail, we turned on GPS to record geographical position and time. During the cruise at a steady speed of the ship, we used goniometer to measure the angle between the ship and the foam. The width of foam ( $P$ ) was estimated using a formula:

$$P=H \cdot \tan (a)$$

And angle b was calculated to keep the sighting angle:

$$\tan (b) = (P+10) / H$$

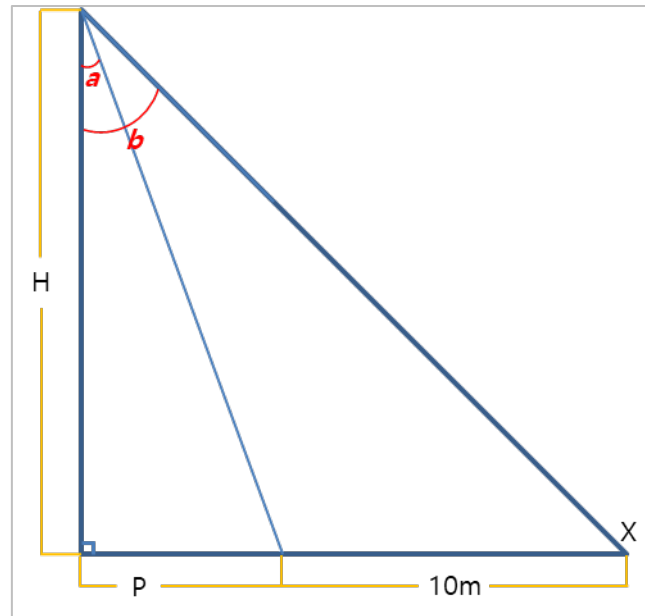


Figure 51. The calculation diagram of sight survey

The number of jellyfish was counted at 5-minute's interval from departure to arrival at port. After the cruise, we calculated the 5-minute distance (from GPS data) and the density of jellyfish.

### 3.2.3 Results and discussion

Due to the poor sea conditions from Yantai to Dalian on August 15, the visibility was undermined, only a brief counting experiment was conducted. This study only processed the results of voyage from Dalian to Yantai. The route map and jellyfish abundance from Dalian to Yantai was shown in Fig 52. We only observed two kinds of jellyfish during our entire voyage of 89 nautical miles. The results showed that the abundance of *Aurelia aurita* in the offshore sea area was relatively high, the abundance of jellyfish in the offshore sea area of Yantai reached  $1.65 \times 10^{-2}$  ind/100m<sup>2</sup>. The average abundance within the entire voyage was  $3.28 \times 10^{-4}$  ind/100m<sup>2</sup>. The number of *Nemopelima nomurai* was low, the distribution in the whole area was average, and the average abundance within the entire voyage was  $4.25 \times 10^{-5}$  ind/100m<sup>2</sup>.

During the process of jellyfish monitoring by visual method, compared with the results of

previous studies in different international areas, the overall abundance of jellyfish was not high, and the individuals were mainly in the coastal waters, which may vary from different monitoring seasons. Our monitoring time is in the middle of August, and the jellyfish has gradually begun to die out. It was found that the overall abundance of *Aurelia aurita* was higher than that of *Nemopelima nomurai*, which was mainly due to its relatively high abundance nearshore, and the distribution of *Aurelia aurita* was mainly concentrated nearshore, while the distribution of *Nemopelima nomurai* decreased nearshore, mainly appearing in the open sea.

