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Proceeding of the Second Coastal Environmental Assessment Workshop
11 September 2008 Toyama, Japan
Northwest Pacific Regional Environmental Cooperation Center

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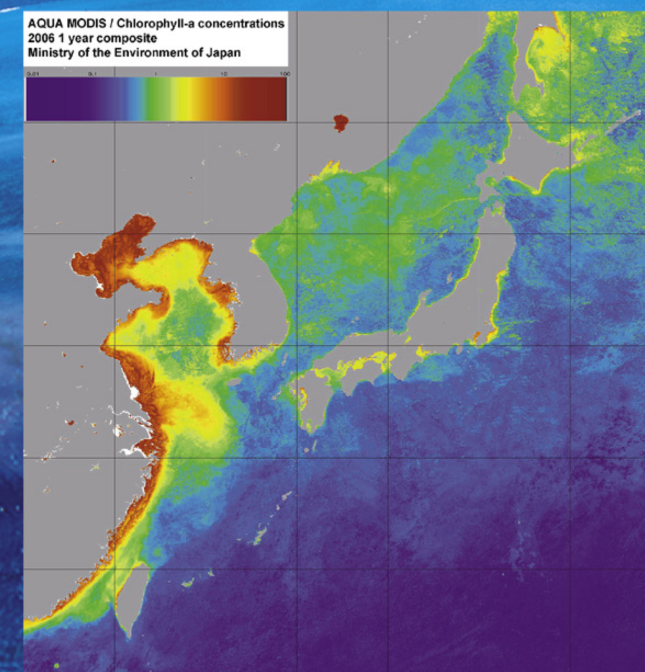

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The Remote Sensing Society of Japan

Toyama Prefecture

Toyama City

Yellow Sea Large Marine Ecosystem Project (YSLME)

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8:30-9:00	**Registration**
9:00-9:30	**Opening Ceremony**
9:30-11:00	**Keynote Speech**
11:00-11:30	***Coffee Break & Photo***
11:30-12:10	**Session 1**: Activities of NOWPAP Partners for Conservation of Coastal Environment
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14:00-15:20	**Session 2**: Interim Report of HAB Case Studies in the NOWPAP Member States
15:20-16:40	**Session 3**: Review of Procedures for Assessment of Eutrophication Status Including Evaluation of Land Based Sources of Nutrients for the NOWPAP Region
16:40-17:00	***Coffee Break***
17:00-18:00	**General Discussion**: Application of NOWPAP Procedures for Assessment of Eutrophication Status Including Evaluation of Land Based Sources of Nutrients in this Region

Keynote Speech

EUTROPHICATION ASSESSMENT OF COASTAL & MARINE WATERS - EUROPEAN APPROACHES -

Ulrich Claussen

German Federal Environment Agency

Eutrophication and its adverse effects in Northern Europe have been dealt with for more than two decades inter alia in the context of international conferences such as the North Sea Conferences, the Oslo-Paris Convention for the Protection of the North-East Atlantic (OSPAR) and the Helsinki Convention for the Protection of the Baltic Sea (HELCOM). Consequently, OSPAR and HELCOM decided to substantially reduce inputs of phosphorus and nitrogen into marine areas by 50 %. Furthermore, OSPAR developed a *Strategy to Combat Eutrophication* to achieve, by the year 2010, a marine environment where eutrophication does not occur. An integrated eutrophication assessment is undertaken by the OSPAR "Common Procedure" consisting of a set of assessment criteria allowing a holistic and harmonised assessment. The criteria cover all aspects of nutrient enrichment as well as possible primary and secondary effects. Based on the OSPAR approach, a pan-european activity has been launched to develop guidance for European water policy aiming at an integrated harmonised assessment of the eutrophication status for rivers, lakes, transitional, coastal and marine waters. HELCOM has started a thematic eutrophication assessment using the HELCOM Eutrophication Assessment Tool. In November 2007, HELCOM agreed on the Baltic Sea Action Plan which inter alia sets challenging national reduction targets for nutrient inputs into the Baltic Sea aiming at a status in 2021 latest, where eutrophication does not longer occur.

Environmental Management of Coastal Seas in Japan with Special Reference to Eutrophication Status, Environmental Standard and Utilization of the Sea

Osamu MATSUDA (Professor Emeritus, Hiroshima University)

Introduction to the coastal seas in Japan

In relation to the utilization of the sea, coastal seas in particular of enclosed coastal seas in Japan are very important for human activities since they provide calm sea condition that are suitable for developing urban area, industrial zone and recreational sites. Ports and harbors are often constructed in order to promote regional economic activities. These coastal waters are also important ground for coastal fisheries and aquaculture. Increased population and human activities brought more pollution loads to coastal seas, and consequently the water quality of coastal seas has degraded and many negative effects of eutrophication occurred. Reclamation from the shallow seas has often been carried out to support the increasing economic activities. Land reclamation has been often accompanied by destruction of seaweed beds, tidal flats and natural coastline. Corresponding to these changes above, the approach to the environmental management of the coastal seas firstly made emphasis on water pollution control. However, the approach has gradually shifted recently from water pollution control to the wider goal that includes the conservation of the biodiversity, biological productivity, restoring and ensuring the healthy hydrological cycle, well-balanced nutrient cycle, ensuring opportunities for people to contact with natural beaches and so on.

History of pollution and legal system

Serious water pollution and environmental deterioration in the coastal area of Japan occurred after the postwar reconstruction following World War II although some small scale water pollution and environmental destruction had already occurred before WWII. Rapid economic growth of Japan during the mid-1960s to mid-1970s was accompanied by serious water pollution and ecological disaster such as frequent occurrence of red tide. In 1967, the Basic Law for Environmental Pollution Control was enacted, and then in 1970, the Parliament passed a number of pioneering anti-pollution laws at the Diet nicknamed “Environmental Pollution Diet”. And then in the following year of 1971, the Environmental Agency was established.

The Seto Inland Sea, the largest and one of the most typical enclosed coastal seas in Japan, had suffered from serious pollution during the rapid economic growth when the sea was called “Dying Sea”, but has gradually recovered by struggling efforts of variety of groups and bodies with the strong support of legal treatment. In 1973, the Law on Temporary Measures for the Environmental Conservation of the Seto Inland Sea was enacted and this law was made permanent in 1978. This law has played a very important role on the environmental conservation of the area after that since area wide total pollution load control in terms of COD load control is one of the major mechanism of the law. This mechanism worked successfully and further countermeasures against eutrophication in terms of total nitrogen and phosphorus load control were also applied in the Seto Inland Sea. These measures are highly evaluated from the viewpoint of improvement of water quality.

In 1993, Basic Environmental Law was firstly enacted in Japan and Ministry of the Environment (former Environmental Agency) established in 2001. However, legal system related to coastal management has been still highly complicated due to many laws based on the individual objective of the utilization of the sea, for examples, land use, fisheries, mineral resources, marine traffic etc. These individual law system is actually controlled by the individual governmental sector, more directly, individual ministry. Also in 1993, a series of standards was enacted to prevent further chemical pollution of public waters. Environmental Quality Standards (EQS) relating to human health were greatly enhanced and strengthened, and environmental standard related to conservation of the living environment of sea was also enacted in order to prevent water pollution (pH, COD, DO, Coliform group number and n-hexane extract) and eutrophication (total nitrogen and total phosphorus) of the coastal area.

As a new type of the legal system, the Law for the Promotion of Nature Restoration was enacted in 2002, and the Special Law on Restoration of the Ariake and Yatsushiro Seas enacted in 2003. In these new type of laws, “Restoration” is the key word indicating the shift of the policy from water pollution control to promoting restoration. Ocean Basic Law was enacted in 2007 in which integrated coastal management (ICM) is one of the key concept. These new types of legal system are expected to play an important role on the future environmental management in the coastal area of Japan.

Non-legal approach for environmental management

1) “Health examination” of the coastal seas

“Health examination” of coastal seas is essential not only for diagnosis of the present status but also for planning of the treatment or environmental restoration. Since the present status of coastal seas in Japan is more or less "damaged" or "deteriorated" mainly due to prolonged impact of human activities, “health examination” was conducted in the officially designated 88 enclosed coastal seas and some additional areas in Japan following the proposed examination scheme based on the “Master Plan and Guideline (2002)”and “Concept and Method (2006)”. In these schemes, two major functions of marine ecosystem which are "ecosystem stability" and "smoothness of material cycling" are highlighted.

Although “health examination” of coastal marine environment is widely accepted as a concept of analogy to the human health examination, definition of marine environmental health and practical methodology of examination has not been adequately developed. As a new ecosystem approach to environmental management and monitoring, concept of “health examination” and scheme of “health examination” which consist of preliminary examination and advanced examination have been proposed as a part of the activities of Ocean Policy Research Foundation. In the present report, concept and scheme of “health examination” as well as outlined results of preliminary examination will be introduced.

2) **Creation of “*Sato Umi*”**

Recently new idea of the creation of "*Sato Umi*" is proposed. "*Sato Umi*" in Japanese, means coastal sea under the harmonization of sustainable wise use with conservation of appropriate natural environment and habitat conditions. Compared with deteriorated coastal environment, "*Sato Umi*" is able to provide higher biological diversity for habitat and higher biological productivity for living resources. These characteristics of "*Sato Umi*" are also suitable for demonstrating multi-functional roles of fisheries.

In order to establish functionally efficient "*Sato Umi*", development of new holistic approach for sustainable biological production and control of eutrophic level are strongly requested. Promotion of integrated environmental management towards environmental restoration of many varieties of habitat is recommended under the international exchange of information, ideas and methodologies. In this context, "*Sato Umi*" Session will be held in the international EMECS8 conference which will be held in Shanghai, China in October, 2008.

Conclusive remarks

As was already stated, the approach to the environmental management of coastal seas in Japan has gradually shifted recently from an initial emphasis on water pollution control to the wider goal that includes the conservation of the biodiversity, biological productivity, restoring and ensuring the well-balanced nutrient cycle etc. These holistic approaches may also play a vital role on the ICM.

As examples of these holistic approaches, concept and some related activities of "health examination" and "*Sato Umi*" are introduced. In Japan, "clean sea", from the viewpoint of only water quality, has already realized to some extent, although there are still some many water quality problems. Next target to be tackled with might be "biologically rich sea" with variety of living resources. In order to restore or create "biologically rich sea", idea of "health examination" and "*Sato Umi*" are expected to contribute.

Overall goal of environmental management in the next stage with use of assessment for eutrophication status and environmental standard might be "Better life through wise and sustainable use of coastal environments".

Current Status of National and International Oceanographic Database

Toru Suzuki
Marine Information Research Center, Japan Hydrographic Association

The oceanographic data and its related information are valuable resource, and then they should be shared and exchanged within marine and environmental science community. To promote and encourage the exchange of oceanographic data and information, the International Oceanographic Data and Information Exchange (IODE) of the Intergovernmental Oceanographic Commission (IOC) was established in 1961. The IODE system forms a worldwide service oriented network consisting of Designated national Agencies, National Oceanographic Data Centers (NODCs) and World Data Centers for Oceanography (WDCs), and IOC Member States have established over 60 oceanographic data centers in many countries in past 40 years. The network has been able to collect, control the quality of, and archive millions of ocean observations, and makes these available to Member States.

In Japan, the Japan Oceanographic Data Center (JODC) was established in the Hydrographic Department of Maritime Safety Agency (present Hydrographic and Oceanographic Department of Japan Coast Guard) in 1965 as a national marine data bank of Japan to fill the role of acquisition of oceanographic data and information obtained by marine research institutes and projects in Japan and providing these data and information to various users. In addition JODC is a leading oceanographic data center in the western pacific region. When the computer system was very expensive and there was no network connection, JODC digitized data and information from analog media such as documents and field notes, and formatted and stored in large mainframe computer and provide them by magnetic media such as magnetic tape and floppy disk. At the present the computer runs much faster and become small year by year, and the Internet is most widely used, then each marine research institutes and organizations establish Web site or database for provide their oceanographic data and information directly. The role of JODC, however, is yet more important because the purpose of data acquisition is not only providing users with these data but also avoiding lost or missing them by unexpected accidents, especially by natural hazard such as big earthquake or Tsunami in Japan. In other words the JODC also has a data backup function, therefore every marine research institutes and organization in Japan should consider submitting their oceanographic data and information to JODC for safety and long-term archive. Furthermore the Global Oceanographic Data Archaeology and Rescue (GODAR) project is promoted by IODE in order to increase the volume of historical oceanographic data available to climate change and other researchers by locating ocean profile and plankton data sets not yet in digital form, digitizing these data, and ensuring their submission to NODCs and WDC systems. In addition, data on electronic media that are risk of loss due to media degradation are also candidates for rescue. JODC supported the GODAR activities in the western pacific region in 2002-2006.

In the Internet age, it is needed to search an appropriate Web site or database server in various them in order to obtain some oceanographic data and information. Internet search engine, such as Google, is tremendously useful tool for all Internet users, and the result of search by keyword usually shows a great number of Web sites but not every site is necessary. To facilitate a search for required oceanographic data and information, an international network for data and information exchange using a Clearinghouse is being constructed. The Clearinghouse, developed by Federal Geographic Data Committee (FGDC), is a distributed system of servers located on the Internet which contain field-level descriptions of available digital spatial data and services. This descriptive information, known as metadata - data about data -, is collected in a standard format to facilitate query and consistent presentation across multiple participating sites. Clearinghouse allows individual institutes, organizations and communities to band together and promote their available digital spatial data through a metadata service. In the present, several sites in PICES (the North Pacific Marine Science Organization) Member Countries are registered in NSDI (National Spatial Data Infrastructure) Clearinghouse Network to provide marine ecosystem and other related metadata in the north pacific region supported by TCODE (Technical Committee on Data Exchange), one of PICES committees. Although the Clearinghouse Network functions as a detailed catalog service with support for links to data and browse graphics, the fundamental goal of Clearinghouse is to provide access to oceanographic data and related online service for data access and visualization. In addition the Global Change Master Directory (GCMD), operated by NASA, is also the metadata-base for oceanography and other sciences, and their information is compatible with FGDC metadata standard.

Session 1

Activities of NOWPAP Partners for Conservation of Coastal Environment

IOC/WESTPAC Ocean Remote Sensing Program
– Toward a satellite-based system of the Asian coastal marine environments

Hiroshi KAWAMURA
(Graduate School of Science, Tohoku University)
(Leader of the IOC/WESTPAC Ocean Remote Sensing Program)

The first remote sensing project of IOC/WESTPAC was "**Remote Sensing for Integrated Costal Area Management (ICAM) Project** (Leader: ***HUANG Weigen***)". In the WESTPAC-V (August 2002), it was reformed to be "**Ocean Remote Sensing Program** (ORSP, Leader: ***KAWAMURA Hiroshi***)". Terms of reference of the ORSP are as follows;

1) Promote of application activities using satellite observations in the WESTPAC region,
2) Conduct international remote sensing projects for better understanding of the WESTPAC region and development of applications, and
3) Contribute to the regional GOOS through the above-mentioned activities.

Under the ORSP, two projects started; one was "**New Generation Sea Surface Temperature Project** (**NGSST-P**, Project leader: ***KAWAMURA Hiroshi***)" and another was "**Red-Tide monitoring Project** (Project leader: ***HUANG Weigen***)". The Red-Tide monitoring project was terminated and joined to the new project "**Ocean Color Project** (Co-Leaders: ***ISHIZAKA Joji*** and ***AHN Yu-Hwan***) was established in 2005.

Since the establishment of NGSST-P, four NGSST meetings and one NGSST working group meeting were held in 2003-2005. Its strategic plan was made in 2003, mentioning that the regional cloud-free, gridded, digital, quality-controlled NGSST should have 1) Spatial resolution: 1km, 2) Temporal resolution: 6-hours, and 3) Coverage: NEAR-GOOS region, then extended to the southern WESTPAC region. It was recognized that the regional high-resolution SST products need to deal with the diurnal SST variations explicitly. The NEARGOOS has established NGSST-Working Group, and its first meeting was held in 2005. The SEAGOOS Consultative Meeting discussed the new satellite-based SST development through cooperation with the ORSP/NGSST-Project in 2005.

Demonstration operation of the real-time NGSST product generation has started in September 2003 (http://www.ocean.caos.tohoku.ac.jp/%7Emerge/sstbinary/actvalbm.cgi?eng=1). Cloud-free, high-resolution (5-km grided), daily, quality-controlled SST (called NGSST-O) is generated through cooperation with ORSP and space agencies.

"Red-tide monitoring project" cooperated with "Red-tide watcher (PI: FURUYA Ken)" supported by a Japanese research fund. The "Red-tide watcher" has organized several international workshops, inviting marine biologists and remote sensing experts in the WESTPAC region. The Red-tide monitoring project was dissolved in order that "Ocean Color (OC) project" may be formed in 2005. The new OC project made significant progress in the regional R&D of Case-2 ocean color algorithm. Cooperating with the Yellow Sea Large Marine Ecosystem (YSLME) and NOWPAP (North-west Pacific Action Plan), the OC project has formed a regional OC expert group which was funded by YSLME. The members are from China, Korea and Japan, and are related to the ORSP/OC project. NOWPAP and YSLME. They have developed the regional bio-optical dataset (YOC-2007 common dataset) and the Yellow/East China Sea Case-2 algorithm.