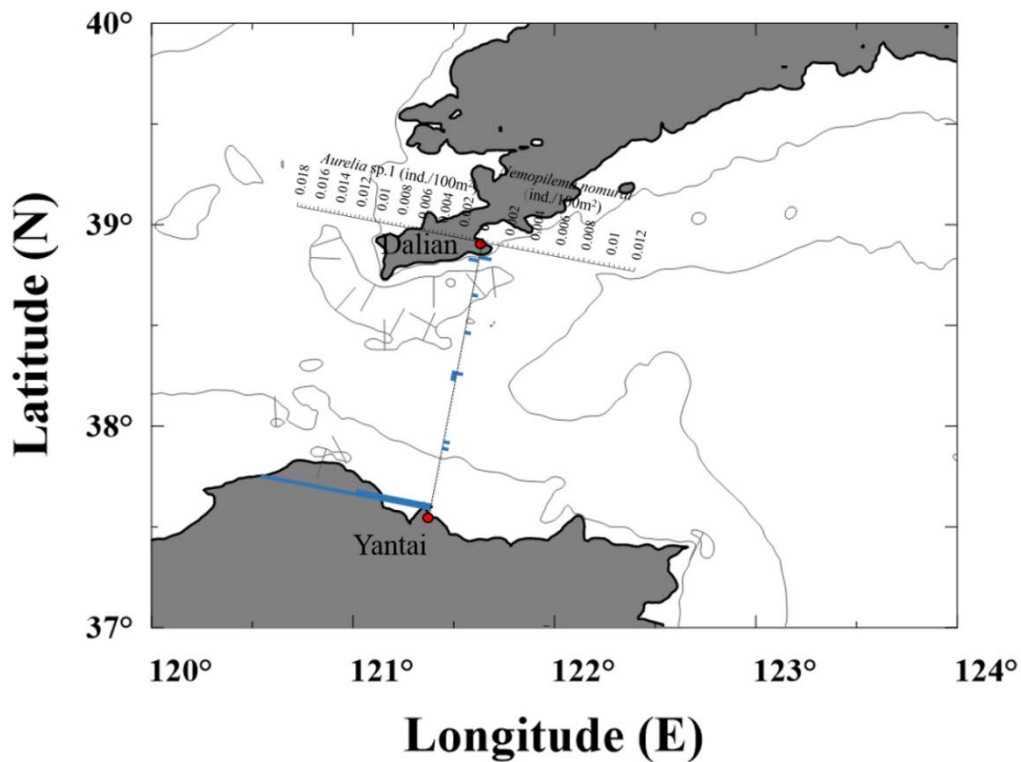


Fig 52. Route map and jellyfish abundance from Dalian to Yantai

Sight survey was firstly carried out on the ferry boat to evaluate the abundance of jellyfish in Yellow Sea. This method has better applicability for the monitoring of giant jellyfish in the offshore waters. It was cheaper than monitoring on research vessel, but its application was subject to weather. It had a good application prospect to monitor the giant jellyfish appearing in the surface layer. The evaluation of this method may underestimate the abundance of jellyfish, but for the purposes of monitoring, it can be extended appropriately for horizontal comparison of large scale different regions.

### 3.2.4 Conclusion

The ferry boat set off from Dalian to Yantai on August 14, 2018. The abundance of giant jellyfish was estimated in the navigation area by visual method. The average abundance of *Aurelia aurita* and *Nemopelima nomurai* were  $3.28 \times 10^{-4}$  ind/100m<sup>2</sup> and  $4.25 \times 10^{-5}$  ind/100m<sup>2</sup> respectively. The *Aurelia aurita* mainly concentrated near the shore, while *Nemopelima nomurai* was mainly distributed in the open sea. Visual method is an appropriate method for large-scale jellyfish monitoring, which can be popularized as a long-term monitoring method, and the variation of jellyfish abundance can be illustrated by comparing between different sea areas.

## 4. General Conclusion and Recommendations

### 4.1. RO Korea

Scientific programs on jellyfish bloom in Korea have started 2004 and followed by policy making programs in 2006. Through multiple programs of more than 15 years, *Aurelia aurita*, one of the 2 bloom-forming jellyfish, such scientific information, data and knowledge were gathered to understand their blooming mechanism and its impact on marine ecosystem as well as their ecological and physiological features. Based on this research results, central government have initiated polyp searching, monitoring and removal in whole Korean coastal areas, and revealed polyp removal as an efficient and effective means in controlling *A. aurita*'s outgrowing population, i.e. bloom.

*Nemopilema nomurai* are another bloom-forming jellyfish, highly venomous, massive in volume and heavy in weight. Their life cycle, ecological and physiological features, and impact on ecosystem as well as on fisheries are well understood. However, their blooming mechanism, population dynamics in source area, drifting paths in the Yellow Sea, and their yearly abundance fluctuation are vaguely understood. This is due to the fact that the sources are in Chinese coastal waters: off Changjiang River of northwestern East China Sea and inner coastal area of Liaodong Bay of Bohai Sea.

Drifting path, one of the above mentioned 'must-do's of *N. nomurai*, is an absolutely required research item to reduce or prevent damages due to their blooms, and is tackled in this program of 'jellyfish monitoring using ship of opportunity'. We monitored 11 sectors in the eastern Bohai Sea, Bohai Strait, and Yellow Sea. Variation in spatiotemporal distribution and abundance of *N. nomurai* were clear: inner Liaodong Bay was the source, and abundance was maximal in July and declined thereafter; decline in abundance in Liaodong Bay was accompanied with increase of that in the Bohai Strait and northern Shandong peninsula; variation in appearance and abundance in the eastern and western Yellow Sea was likely disconnected with those of Bohai Sea.

However, neither the exact source of *N. nomurai* nor the amount of *N. nomurai* population out of the Liaodong Bay, or the area of convergence with population coming from off

Changjiang River could be estimated or determined because of limited spatial coverage of monitoring area; whole Bohai Sea including Bohai Bay and Laizhou Bay, and southern Yellow Sea such as off Changjiang River, area between Shanghai and Lianyungang, and area between southwestern Korean peninsula and Shanghai should be covered in future study to make this objectives possible.

Sighting method using ship of opportunity is at present the best one among monitoring methods, for it is most available and easiest method requiring short time, and less personnel and budget than any other conventional monitoring methods. This method should be adopted as standard one for YSLME jellyfish monitoring because of above-mentioned reasons, regularly applied for other areas that would help to understand the exact drifting paths of *N. nomurai*.

The 5 eventual causes favoring jellyfish blooms were not properly tackled by Korean and/or Chinese government. Reduction and/or prevention of jellyfish blooms would only be possible if two countries government take actions against the jellyfish blooms causes. One of the immediate actions is polyp removal, for its immediate effect in controlling jellyfish bloom. For this reason exact source of *N. nomurai* should be determined, which could be assessed by jellyfish monitoring using ship of opportunity combined in close and successive manner with systematic survey on the area where juveniles are massively appeared. Once the exact source determined, their polyps could be removed by the method of ‘underwater jet’ developed by Korean researchers. Another cause, climate change, is the most threatening since it would change ecosystem structure and function, and entrain and/or favor jellyfish, highly venomous or blooming, invaders in Korean and Chinese waters. This invasion and drifting could be also monitored by using of ship of opportunity if they are distinguishable by naked eyes.

Korean and Chinese scientists and governments should work together to cope with the jellyfish blooms; sharing data and information would be the first step to go further, and joint jellyfish monitoring cruise the second, and making a joint report and countermeasure plan based on each country’s and joint cruise the third, and adoption of that countermeasure plan by two countries’ government the fourth and final. In this process, YSLME would be the most appropriate institution, and should play its important role as intermediate between two countries and between scientist and policy makers.



Related to this process, the first step that YSLME should take in view of jellyfish bloom is establishment of a committee that is composed of jellyfish experts and related public officials of two countries. All information, data, and opinions should be directed to, discussed in, and concluded by this committee in order to take the best available policy to reduce and/or prevent damages due to jellyfish blooms. YSLME should provide space and fund to this committee to fulfill their role. The second step is to organize a joint jellyfish monitoring cruise and later and in more systematic and multidisciplinary research cruise on areas that are suspected as sources of *N. nomurai*. The third step is, based on field multidisciplinary research cruise, to propose the best mean and way to control *N. nomurai* bloom.