AN ECOSYSTEM-BASED APPROACH TO MANAGE THE YELLOW SEA

Connie Chiang
UNDP/GEF Yellow Sea Project

ABSTRACT

The UNDP/GEF "Yellow Sea Project" aims to provide the Yellow Sea with management actions to combat environmental problems that it faces. Transboundary problems such as overfishing, unsustainable mariculture, eutrophication, reduction in biodiversity and habitats, and change in ecosystem structure and function were identified and listed in the "Transboundary Diagnostic Analysis." The scientific information was then used to develop the regional and national "Strategic Action Programmes (SAP)" for the Yellow Sea, which are the management actions to mitigate these problems. The goal of ecosystem management is to maximise and sustain ecosystem services; however, managing these services is a complicated issue as there are linkages and tradeoffs among the services. Because of these linkages and trade-offs, sectoral management fails, and each service should not be managed separately.

The SAP, with its central theme of "Ecosystem Carrying Capacity (ECC)," strives to provide an ecosystem-based approach that will allow the Yellow Sea to sustain its provisioning, regulating, supporting, and cultural services. In the project's context, ECC is defined as the capacity of an ecosystem to provide its services or the sum of all the ecosystem services it can provide. The SAP will offer a comprehensive and holistic way to allow the Yellow Sea to achieve this.

ECC is determined by various ecological processes that are inter-dependent, which in turn are determined by ecosystem configuration and state, and will change under different environmental conditions as the ecosystem structure and processes change. Environmental conditions will change as society's requirements increase, and events such as climate change accelerate. Thus, an ecosystem-based approach is needed to ensure a healthy Yellow Sea.

The presentation will provide an overview of the Yellow Sea Project and some results and outcomes of the project. Activities related to marine environment assessment will be introduced, as well as economic tools the project uses to assess management actions.

Session 2

Interim Report of HAB Case Studies in the NOWPAP Member States

Report of HAB Case Studies in the Coastal Area of Qingdao Region

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Abstract

Jiaozhou Bay and eastern part of Qingdao coastal waters, are some of the HAB occurrence areas in North Yellow Sea. This report takes Jiaozhou Bay and eastern part of Qingdao coastal waters as the target sea area to study the HAB cases, which is also considered as the epitome of North Yellow Sea. The scale of HAB events increased significantly from less than $10km^2$ in early 1990s to 50~70 km^2 on average in recent years. The major causative species include diatoms—mostly *Skeletonema costatum*, as well as zooplankton—mostly *Mesodinium rubrum* and also *Heterosigma Akashiwo* in recent years. Duration HAB events, the maximum density of the HAB organisms reached $9.34x10^7$cells/L. Eutrophication is one of the important reasons of HAB events in the target sea area. The concentration of nutrients in recent years has been present at a much higher level as compared to the early 1990s. Moreover the meteorological conditions in summer and early autumn are suitable for the growth of HAB organisms, especially after nutrient input caused by rainfall, with most HABs events occurring during this period.

Key words: Report, HAB case studies, Coastal area of Qingdao region, North Yellow Sea

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Report of HAB Case Studies in the Coastal Area of Qingdao Region

(Draft)

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1. Introduction

1.1. Objective

The objective of conducting the HAB case study in the coastal area of Qingdao region is to establish the most effective and least laborious ways for sharing among the NOWPAP member states, information on HAB events and associated oceanographic and meteorological conditions. Furthermore, common HAB issues within the NOWPAP region will be identified through the case study. In the case study, both red-tide and toxin-producing planktons will be referred as HAB species.

1.2. Definitions and rules used in the HAB case study

Harmful algal blooms (HABs) were called red tides in the past years because of the intense (often reddish) discoloration of the seawater by the pigments in the algae involved. However, the term red tide is too general: it includes dense accumulation of phytoplankton species which can visibly discolor seawater but have no harmful effects, and it excludes many other blooms which cause negative effects at very low density without any associated water discoloration. In spite of the name, red tides are often not red, and are seldom associated with tides, and in some cases exert no negative effects.

"Harmful algal blooms" (or HABs) is the term now used widely to describe blooms which have negative effects. They take many forms and have equally diverse effects, but they are always toxic or harmful. These effects involve different toxins produced by the algae, killing fish and other marine animals, as well as having more general environmental effects.

Traditionally, Chinese are used to the term "red tides" to describe any marine phytoplankton blooms that either causes water discolorations or results in harmful and toxic events. For the scientific communities in China, HABs is widely used. HABs in this report, therefore, encompass both harmful or toxic blooms and harmless red tides.

1.3. Overview of the target sea area

1.3.1. Location and boundary

The target sea area covers the eastern part of Qingdao coastal area and a semi-enclosed interior gulf of Qingdao named Jiaozhou Bay, which jointed with the North Yellow Sea. The location of the target area is from 35°35'~37°09'N and 119°30'~121°00'E (Fig.1).

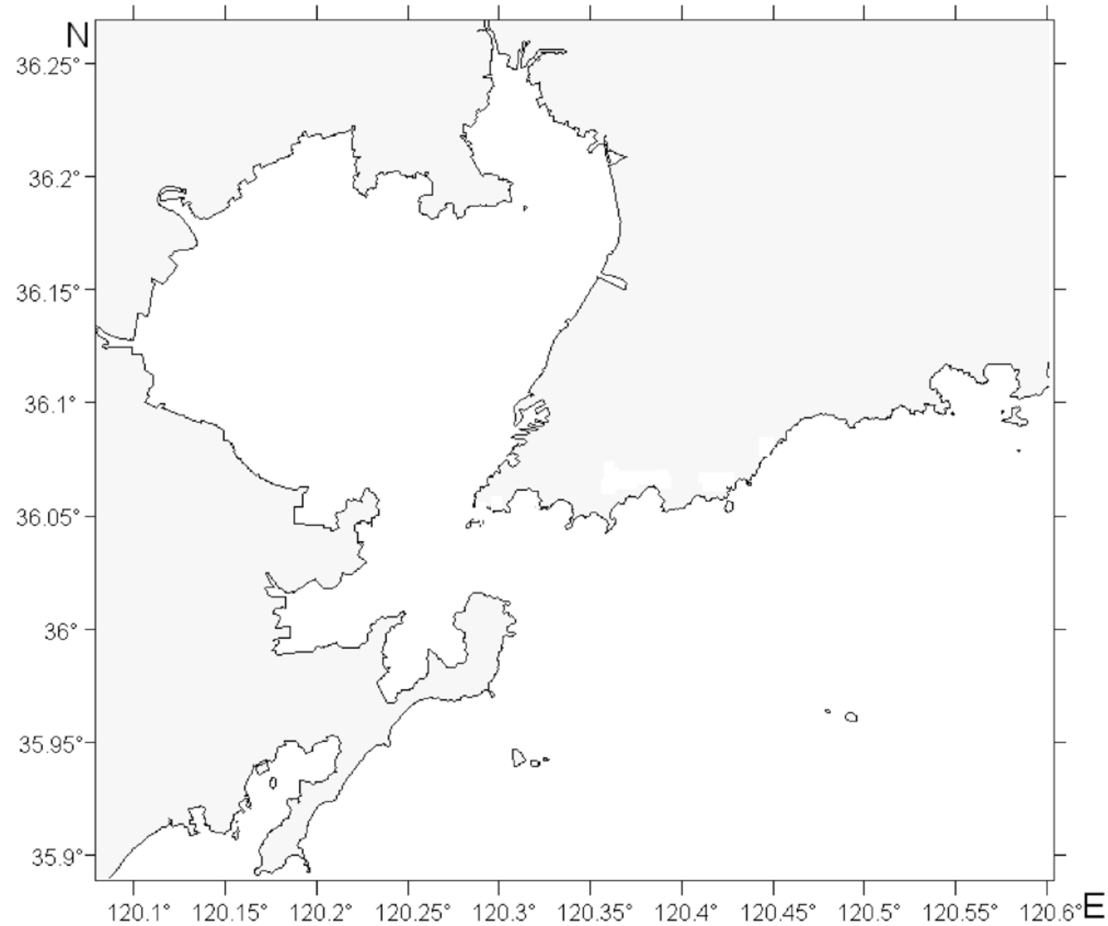


Figure 1 Proposed target sea area for the case study in China

1.3.2. Environmental/geographical characteristics

The target sea area is surrounded by the continent in the northwest and faces North Yellow Sea in the southeast, which includes the waters of Jiaozhou Bay (390km^2) and east coastal waters of Qingdao (140km^2). With an average water depth of 7m and a maximum depth of 64m, most part of Jiaozhou Bay is shallower than 5m. Located in the northern temperate zone, the target sea area is neither extremely hot in summer nor severely cold in winter. The multi-year mean air temperature is 13□ , the sediment depth is about 662 mm and the seawater salinity is between 30.54~33.29.

Major rivers discharging directly into the target sea area include the Haipo, Moshui, Licun, Dagu, 26 rivers in total. The Haipo, Moshui, Licun, Dagu Rivers around the Jiaozhou Bay have important effects on both salinity and hydrography of the target sea area. All rivers have peak runoff in summer and minimum discharge in winter.

Qingdao is a littoral city with a population of approximately 8,300,000 and a population density of about 1517people/km^2.

2. Methodology used in the case study in the Qingdao Coastal Waters

2.1. Methodology used in the case study

Red tide monitoring program in China is conducted by State Oceanic Administration (SOA). The monitoring program started from late 1980s, and the monitoring network is still under construction. SOA has issued "Annual Report of Chinese Marine Environmental Quality" since 1990, in which the data on HABs case is reported. The HAB event in this report is based on two ways, one is the seawater color change found by fisherman or air remote sensing, which is then identified. The other is based on the regular monitoring by SOA. That is one of the data sources in our HAB case study of Qingdao Coastal Waters.

In order to ensure the coastal water quality of Qingdao for the Sailing Regatta of 2008 Olympic game, a HAB monitoring and routine sea quality monitoring programs are conducted by North China Sea Environment Monitoring Centre (NCSEMC) which authorized by SOA in recent years. NCSEMC has issued "Monitoring and warning report of HAB events in costal waters of Qingdao" daily during the July and August since 2005. That is another data source reported in the case study.

Besides, many research programs on HABs are conducted in Jiaozhou Bay because it is a typical bay in North China sea. Related data on HABs event is also used in the report.

2.2. Warning standards against HAB events

In order to prevent damage from HABs, monitoring organizations in the target sea area have established HAB warning standards for major causative species in Qingdao coastal waters by using related international standards as a reference (Table 1). In general, the standard of warning and action is the same in all cases — If exceeded, it will be reported to local government followed by actualization of certain countermeasurements, such as spraying modified clay, moving fish cage, etc..

Table 1 HAB warning standards of Qingdao City

Name	Standards(cells/L)	Toxin
Mesodinium rubrum	5×10^5	No
Noctiluca scintillans	5×10^4	No
Skeletonema costatum	5×10^6	No
Heterosigma akashiwo	5×10^7	No
Eucamipa zoodianus	10^5	No
Alexandrium tamarense	10^6	Yes(PSP)

In China, harvested shellfish are monitored to check the presence of any algal toxins. Safety limits are established by the Government, which are 80μg STXeq/100g of meat for PSP and less than detection limit by means of mouse bioassay (0.05 MU/g) for DSP.

2.3. Target HAB species

The causative HAB species in Qingdao coastal waters are basically non-toxin plankton and zooplankton, therefore, in this case study, the following 5 species of HAB are referred as ‘target HAB species’.

Table 2 Target HAB species in this case study

Name	Red tide causative species	Toxin-producting plankton
Mesodinium rubrum	Yes	
Noctiluca scintillans	Yes	
Skeletonema costatum	Yes	
Heterosigma akashiwo	Yes	
Eucamipa zoodianus	Yes	

3. Monitoring framework and parameters of HAB

3.1. Monitoring framework

As mentioned above, North China Sea Environmental Monitoring Centre (NCSEMC) conducts HAB monitoring in recent years to prevent HABs in Qingdao coastal waters. There're 43 monitoring stations set up in the target sea area, distributed among Jaozhou Bay、Huiquan Bay、Tuandao Bay、Taipingjiao Bay、Fushan Bay、Maidao Bay、Shazikou Bay and adjacent coastal waters. The boundaries and locations of the monitoring stations are presented on Figure 2.

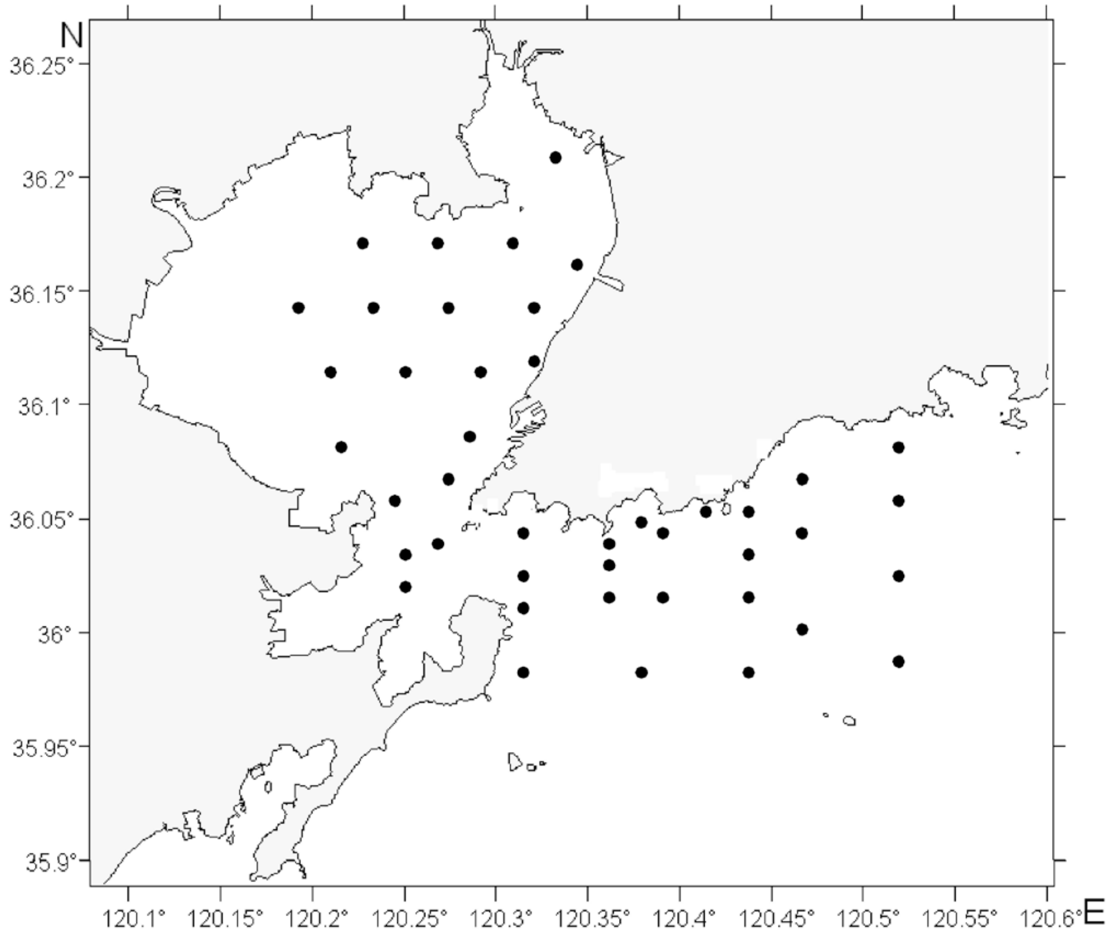


Figure 2 . Monitoring framework in Qingdao target sea area

3.2. Monitoring parameters

In the coastal waters of Qingdao, the following two types of HAB related surveys are conducted: post-HAB survey and regular HAB monitoring survey. Post-HAB survey is conducted when discoloration of water bas been observed and HAB event has occurred. Regular HAB monitoring survey is conducted regularly at fixed locations, irrespective of any HAB events.

This case study will focus mainly on the results of the post-HAB survey, which monitors HAB causative species, cell density, affected area, water temperature, salinity and DO. Meanwhile, the regular HAB monitoring results such as nutrients、wind speed/direction、 weather condition and other water quality as well as meteorological parameters will be used for further discussions.

3.3. Data and information used

Information on HAB events will be mainly collected from the following sources:
Reports published by organizations that conduct HAB monitoring in the target sea area
Monitoring and warning report of HAB events in costal waters of Qingdao (2005-2007)
Annual Report of China Marine Environment (2003-2007)
Annual Report of Marine Environment of Shandong Province (2006)
Annual Report of Offshore Water Environment of China.(2001-2007)
Annual Report of Marine Environment of Qingdao.(2004-2005)
Published references and data
Results from related research projects
Personal communication

Table 3 shows the monitoring parameters that will be referred in the HAB case study

Table 3 Monitoring parameters referred in the HAB case study

	Monitoring parameter	Survey type
HAB	- HAB species (dominant/causative spp.) - Cell density - Bloom area	Post-HAB survey
Water quality	- Water temp. - Salinity - DO	Post-HAB Survey
Others	- Water quality Transparency, Nutrients - Meteorology Weather, Wind, direction/speed	Regular HAB monitoring survey

4. Status of HAB events

The target sea area, Jiaozhou Bay and eastern part of Qingdao coastal waters, is one of HABs occurrence areas in North Yellow Sea. Therefore this chapter will emphasize the records in the past ten or more years of HAB status in Qingdao coastal waters as the epitome of North Yellow Sea.

4.1. Status of HAB events in the past decades or so

As summerized in table 4, 38 HAB events have been recorded by SOA in North Yellow Sea since 1990, in which, 24 HAB events occurred in Qingdao coastal waters. Therefore, Qingdao coastal waters is the typical "target sea area" to study the HAB events occurred in North Yellow Sea.

Table 4 Situation of HAB events in the North Yellow Sea, China

Event No.	Location	Approximate Area suffered(Km2)	Duration (DD/MM/YY)	Causative species	Max Cell Density(Cells/L)	Damage	
						Fishery damage (Chinese Yuan)	Human Health
1	Jiaozhou Bay, Qingdao	2	26/06/1990	*Mesodinium Rubrum*	/	/	
2	Changhai country, Liaoning	/	1990	/		2.5 million due to death scallops	
3	Jiaozhou Bay, Qingdao	/	04/1992	/	/	/	
4	East Qingdao	/	12/05/1992	/	/	/	
5	Jiaozhou Bay, Qingdao	/	08/1992	/	/	/	
6	Dalian Bay, Dalian	40	11/08/1993	/	/	/	
7	Jiaozhou Bay, Qingdao	/	08/1997	*Skeletonema Costatum*	/	/	
8	Jiaozhou Bay, Qingdao	10	03/07/1998-08/07/1998	*Skeletonema Costatum*	$4.5x10^6$	/	
9	Jiaozhou Bay, Qingdao		08/06/1999-15/06/1999	*Eucampia Zodiacus*	$2.3x10^6$	/	
10	Jiaozhou Bay, Qingdao	26	23/07/1999-24/07/1999	*Skeletonema Costatum*、*Eucampia Zodiacus*	/	/	
11	Fushan Bay, Qingdao	60	26/07/1999	*Mesodinium Rubrum*	/	/	
12	Dalian Bay, Dalian		07/1999	*Exuviaella Marina*	$8.1x10^6$	/	DSP detected
13	Dalian Bay, Dalian	100	17/07/1999-21/07/1999	*Noctiluca Scintinllans*	/	/	
14	Penglai, Shandong	680	17/07/1999	*Noctiluca Scintinllans*	/	/	
15	Shidao, Shandong	160	06/08/1999	/	/	/	
16	Zhuanghe, Liaoning	827	02/08/2000	/	/	15 million	
17	Jiaozhou Bay, Qingdao	92	20/07/2000-23/07/2000	*Noctiluca Scintinllans*	/	/	

18	Dandong, Liaoning		24/05/2001	/	/	/	
19	Fushan Bay, Qingdao		04/04/2001	*Noctiluca Scintinllands*	/	/	
20	Jiaozhou Bay, Qingdao	5	11/06/2001-12/06/2001	*Noctiluca Scintillands*	/	/	
21	Jiaozhou Bay, Qingdao	9.8	07/07/2001-13/07/2001	*Mesodinium Rubrum*	/	/	
22	The coast of Jiangsu	1000	20/06/2001	*Skeletonema Costatum*	/	/	
23	Yalujiang Estuary, North Yellow Sea	110	24/08/2001-14/09/2001	*Eucampia Zoodiacus, Chaetocerus Socialis*	/	/	
24	Fushan Bay, Qingdao	60	28/06/2002-02/07/2002	*Mesodinium Rubrum*	/	/	
25	Dandong Waters, Liaoning	30	06/2003	/	/	/	
26	Jiaozhou Bay,Qingdao	200	07/2003	*Coscinodiscus Asteromphalus*	/	/	
27	East Qingdao	450	04/07/2003-10/07/2003	*Mesodinium Rubrum*	/	/	
28	Jiaozhou Bay, Qingdao		02/2004	*Guinaradia Delicatula*	/	/	
29	Jiaozhou Bay, Qingdao	70	09/02/2004-28/02/2004	*Rhizosolenia Delicatula*	/	/	
30	Jiaozhou Bay, Qingdao	70	22/03/2004-25/03/2004	*Thalassiosira NordenskÖldii*	/	/	
31	Jiaozhou Bay, Qingdao		07/2004	*Coscinodiscus Asteromphalus*	/	/	
32	Fushan Bay, Qingdao	50	10/08/2004	*Mesodinium Rubrum*	/	/	
33	Jinshatan, Dalian		06/09/2004	*Chattonella Antiqua*	/	/	
34	Jinshatan, Dalian		25/09/2004	*Alexandrium Catenella*	/	/	
35	Lingshan Bay, Qingdao	80	12/06/2005-17/06/2005	*Heterosigma Akashiwo*	$9.54x10^7$	/	
36	Shazikou Bay, Qingdao	70	07/06/2007-10/07/2007	*Heterosigma Akashiwo*	$5.31x10^7$	/	
37	East Qingdao	15	20/08/2007-23/08/2007	*Skeletonema Costatum*	$1.11x10^7$	/	
38	Shazikou Bay, Qingdao	8	25/09/2007-28/09/2007	*Gonyaulax Spinifera*	/	/	

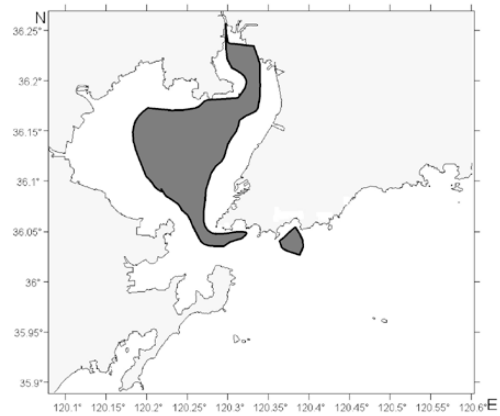
From year 1997-2007, a total of 20 HAB events were recorded in the Qingdao coastal waters. The most frequently observed HAB species were *Skeletonema costatum* and *Mesodinium rubrum*, which constituted almost half of all recorded events.

Table 5 Yearly Trends of HAB enents

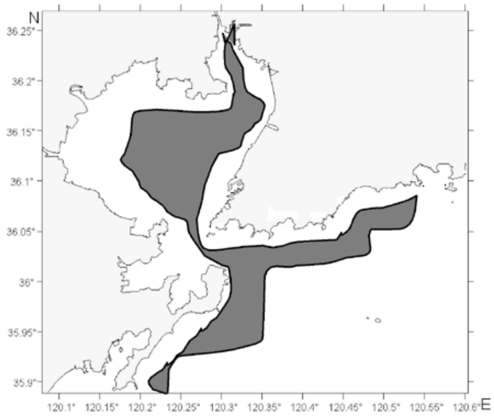
HAB event	HAB area	Causative species	Squares
08/1997	Centre of Jiaozhou Bay	*Skeletonema costatum*	small
03/07/1998-08/07/1998	North-east part of Jiaozhou Bay	*Skeletonema costatum*	$10km^2$
06/1999	North-east part of Jiaozhou Bay	*Eucampia zodiacus*	Small
23/07/1999-24/07/1999	Jiaozhou Bay	*Skeletonema costatum*、 *Eucampia zodiacus*	$26km^2$
26/07/1999	Fushan Bay	*Mesodinium rubrum*	$60km^2$
20/07/2000	Centre of Jiaozhou Bay	*Noctiluca Scintinllans*	$92km^2$
04/04/2001	Fushan Bay	*Noctiluca Scintinllands*	small
11/06/2001-12/06/2001	Jiaozhou Bay	*Noctiluca Scintillands*	$5km^2$
07/07/2001-13/07/2001	Mouth of Jiaozhou Bay	*Mesodinium rubrum*	$9.8km^2$
28/06/2002-02/07/2002	Fushan Bay	*Mesodinium rubrum*	$60km^2$
04/07/2003-10/07/2003	Tuandao Bay、Huiquan Bay、 Taipingjiao Bay、Fushan Bay	*Mesodinium rubrum*	$450km^2$
02/2004	North-east part of Jiaozhou Bay	*Guinaradia delicatula*	Small
09/02/2004-28/02/2004	East part of Jiaozhou Bay	*Rhizosolenia delicatula*	$70km^2$
22/03/2004-25/03/2004	North-east part of Jiaozhou Bay	*Thalassiosira nordenskÖldii*	$70km^2$
07/2004	North part of Jiaozhou Bay	*Coscinodiscus asteromphalus*	Small
10/08/2004	Fushan Bay	*Mesodinium rubrum*	$50km^2$
12/06/2005-17/06/2005	Lingshan Bay	*Heterosigma Akashiwo*	$80km^2$
07/06/2007-10/07/2007	Shazikou Bay	*Heterosigma Akashiwo*	$70km^2$
20/08/2007-23/08/2007	Eastern costal waters	*Skeletonema costatum*	$15\ km^2$
25/09/2007-28/09/2007	Shazikou Bay	*Gonyaulax spinifera*	$8km^2$

According to table 5, the HAB area expanded obviously in recent years. Jiaozhou bay was the major HABs area of Qingdao coastal waters during the whole 90s, however, Fushan bay became to be another main HAB area from the early years of 21st century. Moreover, the HAB area expanded much seriously in recent 4-5years, which was from the western part (Lingshan Bay) to the eastern part (Shazikou Bay) of Qingdao coastal waters as shown in figure 3.

Main HAB area during 90s



Main HAB area during early 21st centery



Main HAB area in recent years

Figure 3 HABs area expansion of Qingdao coastal waters

4.2. Yearly trends of HAB events

During the 10 years between 1997 and 2007, a total of 20 HAB events were recorded. The frequency of HAB events has increased significantly in recent years than before.

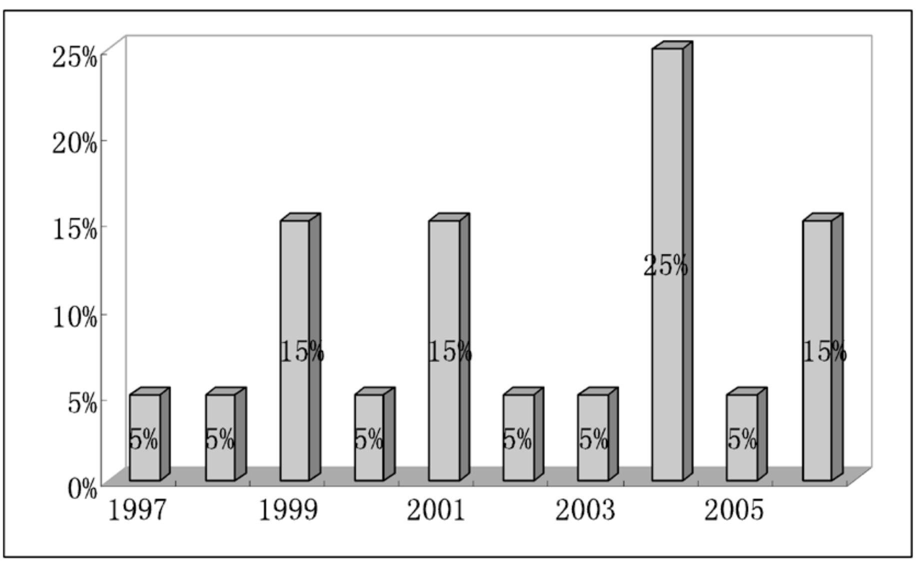


Figure 4 Yearly trend of HAB events in the target area

According to figure 4, almost half of HAB events recorded occurred in the 4 years, especially in 2004, in which 5 HAB events have occurred—accounted for about 25% of total.

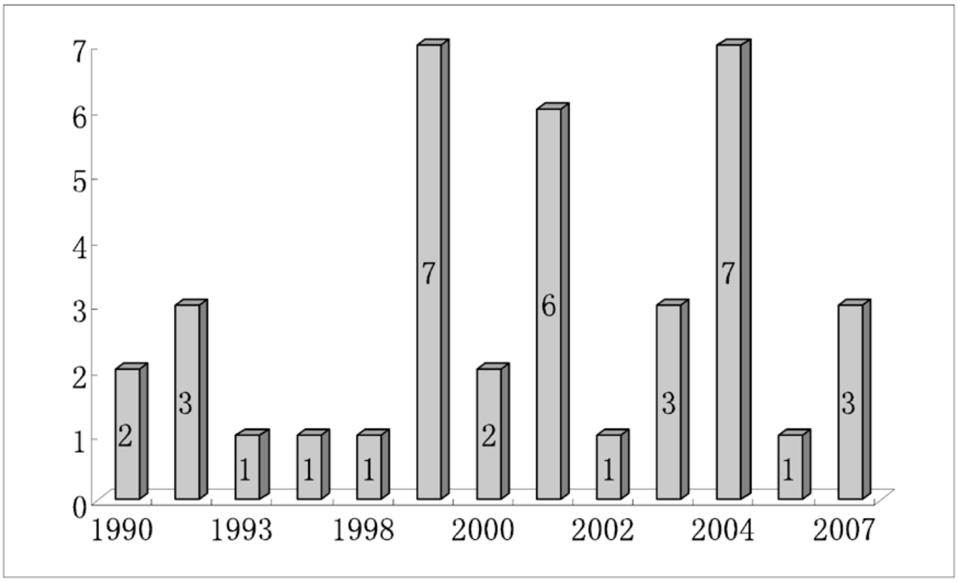


Figure 5 Yearly trend of HAB events in the North Yellow Sea

For the North Yellow Sea region, the same conclusion could be obtained that the frequency of HAB events has increased significantly in recent years than before. Figure 5 shows the yearly trend of HAB events in North Yellow Sea from 1990 to 2007. There're 38 events recorded and among them 11 among them occurred in recent 4 years. The trend of HABs occurrence seemed smooth and annual average was just 2 from 1990 to 1998. The HABs events dramatically increased from 1999 and then appeared a peak value of HABs occurrence in every 2 or 3 years.

4.3. Yearly trends of HAB season

According to the HAB data from 1997-2007, approximately 80% of HAB events occurred during June-September (Figure 6). June、July and August are considered to be the most frequent months of HAB occurrence. Of these 4 months, June and July are considered to be the dominant durations of HAB events, with over half of the total HAB events occurring in the 2 months.

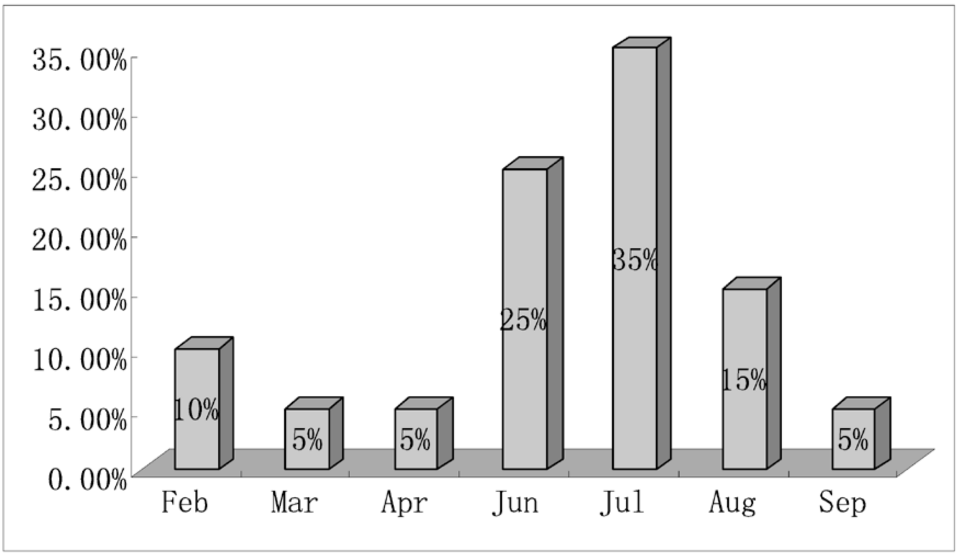


Figure 6 Seasonal trend of HAB events in the target area

The record of North Yellow Sea indicates the same situation. Only less than 20% HAB events occurred during the year except for June to September, with not even a single HAB event recorded during the months of October to December and January. July is also believed to be the dominant durations of HAB events in the whole year, followed by June.