Once get the required data proving that the Chinese coastal area or territorial waters are the sources of bloom forming jellyfish and that drifting path of those jellyfish affects seriously Korean marine ecosystem as well as its economy, Ministry of Ocean and Fisheries of RO Korea should engage, in collaboration with or without YSLME, in making countermeasure plan with Chinese government. For this purpose, existing scientific collaborations such as Korea Marine Environment Management Corporation - Institute of Oceanology, Chinese Academy of Sciences, or National Institute of Fisheries, Korea - East China Sea Fisheries Research Institute, Chinese Academy of Fisheries Sciences – Japan Fisheries Research and Education Agency, could be served as basis for developing such countermeasure plan in common. Other existing committee (Joint Committee of Korea-China Environmental Cooperation) would be also served for that purpose.

## **4.2. PR China**

One or two more trips (excluding Bohai Sea) are advised from China to be introduced from Dalian to Nagasaki (an alternative, Fukuoka) in August and September (Figure 53). There was only a ferry to Yantai or Weihai from Dalian, so we consider that the Yingkou station in the Bohai Sea should not be involved, and the route just end to Dalian in YS.

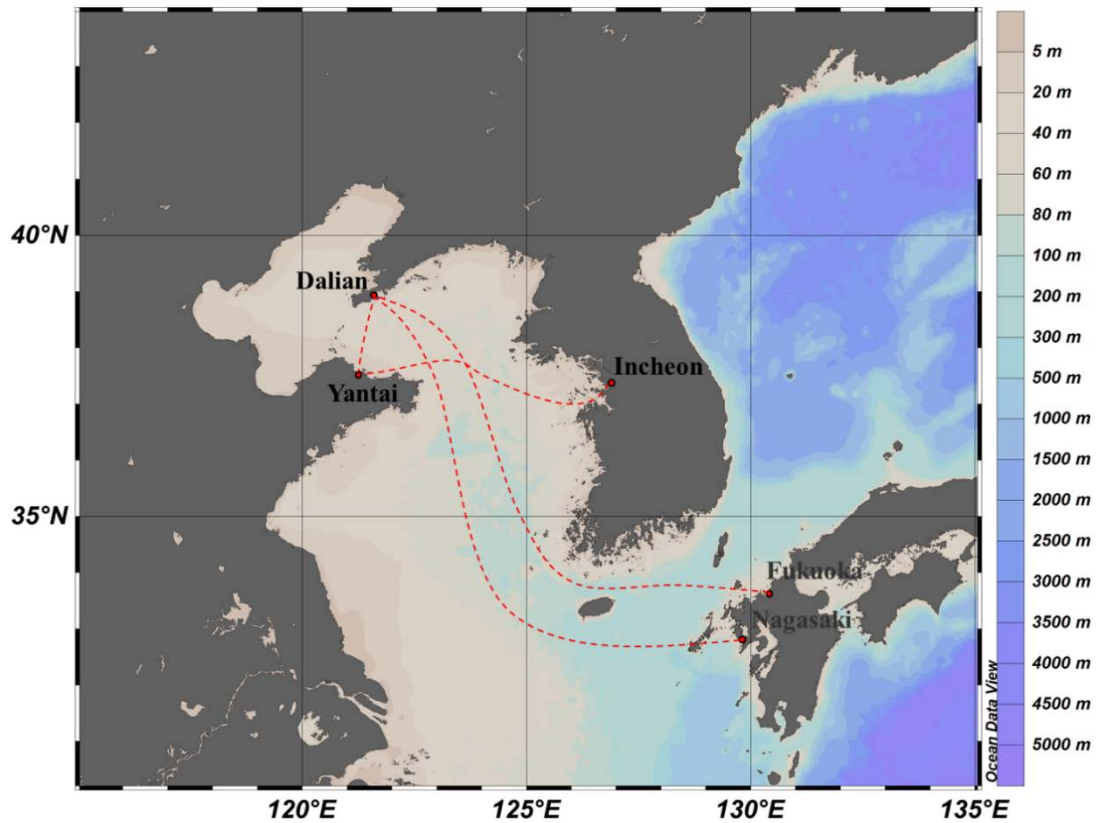


Figure 53. The sight survey route map in YS

We recommend that the anchor drift net is a better choice for medusa monitoring in coastal waters. Such net has been practically used for four years at adjacent regions to Hongyanhe by Guan Chunjiang *et al*, and the sampling proved to be effective. The working diagram of the anchor drift net is shown in Figure 54. The net is single-chip jellyfish anchor drift net, which is a kind of long band net consisting of rectangle net chip. The height and length of the net is 8.00 meter and 60.00 meter, respectively, the mesh is 10.00 cm. The direction of net chip and ocean current should be vertical, the net coupled with ocean currents should be drawn. The wall can catch jellyfish when the net is shocked by ocean currents. Such fishing trip is mainly distributed in Tangshan of Hebei Province, Jinzhou and Yingkou of Liaoning Province, Shandong and other coastal regions. The scale of anchor drift net varies largely, ranging from 30.00 to 90.00m, and such net is fit for fishing boat with 8.82~99.24kW. In addition, the anchor drift net can be applicable for wide fishing regions, where water depth ranges from 5 to 25m in Bohai Sea and coastal regions of Yellow Sea. Monitoring time is often at one-hour's interval. Sight survey is a good method, and we believe that the anchor drift net is a suitable revision of

other methods.

For net gear, species name, abundance and diameter for every species should be recorded. Monitoring results should be demonstrated by ind/(net.h), jellyfish number/(per net . per hour); or kg/(net.h), jellyfish weight/(per net . per hour).

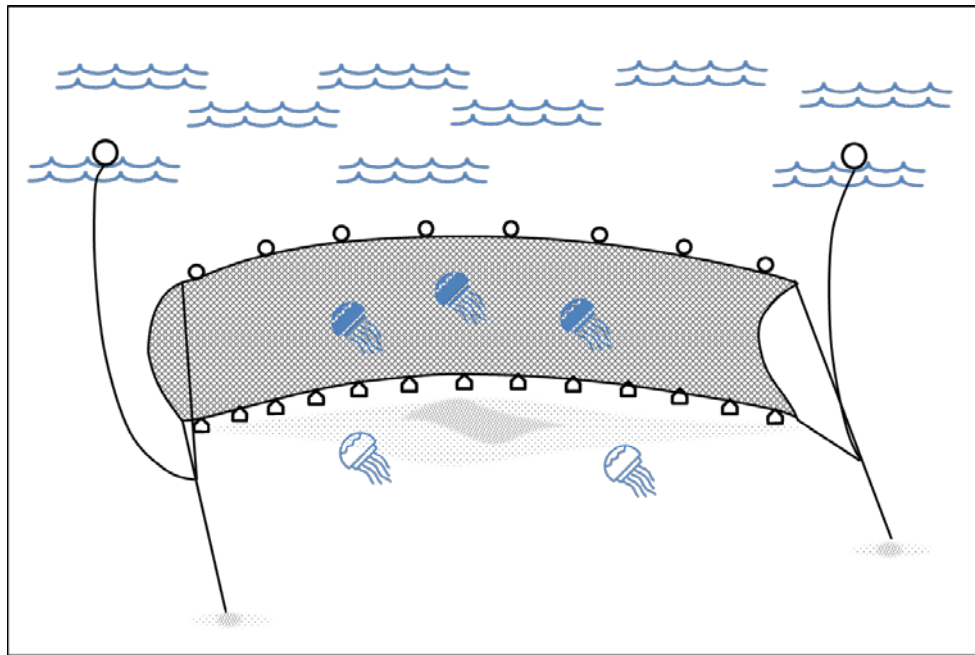


Figure 54. The working diagram of anchor drift net

We suggested that long-term jellyfish blooming demonstration monitoring areas in China and RO Korea could be established to provide guidance for the development of jellyfish monitoring program. For the Chinese side, some areas in southern of YS could be used as long-term demonstration monitoring areas to monitor through the shared voyage. The planned stations were shown in Figure 55.