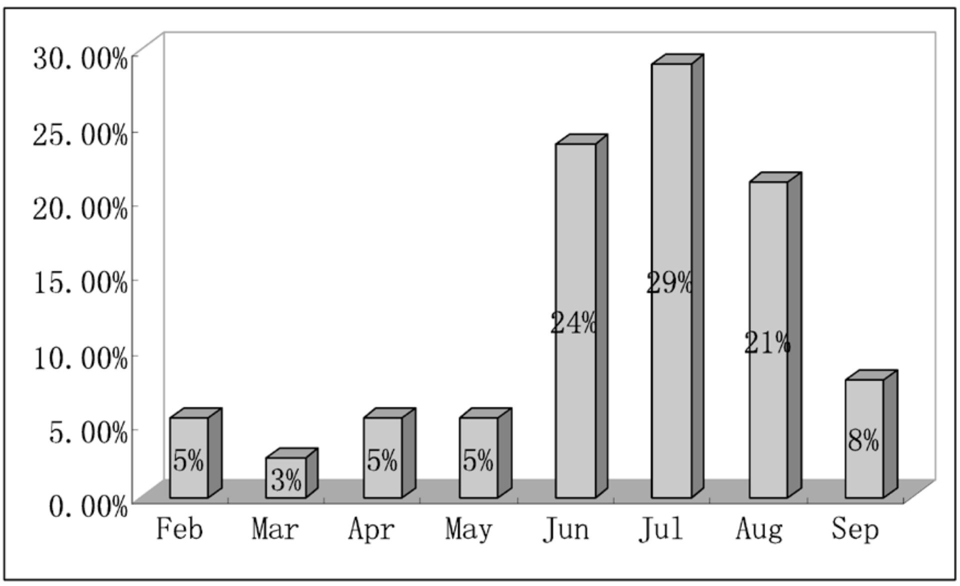


Figure 7 Seasonal trend of HAB events in the yellow sea

4.4. Yearly trends of causative species

Table 6 shows the HAB species that were recorded in the Qingdao coastal area during 1997-2007 and their frequency of occurrences. A total of 10 HAB species were recorded and the most frequent species were *Skeletonema costatum* and *Mesodinium rubrum*. In general, most species belonged to diatoms.

Table 6 Yearly trends of causative species

Specie name	1997	1998	1999	2000	2001	2002	2003	2004	2005	2007	total
Diatom	1	1	3					4			10
Skeletonema costatum	1	1	1							1	4
Eucampia zodiacus			2								2
Guinaradia delicatula								1			1
Rhizosolenia delicatula								1			1
Thalassiosira nordenskÖldii								1			1
Coscinodiscus asteromphalus								1			1
Dinoflagellate				1	2					1	4
Noctiluca Scintinllans				1	2						3
Gonyaulax spinifera										1	1
Zooplankton			1		1	1	1	1			5
Mesodinium rubrum			1		1	1	1	1			5
Others											
Heterosigma Akashiwo									1	1	2

5. Status of recent HAB events and results of environmental monitoring

5.1. Number of HAB events

Records of HAB events in 2005-2007 are chosen to illustrate the status of recent HAB events. A total of 4 HAB events in the target sea area were recorded in the period (table 7).

Table 7 HAB events occurred in recent years

HAB event	HAB area	Causative species	Maximum Density(cells/L)
12/06/2005-17/06/2005	Lingshan Bay	*Heterosigma Akashiwo*	$9.54x10^7$
07/06/2007-10/06/2007	Shazikou Bay	*Heterosigma Akashiwo*	$5.31x10^7$
20/08/2007-23/08/2007	Eastern costal waters	*Skeletonema costatum*	$1.11x10^7$
25/09/2007-28/09/2007	Shazikou Bay	*Gonyaulax spinifera*	/

Besides the HAB events, there were 3 records of high biomass, in which the maximum density of causative species closed to the warning levels (table 8). The most frequently observed HAB species were *Heterosigma Akashiwo* and *Skeletonema Costatum* respectively.

Table 8 High biomass events closed to the warning levels in recent years

Event	Area	Causative species	Maximum Density(cells/L)	Warning Standards(cells/L)
12/06/2005	Fushan Bay	*Skeletonema costatum*	$3.6x10^5$	$5x10^6$
05/07/2006-09/07/2006	Fushan Bay	*Mesodinium rubrum*	$5.6x10^4$	$5x10^5$
23/08/2006-24/08/2006	Fushan Bay	*Chaetoceros socialis*	$2.6x10^5$	10^6

5.2. Period of HAB events

As shown in the figure 8, June is the most possible period of HAB events and high biomass events that approach the warning levels in the target sea area. Summer and early autumn are the most possible seasons.

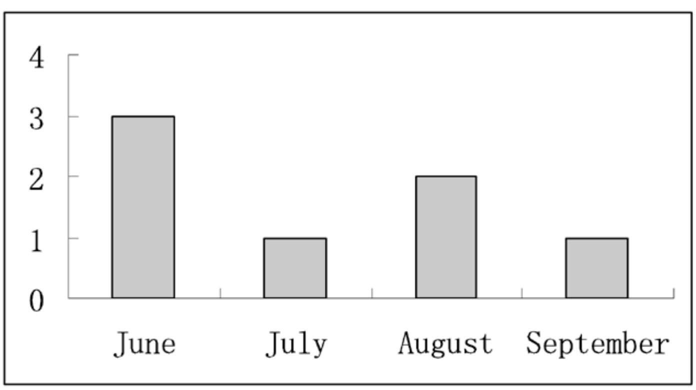


Figure 8 Period of HAB events

5.3. Duration of HAB events

Table 9 shows the number of HAB events and high biomass events by duration (number of days) in 2005-2007. A total of 7 events occurred during the period, in which 1 event lasted for 5 days, 1 event was 4 days, 3 events were 3 days and 2 events were just 1 day. The longest HAB duration was 5 days by *Heterosigma akashiwo*, which occurred in Lingshan Bay with an area of 80 km^2 during June. Therefore, we could say that the HABs events in the target area are smaller and the duration of each event is shorter.

Table 9 Duration of HAB events in recent years

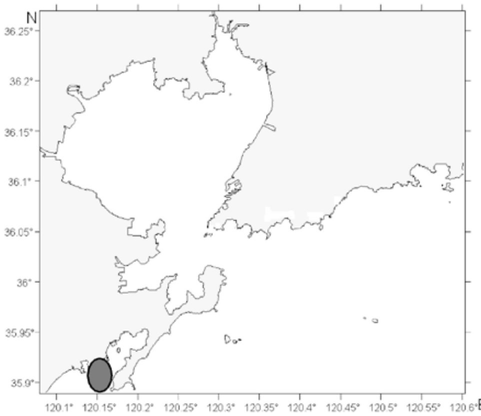
HAB event	Duration	Causative species
12/06/2005-17/06/2005	5 days	*Heterosigma Akashiwo*
12/06/2005	1 day	*Skeletonema Costatum*
05/07/2006-09/07/2006	4 days	*Mesodinium rubrum*
23/08/2006-24/08/2006	1 day	*Chaetoceros socialis*
07/06/2007-10/06/2007	3 days	*Heterosigma Akashiwo*
20/08/2007-23/08/2007	3 days	*Skeletonema costatum*
25/09/2007-28/09/2007	3 days	*Gonyaulax spinifera*

5.4. Location of HAB events

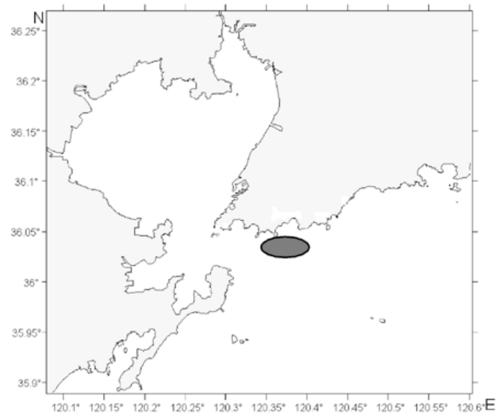
The location of above HABs and high biomass events in the target sea areas is shown as the table 10 and figure 9. The events often occured in Fushan bay and Shazikou bay during the period. Eutrophication and the weaker water exchange in the two bays are considered to be the major reasons. The two bays are the smaller semi-enclosed gulf and the water exchange is weaker. There is a major living waste-water discharge near Fushan bay, which often results in the eutrophication of nearby waters. Shazikou bay is surrounded by many culture fishery places and fishery ports, and as a result, the water there is believed to suffer from serious eutrophication.

Table 10 Location of HAB events in recent years

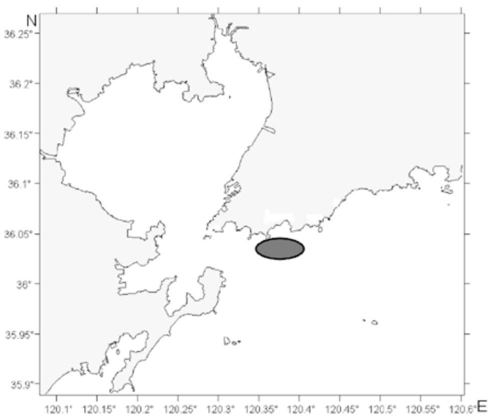
HAB event	HAB area	Causative species
12/06/2005-17/06/2005	Lingshan Bay	*Heterosigma Akashiwo*
12/06/2005	Fushan Bay	*Skeletonema Costatum*
05/07/2006-09/07/2006	Fushan Bay	*Mesodinium rubrum*
23/08/2006-24/08/2006	Fushan Bay	*Chaetoceros socialis*
07/06/2007-10/06/2007	Shazikou Bay	*Heterosigma Akashiwo*
20/08/2007-23/08/2007	East costal waters	*Skeletonema costatum*
25/09/2007-28/09/2007	Shazikou Bay	*Gonyaulax spinifera*



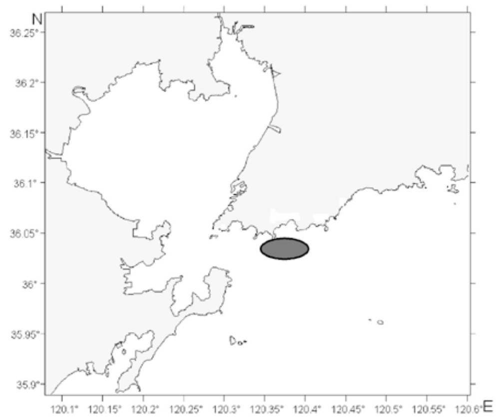
June,2005



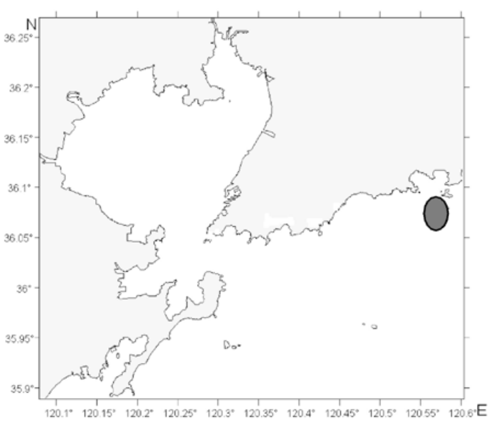
June,2005



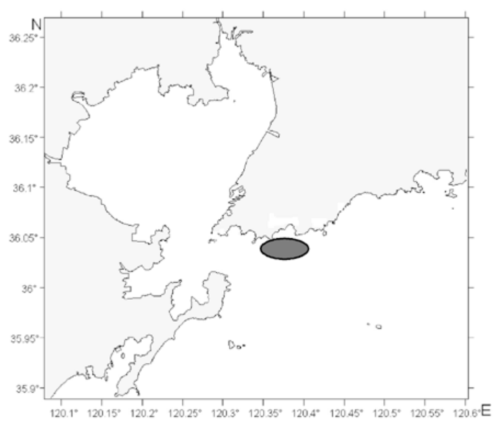
July,2006



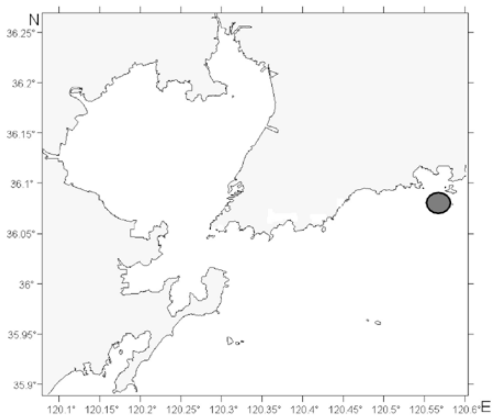
August,2006



July,2007



August,2007



September,2007

Figure 9 Locations of HAB events in recent years

Comparison with the historical records, Jiaozhou Bay is believed to be another source of HAB events, especially in the northeastern part because of its weak seawater exchange ability and great pollution. However, more attentions were attracted to the eastern part of Qingdao coastal waters from 2005 to 2007 due to where will be 2008 Olympic sailing competition waters. Therefore, more data on the HABs from 2005 to 2007 in the eastern part of Qingdao coastal waters were available. As a result, this chapter will discuss the status of recent HAB events and results of environmental monitoring mostly based on the data on the eastern part of Qingdao coastal waters.

5.5. Causative species

As shown in the table 11, there were 5 causative species in the events and the most frequent species were *Heterosigma Akashiwo* and *Skeletonema Costatum*, 2 times respectively.

Table 11 Causative species of HAB events in recent years

HAB event	Causative species	Causative genus
12/06/2005-17/06/2005	*Heterosigma Akashiwo*	Raphidophyceae
12/06/2005	*Skeletonema Costatum*	Diatom
05/07/2006-09/07/2006	*Mesodinium rubrum*	Micro-zooplankton
23/08/2006-24/08/2006	*Chaetoceros socialis*	Diatom
07/06/2007-10/06/2007	*Heterosigma Akashiwo*	Raphidophyceae
20/08/2007-23/08/2007	*Skeletonema costatum*	Diatom
25/09/2007-28/09/2007	*Gonyaulax spinifera*	Dinoflagellate

According to the monitoring results during 2004~2006 conducted by the NCSEMC, diatoms are the dominant species of the community in the target sea area. 86 species of diatoms were tested out of 108 species in total, and the percentage was 79.63%. The *Skeletonema Costatum* was the most common specie of diatoms. Besides *Skeletonema Costatum*, the *Mesodinium Rubrum* and *Heterosigma Akashiwo* are another important species that occurred during HAB events and have caused HABs to occur more and more frequently in the target area.

5.6. Maximum density of each HAB event

Table 12 shows the maximum density of each HAB event that occurred in the target sea area during 2005-2007. Within these HAB events, the maximum density was recorded in June 2005 at Lingshan Bay, reaching 9.54×10^7 cells/L.

Table12 Maximum density of HAB events in recent years

HAB event	Causative species	Maximum density(cells/L)
12/06/2005-17/06/2005	*Heterosigma Akashiwo*	9.54×10^7
07/06/2007-10/06/2007	*Heterosigma Akashiwo*	5.31×10^7
20/08/2007-23/08/2007	*Skeletonema costatum*	1.11×10^7
25/09/2007-28/09/2007	*Gonyaulax spinifera*	/

5.7. Status of HAB induced fishery damage

There were not official statistic data on fishery damage caused by HAB events in the target sea area. According to the estimate from the fishermen, the HAB event occurred in the Lingshan Bay 2005 caused great fishery damage. This HAB event was caused by the *Heterosigma Akashiwo* and resulted in serious damage of culture and capture fishery. During this event, the total catch decreased significantly and most yellow croaker captured were dead totally.

5.8. Status of target species

According to the recent 10-year record of HAB events in table 5, the major causative species are *Heterosigma Akashiwo*, *Mesodinium Rubrum* and *Skeletonema Costatum*, with diatoms and zooplankton especially played a significant role. In some cases, although the maximum density did not reach HABs level, the density of *Mesodinium Rubrum* and *Skeletonema Costatum* frequently maintained at a higher level. Therefore, the target species in Qingdao coastal waters should be were diatoms, *Heterosigma Akashiwo* and micro-zooplankton, especially *Mesodinium Rubrum* and *Skeletonema Costatum* (Table 13). A decreasing trend of the size of the causative species is also present, and as such, some small micro-diatoms and micro-zooplankton are taking the place of macro-planktons such as *Noctiluca Scintinllans*.

Table 13 status of target species of HAB and high biomass event in recent years

Specie name	2005	2006	2007	total
Diatom				3
Skeletonema costatum	1		1	2
Chaetoceros socialis		1		2
Dinoflagellate			1	1
Gonyaulax spinifera			1	1
Zooplankton				1
Mesodinium rubrum		1		1
Others				
Heterosigma Akashiwo	1		1	2

5.9. Environmental monitoring results during HAB events

The environmental parameters were monitored during the HAB event of *Skeletonema*

Costatum occurred in 2007. The major monitored parameters included temperature、salinity、pH、DO as shown in Table 14. During the HAB event, the water temperature ranged in22.68-25.32°C, salinity ranged in 27.928 - 29.599, pH ranged in 6.97- 8.2 and DO ranged in 6.66 - 7.81.

Table 14 Environmental monitoring results during HAB event

Spot	Temperature(°C)	Salinity	pH	DO(mg/L)
6	22.7~25.08	29.141~29.599	6.97~8.05	6.66~7.42
8	22.68~25.21	28.528~29.495	7.93~8.09	6.9~7.46
9	23~25.2	29.032~29.461	7.96~8.14	6.99~7.49
14	23.56~25.12	29.012~29.298	7.93~8.2	6.91~7.57
15	23.48~25.17	29.039~29.336	7.94~8.19	7.04~7.68
18	24.08~25.32	28.197~29.171	8~8.16	7.15~7.68
19	23.94~25.1	28.48~29.215	7.99~8.19	7.17~7.81
20	24.22~25.32	27.928~28.31	7.97~8.16	7.22~7.73
21	24.16~25.3	28.439~28.627	7.98~8.15	7.2~7.71

Because there was a continuous rainstorm before the HAB event, the salinity was lower than the normal level and the water temperature was also lower than multi-year mean level. *Skeletonema Costatum* is a species that can grow in a wide range of salinity. As a result, the *Skeletonema Costatum* became the dominant specie during this HAB event.