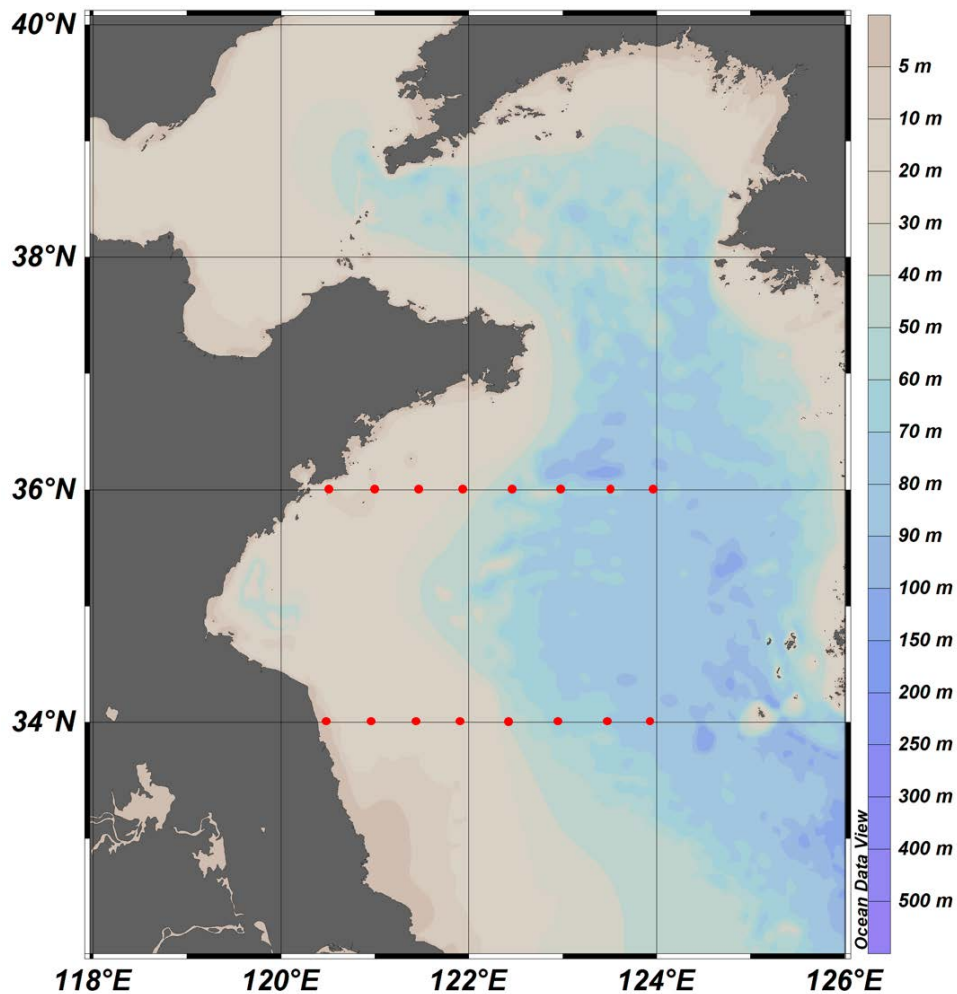


Figure. 55 The distribution of planned stations

The high biomass of jellyfish occurred between the sea of China and the Korean Peninsula: Bohai Sea, YS and the north coast of the ECS. Many places were potential headstreams for Korea, so we could not ensure the specific place and need to discuss deeply. Moreover, some researchers in Japan pointed out that the increasing temperature of the early summer caused polyp strobilates (the 2-3mm), which reached the coast of Japan along the current (weighing 100kg) (上真一, 2005). Jellyfish were mature in April every year along the north of the Yangtze River and reached to Japan along the warm current. They were always seen in Japan from September to December(益田玲爾, 2006). Besides, the density of jellyfish in the middle of the YS was higher than that in coastal waters according to the investigation of jellyfish larvae in the middle of the yellow sea in the ECS, which proved the possibility that the place where the jellyfish occur was offshore(河原正人, 2006). Some researchers considered that the source of

jellyfish in Korea is in the Bohai Sea, if so, are there some details about advection path and time?