5.10. Water quality parameters of regular HAB monitoring survey

Table 15 shows the regular HAB monitoring survey results during the *Skeletonema Costatum* HAB event occurred in 2007. The major monitored parameters included temperature、salinity、DO and nutrients. Figure 10 shows the change in nutrients during the HAB event.

Table 15 Water quality parameters during the *Skeletonema Costatum* HAB event in 2007

Spot	Temperature (°C)	Salinity	DO(mg/L)	SiO3-Si (μg/L)	PO4-P (μg/L)	NO2-N (μg/L)	NO3-N (μg/L)	NH4-N (μg/L)
6	22.7~25.08	29.141~29.599	6.66~7.42	338~470	2.25~6.3	31.5~38.9	71~198	17.6~76.4
8	22.68~25.21	28.528~29.495	6.9~7.46	242~430	1.35~3.6	29.3~41.4	84.6~261	23.2~200
9	23~25.2	29.032~29.461	6.99~7.49	308~448	0.9~3.6	27.1~32.3	83.6~171	13.5~82.1
14	23.56~25.12	29.012~29.298	6.91~7.57	290~308	0.9~4.95	26.5~29.2	94~132	24.1~52.9
15	23.48~25.17	29.039~29.336	7.04~7.68	282~378	1.35~5.4	26.1~31.7	56.4~138	23.8~69.9
18	24.08~25.32	28.197~29.171	7.15~7.68	253~326	2.25~4.95	30.5~44.3	122~265	32.7~59.6
19	23.94~25.1	28.48~29.215	7.17~7.81	242~326	2.25~4.5	25.2~35.9	57.4~185	16.7~59.9
20	24.22~25.32	27.928~28.31	7.22~7.73	271~326	1.8~5.4	31.5~38.5	174~222	33.6~52.6
21	24.16~25.3	28.439~28.627	7.2~7.71	245~319	2.25~4.05	33.4~45.3	110~277	6.4~52.9

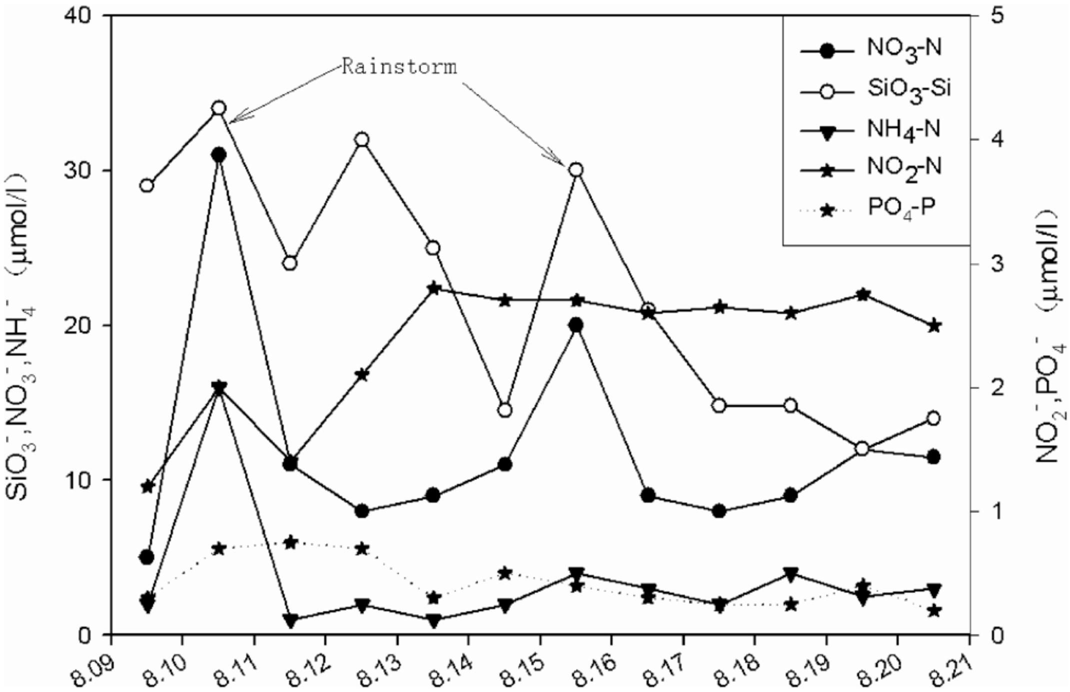


Figure 10 Nutrients during the *Skeletonema Costatum* HAB event in 2007

According to monitoring results by NCSEMC, there were several times of rainfall in Qingdao before the HABs event, especially on 10th ~11th of August the rainfall was over 240mm. The rainfall input terrestrial nutrients into the target sea area. As a result, the concentration of silicate increased over 10 times, along with the significant increase in concentrations of other nutrients. As shown in figure 7, the concentrations of both silicate、nitrate and ammonium were over 30μmol/L, and the concentration of phosphate was over 0.6μmol/L. Therefore, sufficient nutrients and suitable environmental conditions resulted in the HABs event that lasted for 4 days.

5.11. Meteorological observation parameters

The meteorological data were recorded in table 16 during the *Skeletonema Costatum* HAB event in 2007. The major parameters included temperature、air pressure、wind speed、wind direction and so on.

Table 16 Meteorological observation parameters during HAB event

Spot	Temperature (ºC)	Air pressure (hpa)	Wind speed(m/s)	Wind direction(º)				Weather condition
				20th	21th	22th	23th	
6	22.2~26.8	1000.4~1008.1	0~5.3	C	164	34	94	Sunny
8	22.2~26.8	1000.4~1008.1	0~5	C	144	34	94	Sunny
9	22.3~26.9	1000.4~1008.1	0~5.7	C	124	24	84	Sunny
14	22.5~26.9	1000.4~1008.1	0~5.7	C	144	34	84	Sunny
15	22.5~27.0	1000.4~1008.1	0~5.4	C	104	34	94	Sunny
18	22.9~26.8	1000.3~1008.1	1.5~5.7	164	134	24	84	Sunny

19	22.8~26.8	1000.3~1008.1	1.3~5.5	174	134	44	84	Sunny
20	26.2~26.9	1000.3~1008.1	1.9~4.2	184	124	34	94	Sunny
21	26.1~26.9	1000.3~1008.1	1.7~4.6	194	124	24	94	Sunny

As shown in the above table, during the HAB event, the weather maintained sunny with no rain, which was favorable for plankton growth because of strong photosynthesis. The wind was mild, less than 5m/s in most cases, and in some spots only static wind existed. Slow wind speed is favorable for phytoplankton growth, without being disturbed by strong waves. In summary, the meteorological condition was also fit for *skeletonema costatum* blooming.

6. Conclusion

The target sea area in the report, Jiaozhou Bay and eastern part of Qingdao coastal waters, are some of the HAB occurrence areas in North Yellow Sea. The scale of HAB events increased significantly from less than $10km^2$ in early 1990s to 50~70 km^2 on average in recent years. The major causative species include diatoms—mostly *Skeletonema costatum*, as well as zooplankton—mostly *Mesodinium rubrum* and also *Heterosigma Akashiwo* in recent years. Duration HAB events, the maximum density of the HAB organisms reached $9.34x10^7$cells/L. Eutrophication is one of the important reasons of HAB events in the target sea area. The concentration of nutrients in recent years has been present at a much higher level as compared to the early 1990s. Moreover the meteorological conditions in summer and early autumn are suitable for the growth of HAB organisms, especially after nutrient input caused by rainfall, with most HABs events occuring during this period.

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Interim Report of HAB Case Study in the Northwestern Sea Area of Kyushu Region

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NOWPAP CEARAC

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1 Introduction

1.1 Objective

The objective of conducting the HAB case study in the northwestern sea area of Kyushu region (hereinafter abbreviated as 'case study') is to establish the most effective and laborsaving ways for sharing among the NOWPAP member states, information on HAB events and associated oceanographic and meteorological conditions.

1.2 Background information of the case study

The case study provides information on the red tides and toxin-producing planktons that have occurred in the northwestern sea area of Kyushu region. As defined by NOWPAP CEARAC (2005), red tides can be merely a water discoloration event or can be harmful and in some cases induce fishery damage. On the other hand, toxin-producing planktons can contaminate fish and shellfish even under low densities. In this case study, HAB refers to blooms of both unharmful/harmful red tides and toxin-producing planktons. Information on toxin-producing planktons is provided through two sources: regular monitoring data of toxin-producing planktons and records of shipment stoppage due to shellfish contamination.

In regards to the scientific names of the HAB species, in principal, the names used in the past CEARAC reports (e.g. Integrated Report) were used. However, updated names or country-specific names were also concurrently listed as far it was possible. The information presented in the case study was mainly based on the published reports and websites of the national or local government monitoring organizations.

The status of HAB events is presented for two time periods. Chapter 4 describes the yearly trend of HAB events from the initiation of HAB monitoring to the present. Chapter 5 describes the HAB events in 2006, which include information such as the season and location of occurrence, and the associated environmental conditions.

In addition, the case study discusses the prospects and issues of using satellite remote sensing technology for red-tide monitoring.

1.3 Overview of the target sea area

1.3.1 Location and boundary

The northwestern sea area of Kyushu region (hereinafter called as 'target sea area') was selected for Japan's HAB case study. The target sea area faces the East China Sea, and includes the sea areas of Nagasaki, Saga and Fukuoka Prefecture, and the Sea of Japan side of Yamaguchi Prefecture. The target sea area was broadly demarcated into the following 4 sea regions: coastal area of Yamaguchi Prefecture, north Kyushu sea area (coastlines of Fukuoka, Saga and part of Nagasaki Prefecture), west Kyushu sea area (Nagasaki Prefecture) and remote islands (Nagasaki Prefecture). Inland seas such as the Ariake Sea, Yatsushiro Sea and Seto Insland Sea were not included. Figure 1.1 shows the locations of the above 4 sea regions. The monitoring areas/sites of each prefecture are described in Section 3.1.

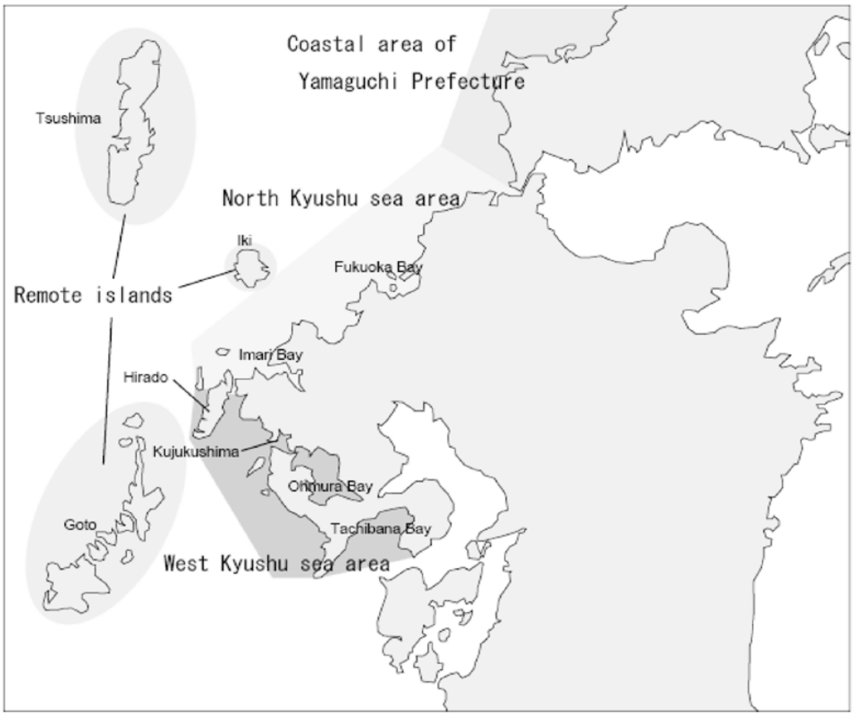


Figure 1.1 Target sea area of Japan's HAB case study

1.3.2 Environmental and geographical characteristics

The target sea area is strongly influenced by the Tsushima Warm Current. The topography of the coastline is complex; comprised of many beaches and small inlets. In some areas, such as in the west Kyushu sea area, numerous small islands (Kujuku-shima Islands) are scattered along the coast. Also there are many remote islands such as the Goto Islands, Tsushima and Iki.

Fishery is a major industry in the coastal areas of the target sea area, and many aquaculture farms operate along the calm inlets. Table 1.1 shows the types of aquaculture product and the amount of aquaculture production in the prefectures of the target sea area. Figure 1.2 shows the areas where the fish/shellfish/seaweed aquaculture farms are operated in the target sea area.

The main aquaculture products in Yamaguchi Prefecture (side of Sea of Japan) are seaweed (Undaria pinnatifida), amberjack, red seabream and flatfish. In the north Kyushu sea area, the main aquaculture products of Fukuoka Prefecture are oyster, seaweed (Undaria pinnatifida) and prawn; and the main aquaculture products of Saga Prefecture are red seabream, amberjack, prawn and pearls. The main aquaculture products of Nagasaki Prefecture are amberjacks, red seabream, pufferfish, oyster and seaweeds (laver, Undaria pinnatifida); with particularly high production of amberjacks. Within the 4 prefectures, Nagasaki has the highest aquaculture production (21,424 tons in 2004).

Apart from aquaculture, the coastal fisheries in the target sea area generally target migratory fish species such as sardine, horse mackerel and Pacific mackerel; although there are some variations in the target species between the prefectures.

Table 1.1 The types of aquaculture products and the amount of aquaculture production in the prefectures of the target sea area

Area	Type of aquaculture product	Aquaculture production (ton)	Note
Yamaguchi Pref. (Sea of Japan)	Seaweed (Undaria pinnatifida), Amberjack, Red seabream, Flatfish, Shellfish, etc.	862 (In 2001)	• The following fish/shellfish are mainly caught by the coastal fisheries: Non-migratory species: Rockfish, Chicken grunt, Abalone, etc. Migratory species: Sardine, Horse mackerel, Pacific mackerel, Puffer fish, Tilefish, Squids, etc.
Fukuoka Pref. (North Kyushu sea area)	Oyster, Seaweed (Undaria pinnatifida), Prawn, etc.	199 (In 2004)	• Horse mackerel, Pacific mackerel and shellfish (Japanese littleneck) are mainly caught by the coastal fisheries.
Saga Pref. (North Kyushu sea area)	Red seabream, Amberjack, Prawn, Pearl oyster, etc.	Unknown	• Aquaculture production amounts to 80,460 t, if laver aquaculture production in Ariake Sea is included. • Red seabream, Flatfish, Flounder, Squid, Tiger prawn are mainly caught by the coastal fisheries.
Nagasaki Pref (West Kyushu sea area, remote islands)	Amberjack, Red seabream, Globefish, Oyster, Seaweed (laver, Undaria pinnatifida), etc.	21,424 (In 2004)	• Sardine, Horse mackerel, Squid and Pacific mackerel are mainly caught by the coastal fisheries.

Source:
Statistical Yearbook of Yamaguchi Prefecture
(http://www.pref.yamaguchi.jp/gyosei/tokei-b/nenkan/mokuji07.htm)

(http://www.pref.yamaguchi.lg.jp/cms/a16600/port/pdf.html)
(http://www.pref.yamaguchi.lg.jp/cms/a16500/uminari/uminari-top.html)

Fukuoka Prefecture Web Site
(http://www.pref.fukuoka.lg.jp/d07/fukuoka-gyoko.html)

Kyusyu Regional Agricultural Administration Office Web Site
(http://www.maff.go.jp/kyusyu/index.html)

Nagasaki Prefecture Web Site
(http://www.n-suisan.jp/yumetobi/)

Saga Prefecture Web Site
(http://www.pref.saga.lg.jp/web/gaiyou-gennkai.html)

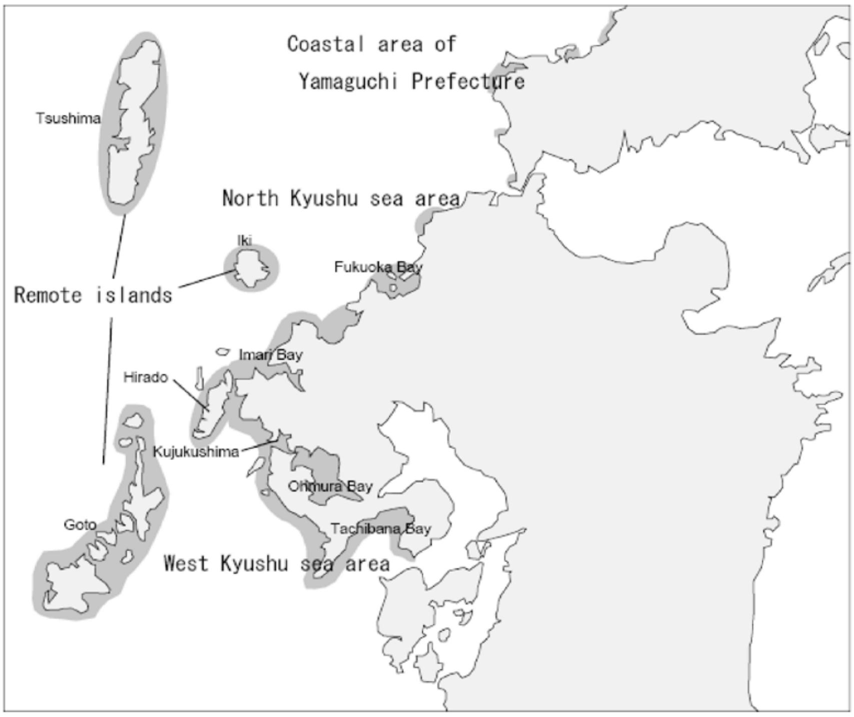


Figure 1.2 Areas where fish/shellfish/seaweed aquaculture farms are operated in the target sea area

2 Definitions of HAB and related regulations and standards

2.1 Definition of a HAB event

2.1.1 Definition of a red-tide event

Most red-tide events that were recorded in the reports of the monitoring organizations resulted from the red-tide surveys that the monitoring organizations conduct after water discoloration or fishery damage event is reported, such as by fishermen. In the above reports, a red-tide event was considered as '1 event' from the initiation to the cessation of water discoloration.

In this case study, the statistics on the red-tide events are based on the reports of the monitoring organizations. The reports also differentiate red-tide events that induced fishery damage, and provide information on the extent of damage caused by each red-tide. The case study, therefore also includes statistics on the red-tide events that induced fishery damage.

2.1.2 Definition of a toxin-producing plankton event

In order to prevent shipment of contaminated shellfish by toxin-producing planktons, monitoring organizations in the target sea area regularly inspect toxin levels in the harvested shellfish and also monitor for the presence of toxin-producing planktons in aquaculture areas. However, there are no established regulatory standards for toxin-producing planktons because shellfish contamination is not necessarily related to the concentration of toxin-producing planktons, i.e. shellfish contamination may occur even under low concentration of toxin-producing planktons. Monitoring organizations conduct the shellfish inspections mainly during the shipment period and stops shipment when the toxin levels exceed the set toxin standards (in Mouse Unit: MU). In Japan, inspections are conducted for toxins of diarrhetic shellfish poisoning (DSP) and paralytic shellfish poisoning (PSP).

In the case study, the monitoring results of the toxin-producing planktons and the status of shipment stoppage are presented.

2.2 Regulations and standards for HAB events

2.2.1 Regulations and standards for red-tide events

In order to prevent fishery damage, monitoring organizations have set 'warning/action standards' against red-tide species known to induce fishery damage. If the concentrations of these species exceed the set warning/action standards, the monitoring organizations issue warnings to fishermen and coastal users. Tables 2.1, 2.2 and 2.3 show the warning/action standards set by Nagasaki, Fukuoka and Yamaguchi Prefecture, respectively. Table 2.4 shows the red-tide species with warning/action standards for each prefecture.

Table 2.1 HAB warning/action standards of Nagasaki Prefecture

Species name	Warning/action standards (cells/mL)		Note (Affected fish/shellfish)
	Warning level*1	Action level*2	
Chattonella antiqua	1	10	Yellowtail, cockles etc.
Chattonella marina	1	10	Yellowtail etc.
Karenia mikimotoi	100	500	Fish, shellfish, crustaceans etc.
Cochlodinium polykrikoides	50	500	Yellowtail, red seabream, pufferfish, striped jack etc.
Heterosigma akashiwo	1,000	10,000	Yellowtail, grouper etc.
Heterocapsa circularisquama	10	50	Shellfish (mainly bivalves)

*1Warning level: Track plankton movement/Stop or prepare to stop feeding/ Move or prepare to move fish-cage
*2Action level: Stop feeding or move fish cage
Source: Nagasaki Prefectural Institute of Fisheries
(http://www.marinelabo.nagasaki.nagasaki.jp/news/gyorendayori/H13/1307no75akasio-tyui.pdf)

Table 2.2 HAB warning/action standards of Fukuoka Prefecture

Species name	Warning/action standards (cells/mL)		Note
	Warning level	Action level *1	
Heterosigma akashiwo	-	10,000	

*1 Action level: Levels that could cause fish mortality
Source: Website of Fukuoka Fisheries and Marine Technology Research Center
(http://www.sea-net.pref.fukuoka.jp/)

Table 2.3 HAB warning/action standards of Yamaguchi Prefecture

Species name	Warning/action standards (cells/mL)		Note
	Warning level	Action level *1	
Karenia mikimotoi	500	5,000	
Heterosigma akashiwo	5,000	50,000	

*1 Action level: Levels that could cause fish mortality
Source:Yamaguchi Prefecture Web Site" (http://www.pref.yamaguchi.lg.jp/cms/a16500/uminari/uminari-top.html)

Table 2.4 Red-tide species with warning/action standards by each prefecture

Species name	Nagasaki	Saga	Fukuoka	Yamaguchi
Dinophyceae				
Karenia mikimotoi	✔	✔	✔	✔
Cochlodinium polykrikoides	✔	✔		
Heterocapsa circularisquama	✔	✔	✔	

Raphidophyceae				
Chattonella antiqua	✔			
Chattonella marina	✔	✔		
Heterosigma akashiwo	✔	✔	✔	✔

Source:
Nagasaki Prefectural Institute of Fisheries (2007)
(http://www.marinelabo.nagasaki.nagasaki.jp/news/gyorendayori/H13/1307no75akasio-tyui.pdf)Saga Prefectural Genkai Fisheries Promotion Center (2007)
Fukuoka Fisheries and Marine Technology Research Center (2007)
(http://www.sea-net.pref.fukuoka.jp/gaiyo/oshirase.htm)
Yamaguchi Prefectural Fisheries Research Center (2007)
"(http://www.pref.yamaguchi.lg.jp/cms/a16500/uminari/uminari-top.html)

2.2.2 Regulations and standards for shellfish contamination

As described previously, there are no regulatory standards against toxin-producing planktons because shellfish contamination occurs even under low concentration of toxin-producing planktons. However, monitoring organizations regularly monitor for the presence of several toxin-producing plankton species during the shellfish harvest seasons. Table 2.5 shows the toxin-producing plankton species that are monitored by each prefecture.

Table 2.5 Toxin-producing plankton species that are regularly monitored by each prefecture

Species name	Nagasaki	Saga	Fukuoka	Yamaguchi
Dinophyceae				
Dinophysis spp. (*Dinophysis fortii, Dinophysis acuminata, Dinophysis caudata*)	✔	✔	✔	✔
Gymnodinium catenatum	✔	✔	✔	✔
Alexandrium spp. (*Alexandrium catenella, Alexandrium tamarense*)	✔	✔	✔	✔

Source:
Nagasaki Prefectural Institute of Fisheries (2007)
Saga Prefectural Genkai Fisheries Promotion Center (2007)
Fukuoka Fisheries and Marine Technology Research Center (2007)
Yamaguchi Prefectural Fisheries Research Center (2007)

In order to prevent shipment and harvesting of contaminated shellfish, monitoring organizations conduct regular inspections of shellfish that are produced at the shellfish farming areas. If the toxin level in the shellfish exceeds the regulatory standards, shipment will be stopped voluntarily. Warnings will also be sent to recreational shellfish diggers via the media. The regulatory standard is expressed in terms of per unit gram of wet shellfish meat, which is based on the notifications of the Ministry of Agriculture, Forestry and Fisheries and Ministry of Health, Labour and Welfare. The regulatory standards are 4 MU/g wet weight for PSP and 0.05 MU/g wet weight for DSP. In principal, shipment of shellfish will be stopped until the toxin levels return to acceptable levels for 3 consecutive inspections.

For reference: Website of Ministry of Agriculture, Forestry and Fisheries
(http://www.maff.go.jp/fisheat/fish-top.htm)

3 Framework and parameters of HAB monitoring

3.1 Monitoring framework

3.1.1 Framework of red-tide monitoring

To prevent fishery damages from red tides, monitoring organizations of each prefecture conduct 'regular red-tide monitoring' and 'post red-tide monitoring'. Post red-tide monitoring is conducted after receiving reports of red-tide events from fishery associations. Table 3.1 lists the sea areas that are regularly monitored by the monitoring organizations of each prefecture. Figures 3.1-3.3 show the locations of the regular red-tide monitoring sites in Fukuoka, Saga and Nagasaki Prefecture, respectively. Figure 3.4 shows the locations of the fishery associations in Nagasaki Prefecture that report on red-tide events to the monitoring organizations.

Table 3.1 Sea areas that are regularly monitored by the monitoring organizations of each prefecture (red tide)

Monitoring organization	Monitored sea area
Nagasaki Prefectural Institute of Fisheries (http://www.marinelabo.nagasaki.nagasaki.jp/)	Northern Kyushu Imari Bay, Hirado (Usuka/Furue Bay) Western Kyushu Ohmura Bay, Tachibana Bay, coasts of Kitamatsu, Kujukushima, coast of Seihi, Ariake Sea Remote Islands Goto, Iki, Tsushima
Saga Prefectural Genkai Fisheries Promotion Center (http://www.pref.saga.lg.jp/at-contents/shigoto/suisan/gensui/)	Northern Kyushu Karatsu Bay, Nagoyaura, Kariya Bay, Imari Bay
Fukuoka Fisheries and Marine Technology Research Center (http://www.sea-net.pref.fukuoka.jp/)	Northern Kyushu Fukuoka Bay, Karatsu Bay, Genkai Sea, Hibiki Sea
Yamaguchi Prefectural Fisheries Research Center (http://www.pref.yamaguchi.lg.jp/cms/a16500/uminari/uminari-top.html)	Coastal area of Yamaguchi Pref. (Sea of Japan)

Note: Regular red-tide monitoring is conducted in the sea areas enclosed by square line

Source:
Nagasaki Prefectural Institute of Fisheries (2007)
Saga Prefectural Genkai Fisheries Promotion Center (2007)
Fukuoka Fisheries and Marine Technology Research Center (2007)
Yamaguchi Prefectural Fisheries Research Center (2007)

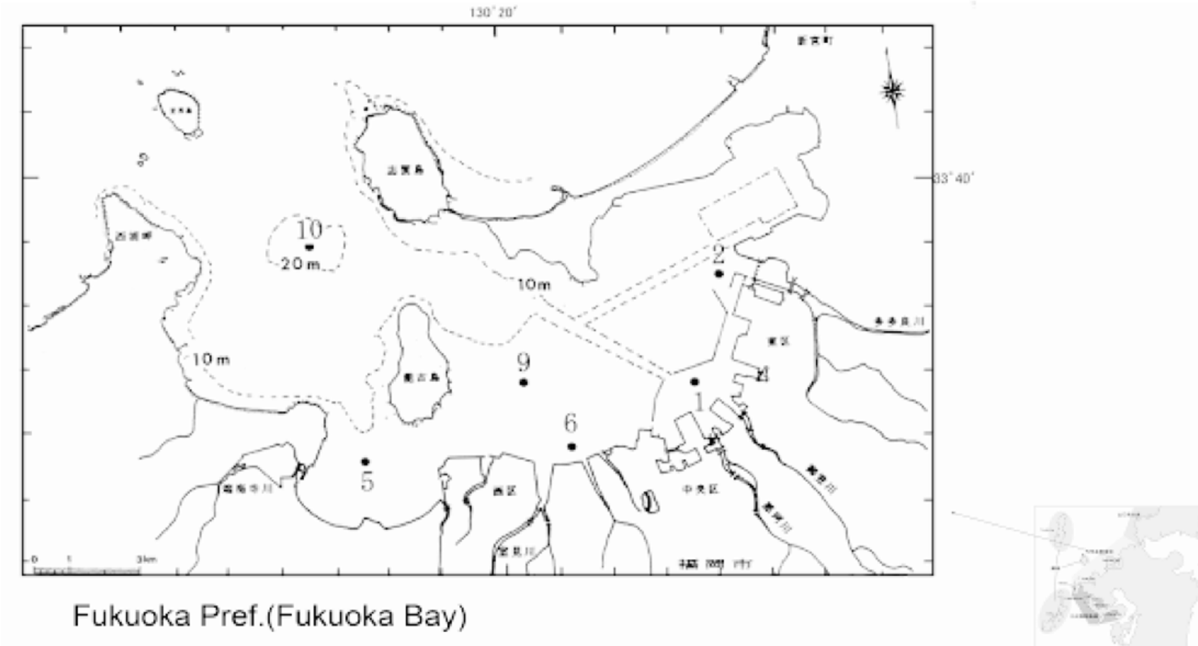


Figure 3.1 Regular red-tide monitoring sites in Fukuoka Prefecture
Source: Fukuoka Fisheries and Marine Technology Research Center (2007)

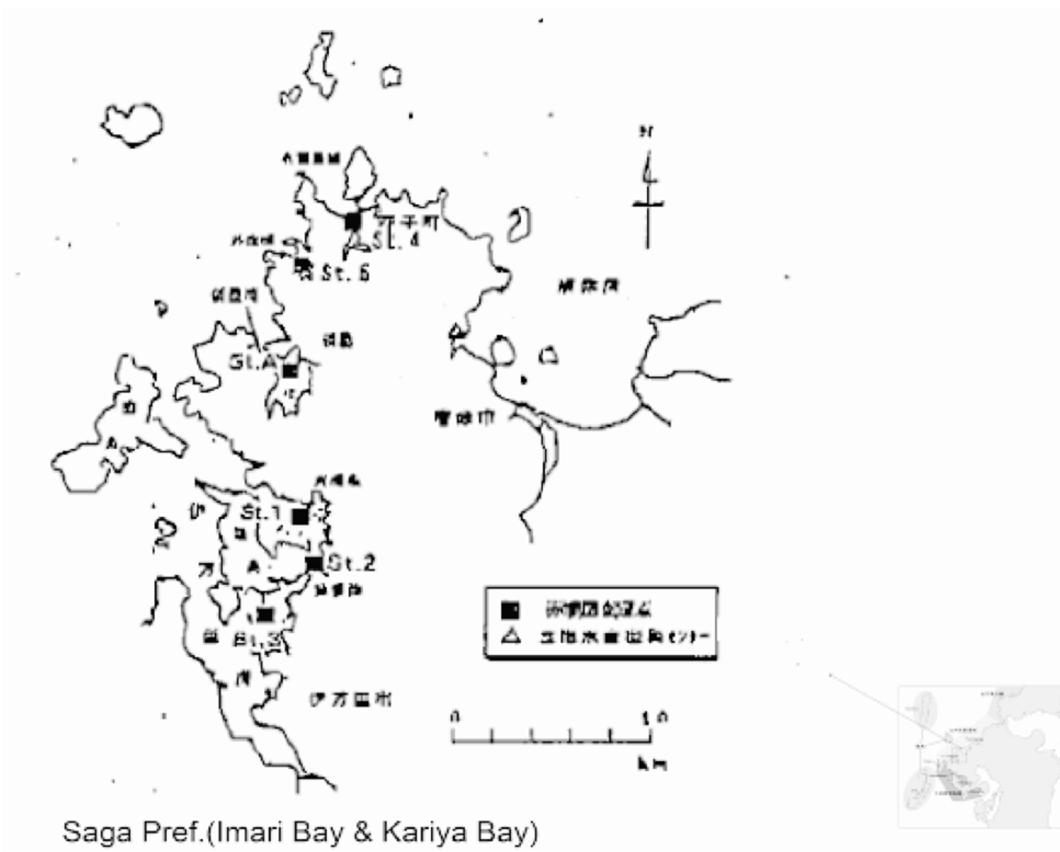


Figure 3.2 Regular red-tide monitoring sites in Saga Prefecture
Source: Saga Prefectural Genkai Fisheries Promotion Center (2007)