A few ephyrae, metephyrae and juvenile medusae of this species first appear in China and Korea coastal sea areas in May and June. They first appear offshore of the Changjiang River, then are found successively in other northern sea areas: southwest of Cheju Island, the eastern coastal sea of Korea, the offshore of Gunsan, Korea. We suggested that some long-term monitoring stations or areas can be selected in Korea.

Once scientific confirmation was made on the sources of *N. nomurai* in the Chinese or Korean coastal area or territorial waters, on the drifting path of bloom forming jellyfish, and on the damages in Chinese and Korean marine ecosystem and their economy, both China and Korean should engage, in collaboration with or without YSLME, in making countermeasure plan with each other government. For this purpose, existing scientific collaborations between KOEM and Institute of Oceanology, Chinese Academy of Sciences, or among NIFS, East China Sea Fisheries Research Institute, Chinese Academy of Fisheries Sciences, and Japan Fisheries Research and Education Agency, and/or other joint committee such as Joint Committee of Korea-China Environmental Cooperation would be served for this purpose.

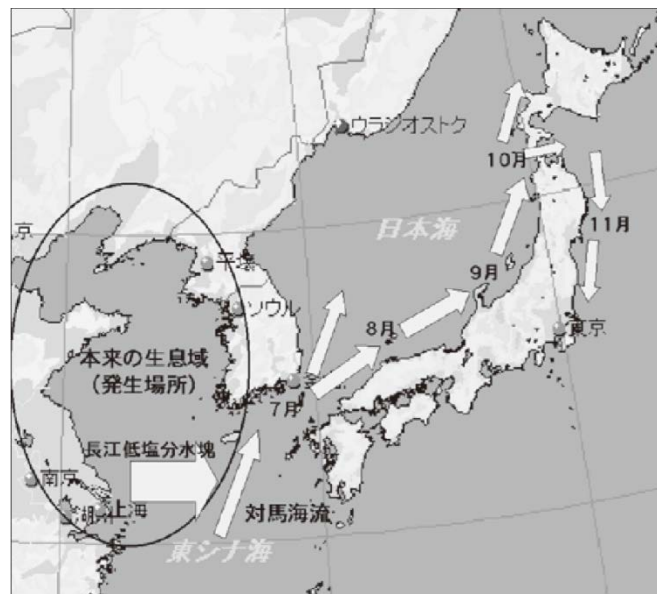


Figure 56. Drift path of *N. nomuri* in Japan(河原正人, 2006)

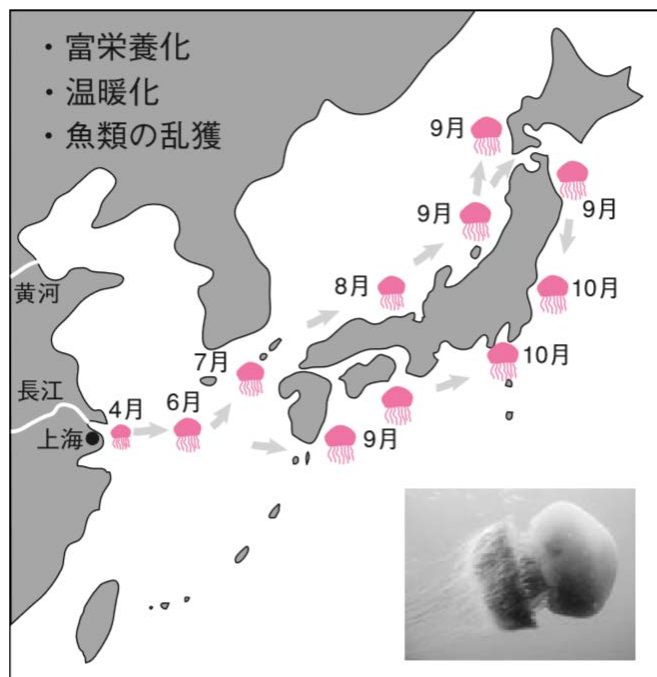


Figure 57. Drift path of *N. nomuri* bloom in Japan in 2005 (益田玲爾, 2006)

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