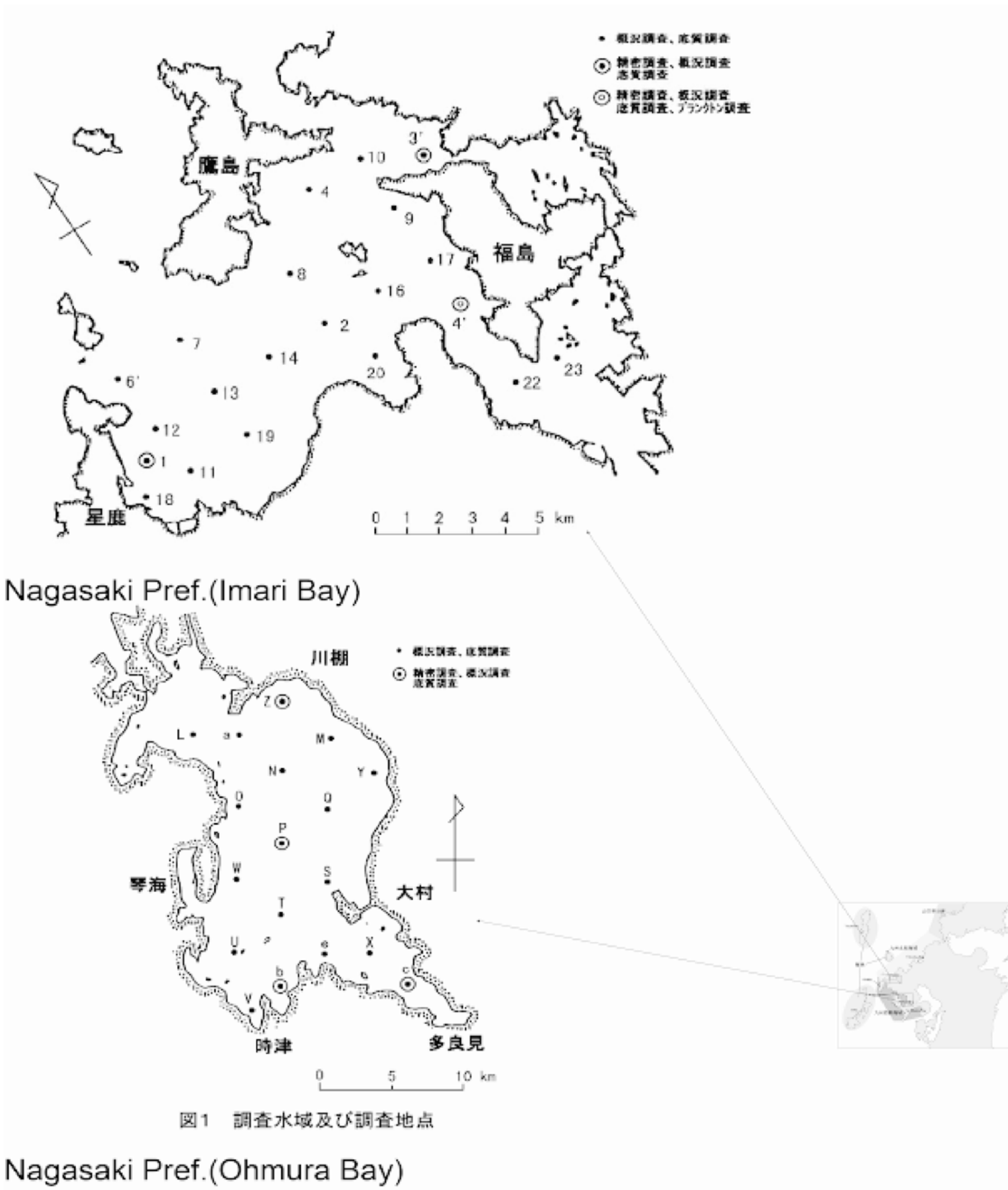


Figure 3.3 Regular red-tide monitoring sites in Nagasaki Prefecture

Source: Nagasaki Prefectural Institute of Fisheries (2007)

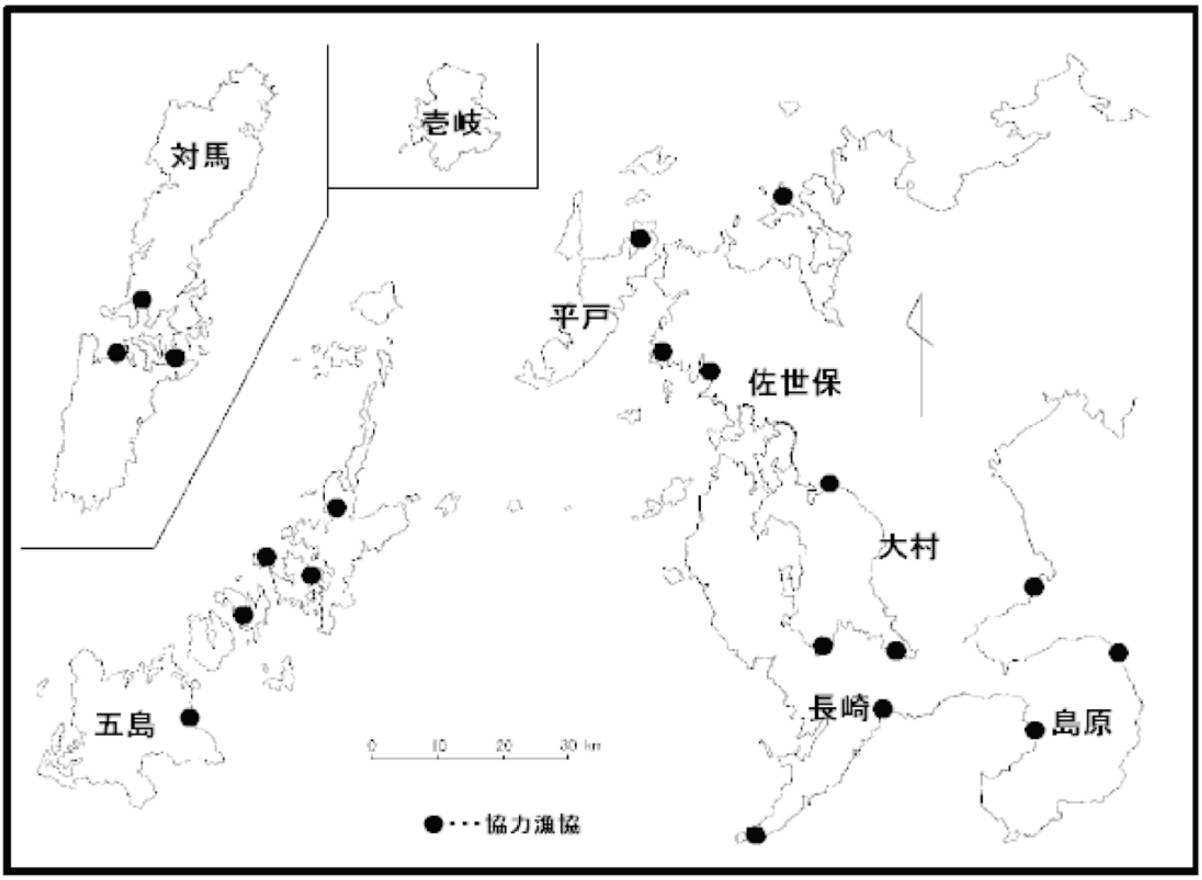


Figure 3.4 Locations of the fishery associations in Nagasaki Prefecture that cooperate in red-tide monitoring (the black dots indicate the locations of the fishery associations)
Source: Nagasaki Prefectural Institute of Fisheries (2007)

3.1.2 Framework of shellfish and toxin-producing plankton monitoring

In order to prevent shipment of contaminated shellfish by toxin-producing planktons, monitoring organizations conduct 'regular shellfish-contamination monitoring', which include inspections of toxin levels in shellfish and monitoring for the presence of toxin-producing planktons in the aquaculture areas. Table 3.2 lists the sea areas that are monitored by the monitoring organizations of each prefecture. Figures 3.5-3.8 show the locations of shellfish sampling and toxin-producing plankton monitoring sites in Yamaguchi, Fukuoka, Saga and Nagasaki Prefecture, respectively.

Table 3.2 Sea areas that are monitored by the monitoring organizations of each prefecture (shellfish and toxin-producing planktons)

Monitoring organization	Monitored sea area
Nagasaki Prefectural Institute of Fisheries (http://www.marinelabo.nagasaki.nagasaki.jp/)	Western Kyushu Tachibana bay Remote Islands Tsushima
Saga Prefectural Genkai Fisheries Promotion Center (http://www.pref.saga.lg.jp/at-contents/shigoto/suisan/gensui/)	Northern Kyushu Karatsu Bay, Nagoyaura, Kariya Bay, Imari Bay
Fukuoka Fisheries and Marine Technology Research Center (http://www.sea-net.pref.fukuoka.jp/)	Northern Kyushu Fukuoka Bay, Karatsu Bay

Yamaguchi Prefectural Fisheries Research Center (http://www.pref.yamaguchi.lg.jp/cms/a16500/uminari/uminari-top.html)	Coastal area of Sea of Japan Sensaki Bay

Source:
Nagasaki Prefectural Institute of Fisheries (2007)
Saga Prefectural Genkai Fisheries Promotion Center (2007)
Fukuoka Fisheries and Marine Technology Research Center (2007)
Yamaguchi Prefectural Fisheries Research Center (2007)

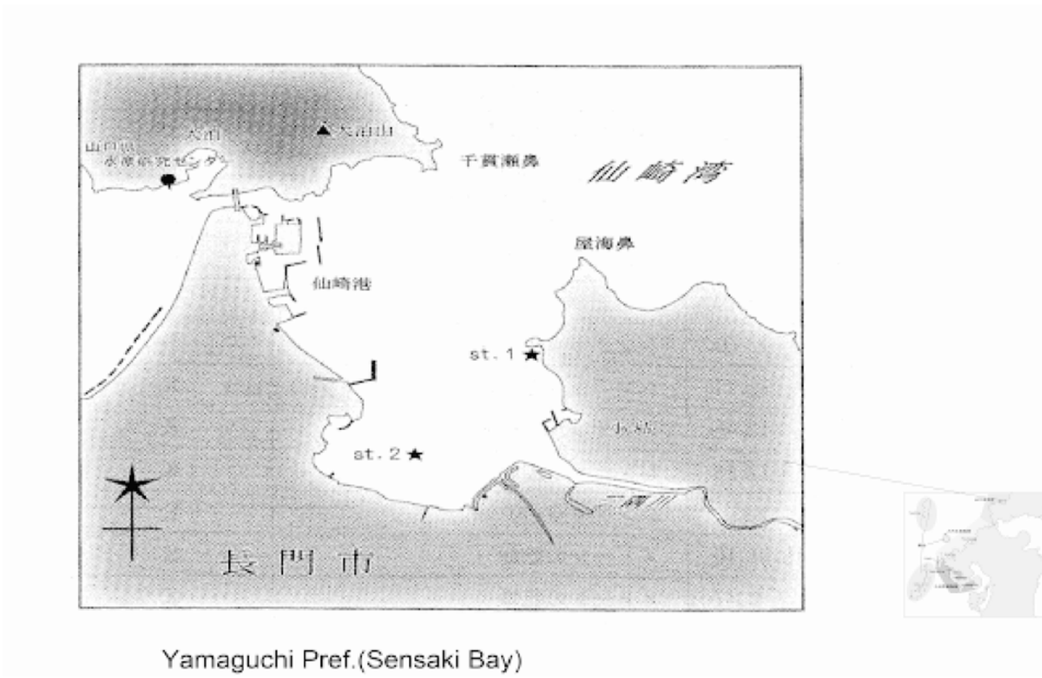


Figure 3.5 Locations of shellfish sampling and toxin-producing plankton monitoring sites in Yamaguchi Prefecture

Source: Yamaguchi Prefectural Fisheries Research Center (2007)

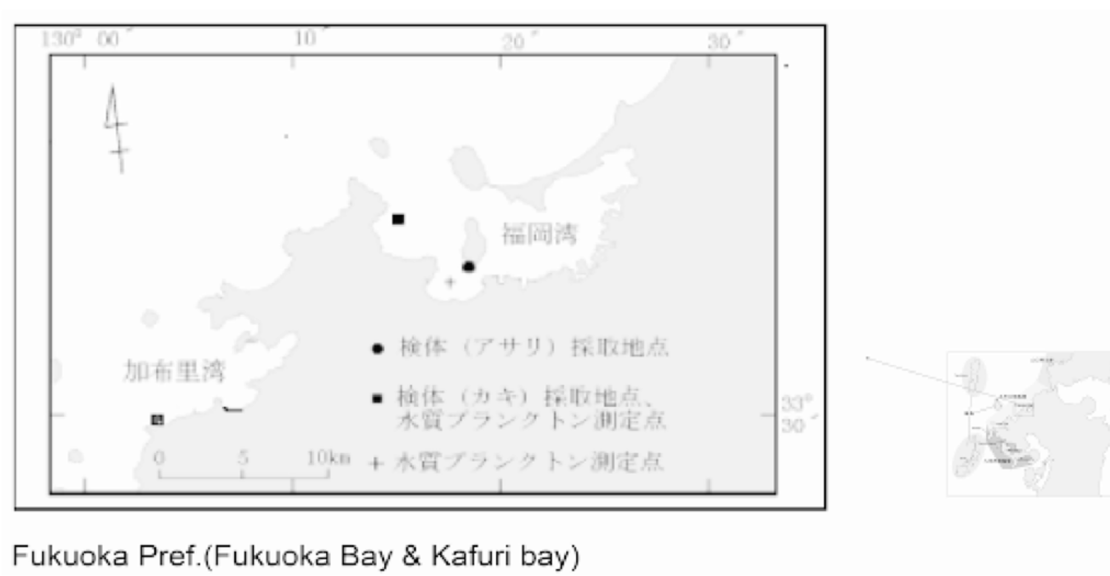


Figure 3.6 Locations of shellfish sampling and toxin-producing plankton monitoring sites in Fukuoka Prefecture

Source: Fukuoka Fisheries and Marine Technology Research Center (2007)

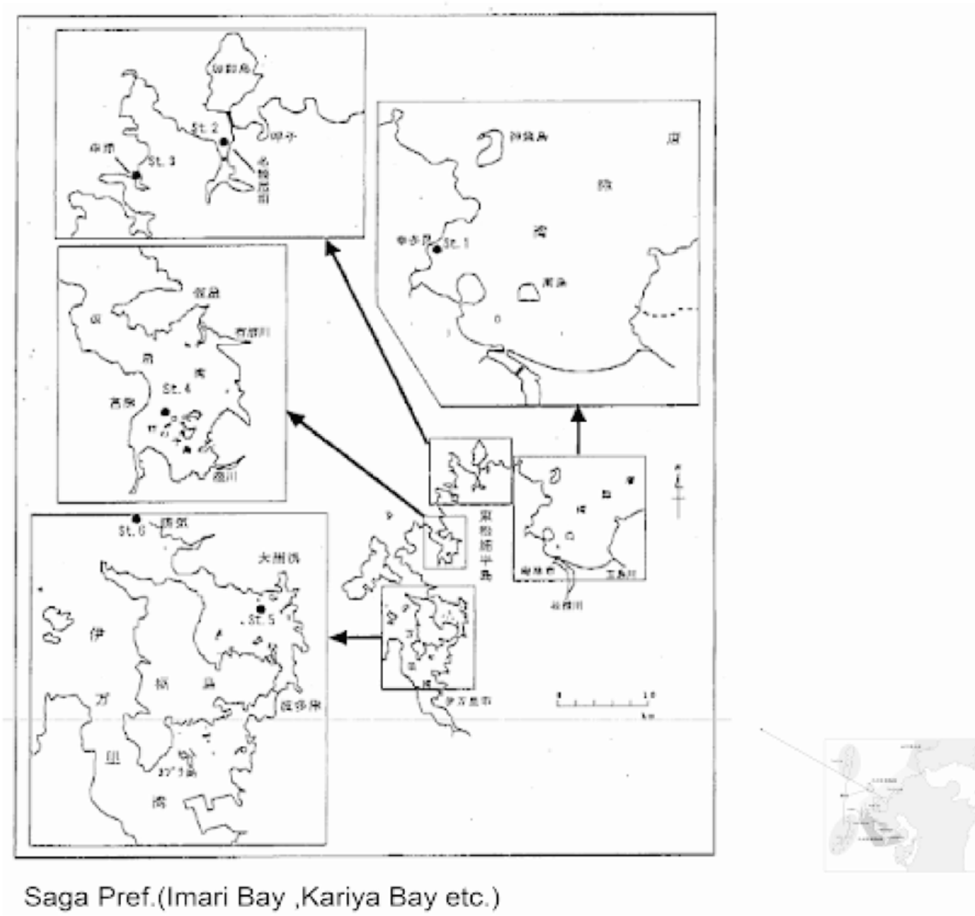


Figure 3.7 Locations of shellfish sampling and toxin-producing plankton monitoring sites in Saga Prefecture

Source: Saga Prefectural Genkai Fisheries Promotion Center (2007)

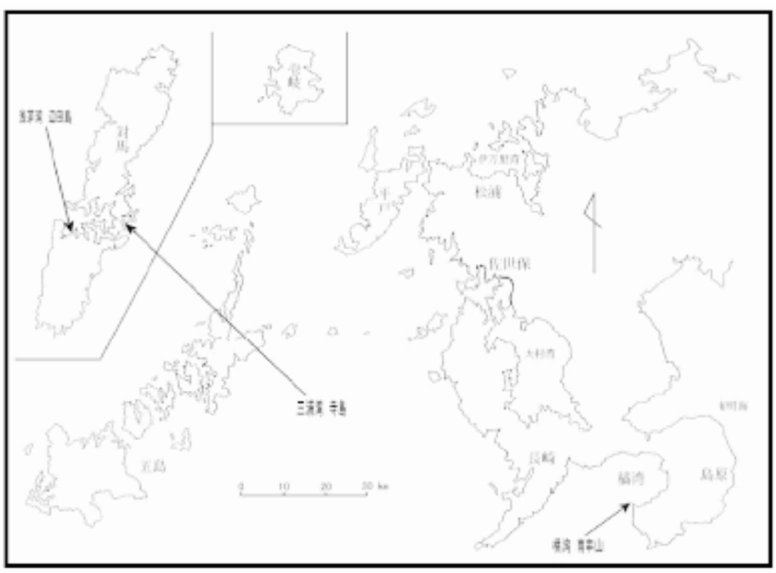


Figure 3.8 Locations of shellfish sampling and toxin-producing plankton monitoring sites in Nagasaki Prefecture

Source: Nagasaki Prefectural Institute of Fisheries (2007)

3.2 Monitoring parameters

As described in Section 3.1, the following three types of HAB related monitoring are conducted in the target sea area: post red-tide monitoring, regular red-tide monitoring and regular shellfish-contamination monitoring. Table 3.3 shows the objectives and monitoring parameters of the above monitoring types.

Post red-tide monitoring is conducted only after water discoloration or fishery damage is reported. Regular red-tide monitoring and regular shellfish-contamination monitoring are conducted regularly at fixed locations, irrespective of any HAB events.

Table 3.3 Objectives and monitoring parameters of the HAB monitoring

Monitoring type	Main objectives	Monitoring parameter				Monitoring frequency
		HAB	Water quality	Meteorology	Others	
Post red-tide monitoring	To monitor fishery damage by red tides	-Type of red-tide spp. (priority/causative spp.) -Cell concentration -Bloom area -Water color -Fishery damage	-Water temp. -Salinity -DO	None		Immediately after water discoloration or fishery damage is reported
Regular red-tide monitoring	To monitor the occurrence of red-tide regularly.	-Type of red-tide spp. -Cell concentration -Water color -Sedimentation	-Water temp. -Salinity -DO -pH -COD -Transparency -Nutrients -Chlorophyll-a	-Weather -Cloud cover -Wind direction/speed -Precipitation -Daylight time	Sediment quality	Fukuoka : 1/month Saga :1/month (May-October) Nagasaki : 1/month (June-October)
Regular shellfish-contamination monitoring	To monitor the occurrence of toxin-producing plankton spp.	-Type of toxin-producing plankton spp. -Cell concentration -Water color	-Water temp. -Salinity -DO -pH -Transparency -Nutrients -Chlorophyll-a			12-16/year (approx. 1/month)
	To monitor the shellfish poisoning				Toxin levels in shellfish (MU/g)	1/week until toxin levels in shellfish satisfy the regulatory standards

Source:
Nagasaki Prefectural Institute of Fisheries (2007)
Saga Prefectural Genkai Fisheries Promotion Center (2007)
Fukuoka Fisheries and Marine Technology Research Center (2007)
Yamaguchi Prefectural Fisheries Research Center (2007)

3.3 Data and information used in the HAB case study

Information and data on HAB events were mainly collected from the following sources:

- Reports published by organizations that conduct HAB monitoring in the target sea area
- Reports of the Fisheries Agency Kyushu regional office

Since the monitored parameters are slightly different between the monitoring organizations, the non-monitored parameters are left blank to indicate that there are no data.

Table 3.4 shows the monitoring parameters that will be referred in the case study.

Table 3.4 Monitoring parameters referred in the case study

	Monitoring parameter	Information/data source
HAB	-HAB species (priority/causative spp.) -Cell concentration -Bloom area -Fishery damage	Post red-tide monitoring
Water quality	-Water temperature -Salinity -DO	Post red-tide monitoring
Others	-Water quality Transparency, nutrients, chlorophyll-a -Meteorology Weather, cloud cover, wind direction/speed	Regular red-tide monitoring Regular shellfish-contamination monitoring

4 Status of HAB events

4.1 Status of red-tide events from 1979-2006

4.1.1 Number of red-tide events

Figure 4.1 shows the number of red-tide events that occurred in the target sea area from 1979-2006. A total of 1,274 red-tide events were recorded during this period, in which 112 events induced fishery damage.

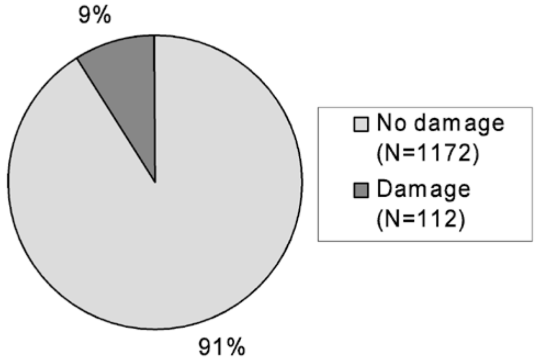


Figure 4.1 Number of red-tide events in the target sea area from 1979-2006

Note: Data of year 2005 and Yamaguchi Prefecture are not included (Data of 2005 should be available soon).

4.1.2 Number of red-tide events by year

Figure 4.2 shows the number of red-tide events by year in the target sea area. The annual number of red-tide events fluctuated between 29-92 events, and was highest in 1980 and lowest in 1997. The annual number of red-tide events that induced fishery damage fluctuated between 1-12 events. High number of events occurred in 1991 (10 events) and 2000 (12 events). The dinoflagellate *Karenia mikimotoi* was the main causative species of fishery damage in 1991 and 2000.

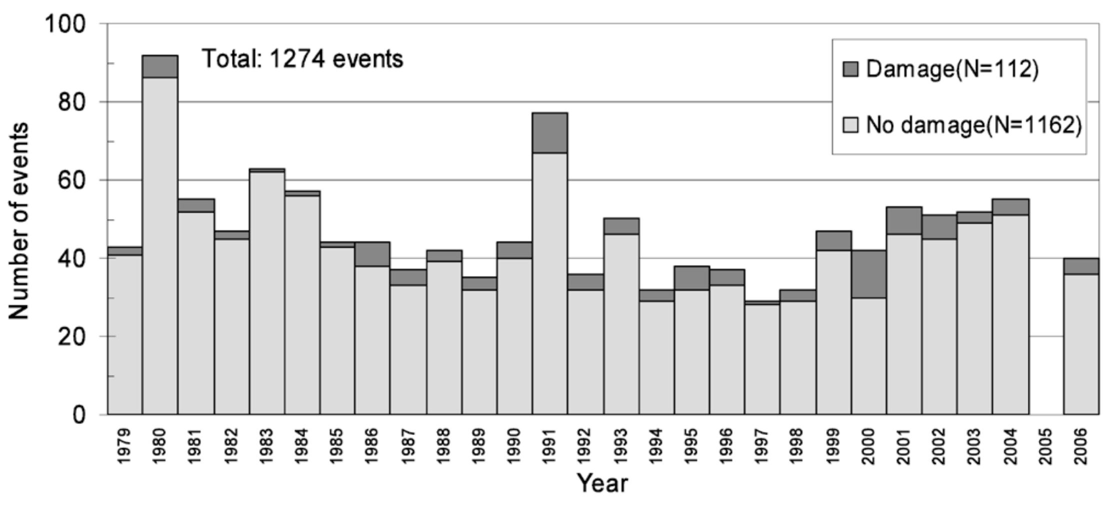


Figure 4.2 Number of red-tide events by year in the target sea area (1979-2006)

Note: Data of year 2005 and Yamaguchi Prefecture are not included (Data of 2005 should be available soon).
Source: Fisheries Agency (2006)

4.1.3 Number of red-tide events by month

Figure 4.3 shows the number of red-tide events by month in the target sea area. Approximately 50% of red-tide events occurred during June-August. Fishery damage occurred most frequently during July-August.

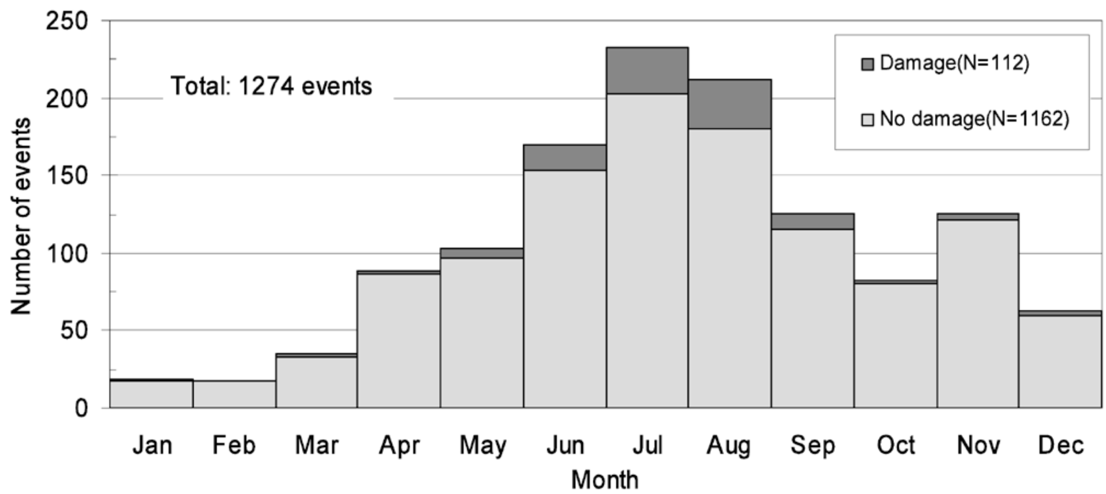


Figure 4.3 Number of red-tide events by month in the target sea area (1979-2006)

Note: Data of year 2005 and Yamaguchi Prefecture are not included (Data of 2005 should be available soon).
Source: Fisheries Agency (2006)

4.1.4 Types of red-tide species

Table 4.1 shows the red-tide species that were recorded in the target sea area and their frequency of occurrences from 1979-2006. A total of 98 red-tide species were recorded and were comprised from the following groups: dinoflagellates (35 species), diatoms (32 species), Raphidophyceae (7 species) and others (24 species). The following 7 species were recorded 50 or more times during 1979-2006: the dinoflagellates *Prorocentrum dentatum*, *Karenia mikimotoi* (=*Gymnodinium mikimotoi*), *Akashiwo sanguinea* (=*Gymnodinium sanguineum*), *Noctiluca scintillans;* the diatom *Skeletonema costatum*; the Raphidophyceae *Heterosigma akashiwo*; and the ciliate *Mesodinium rubrum*.

In regards to the red-tide species that are known to induce fishery damage (refer to Section 2.2), *Cochlodinium polykrikoides* was recorded 38 times and its frequency has increased over recent years. *Karenia mikimotoi* was recorded 142 times and has been constantly being recorded from 1979-2006. *Heterocapsa circularisquama* was recorded 16 times and was all after 1996. *Chattonella antique* was recorded 10 times and was all after 1990. *Chattonella marina* was recorded twice each in 1990 and 1992. *Heterosigma akashiwo* was recorded 84 times and has been constantly being recorded from 1985 onwards.

Table 4.1 Red-tide species recorded in the target sea area and their frequency of occurrences from 1979-2006

Genus and Species	1979 -1980	1981 -1985	1986 -1990	1991 -1995	1996 -2000	2001 -2005	2006	Total
Cyanophyceae								
Microcystis sp.			1					1
Trichodesmium erythraeum		1		1				2
Trichodesmium sp.		1						1
Cryptophyceae								
Cryptomonas sp.			1					1
Cryptophyceae							1	1
Dinophyceae								
Prorocentrum balticum				1				1
Prorocentrum compressum				1				1
Prorocentrum dentatum	2	6	16	21	16	3		64
Prorocentrum micans	2	3	2	2	1			10
Prorocentrum minimum	2	1			5	2	1	11
Prorocentrum sigmoides		19	5	8	6	6	2	46
Prorocentrum triestinum	3	8	9	10	3	1	3	37
Prorocentrum sp.	11	8	2	6	1		2	30
Cochlodinium polykrikoides				3	8	27	2	40
Cochlodinium sp.	5	5	4					14
Gymnodinium breve(=Karenia brevis)				5	1	1		7
Gymnodinium mikimotoi(=Karenia mikimotoi)	26	20	28	20	32	16	7	149
Gymnodinium sanguineum(=Akashiwo sanguinea)	4	6	6	18	6	12		52
Gymnodinium catenatum				1		1		2
Gymnodinium sp.(midorishio)		9	2	5				16
Gymnodinium sp.	8	20	6	8	4	1		47
Gyrodinium sp.	1		1	1	1	1		5
Pheopolykrikos hartmannii			1	4	2	2		9
Polykrikos sp.	3	4		1				8
Noctiluca scintillans	13	20	23	38	19	43	2	158
Noctiluca sp.		2			3	2	2	9
Heterocapsa circularisquama					8	8		16
Heterocapsa triquetra	2	1	2	1	1			7
Heterocapsa sp.				2	1	1		4
Peridinium quinquecorne				2				2
Peridinium sp.		1	1					2
Alexandrium affine				8				8
Alexandrium catenella						3		3
Alexandrium sp.			1	2				3
Gonyaulax polygramma	4			2				6
Gonyaulax sp.		1	1					2
Ceratium furca	4	1	2	6	4	1	3	21
Ceratium fusus	1	1						2
Ceratium sp.	1	1						2
Haptophyceae								
Emiliania huxleyi						1		1
Gephyrocapsa oceanica						2		2
Prymnesium sp.			1					1
Haptophyceae					1			1
Chrysophyceae								
Dictyocha fibula		1			1			2
Dictyocha sp.		1				1		2
Distephanus speculum			1					1
Distephanus sp.						1		1

Bacillariophyceae								
Skeletonema costatum	17	17	12	13	21	2	1	83
Skeletonema sp.		1			1	1		3
Thalassiosira diporocyclus						1		1
Thalassiosira sp.	11	3	3	8	10		1	36
Leptocylindrus danicus	1		2		2			5
Leptocylindrus minimus	1		2					3
Leptocylindrus sp.			1		2	1		4
Rhizosolenia alata	1							1
Rhizosolenia delicatula						1		1
Rhizosolenia sp.		2		1	2			5
Cerataulina bicornis		1	1					2
Cerataulina pelagica		1						1
Cerataulina sp.	1	1						2
Eucampia zodiacus				1				1
Chaetoceros affine		1						1
Chaetoceros curvisetum			1					1
Chaetoceros didymum		1	1					2
Chaetoceros lauderi		1						1
Chaetoceros pendulum	1							1
Chaetoceros subsecundum			1					1
Chaetoceros sp.	2	7	6	4	8	4		31
Lithodesmium variabile					1			1
Odontella sp.	1							1
Asterionella glacialis	1	2						3
Asterionella sp.					1			1
Neodelphineis pelagica		2	1		2			5
Pseudo-nitzschia pungens				1		1		2
Pseudo-nitzschia seriata	1							1
Pseud-nitzschia sp.					1			1
Nitzschia sp.		1	1		3			5
Diatoms (mixture of several spp.)							5	5
Raphidophyceae								
Chattonella antique			1	3	1	5		10
Chattonella globosa						2		2
Chattonella marina			2	2				4
Chattonella sp.			2		2			4
Fibrocapsa japonica			2	3	2			7
Heterosigma akashiwo		3	19	24	21	17	3	87
Heterosigma sp.		9	6	1				16
Olisthodiscus sp	12	8	1					21
Euglenophyceae								
Eutreptiella gymnastica						1		1
Eutreptiella sp.	2	3	1					6
Prasinophyceae								
Pyramimonas sp.						1		1
Tetraselmis sp.		1						1
Others								
Mesodinium rubrum	16	58	37	22	21	48	4	206
Mesodinium sp.	2							2
Unknown micro-flagellates					1	1		2
Stromdinium sp.							1	1
Tontonia sp.						1		1
Oithona brevicornis	1							1
Unidentified	14	22	5	4	1			46

Note:
*1: The underlined species indicate red-tide species that are known to induce fishery damage (refer to Section 2.2)
*2: Data of year 2005 and Yamaguchi Prefecture are not included (Data of 2005 should be available soon).
Source:
Fisheries Agency Kyushu regional office (1979-2006)
Nagasaki Prefectural Institute of Fisheries (2007)
Saga Prefectural Genkai Fisheries Promotion Center (2007)
Fukuoka Fisheries and Marine Technology Research Center (2007)

Yamaguchi Prefectural Fisheries Research Center (2007)

4.2 Status of shipment stoppage and the causative toxin-producing planktons

Table 4.2 shows the status of shipment stoppage caused by shellfish contamination in the target sea area. Shipment of shellfish has stopped 10 times during 1978-1999, and their duration ranged between 22-367 days. Shipment stoppage occurred in Senzaki Bay (coastal area of Yamaguchi Prefecture), Tsushima and Goto (both Nagasaki Prefecture). The contaminated shellfish were bivalves such as Japanese oyster and noble scallops, and were all contaminated by PSP-inducing toxins. The toxin levels in their meat ranged between 7.8-135 MU/g. The causative toxin-producing plankton species were *Gymnodinium catenatum* (at Senzaki Bay) and *Alexandrium catenella* (at Tsushima). Information on the status (e.g. cell concentration) of the causative species was not available.

Table 4.2 Status of shipment stoppage caused by shellfish contamination in the target sea area (1978-1999)

Date	Duration (day)	Region	Spot	Contaminated species	Toxin level (MU/g whole meet)		Causative species
					PSP	DSP	
24 Nov., 1988 - 10 Jan., 1989	48	Coastal area of Yamaguchi Pref.	Sensaki Bay	Japanese oyster	Unknown	-	*Gymnodinium catenatum*
27 Nov., 1991 - 14 Jan., 1992	49	Coastal area of Yamaguchi Pref.	Sensaki Bay	Japanese oyster	Unknown	-	*Gymnodinium catenatum*
6 Dec., 1995 - 23 Jan., 1996	49	Coastal area of Yamaguchi Pref.	Sensaki Bay	Japanese oyster	Unknown	-	*Gymnodinium catenatum*
4 Dec., 1996 - 21 Jan., 1997	49	Coastal area of Yamaguchi Pref.	Sensaki Bay	Japanese oyster	Unknown	-	*Gymnodinium catenatum*
7 Jan., 1998 - 28 Jan., 1998	22	Coastal area of Yamaguchi Pref.	Sensaki Bay	Japanese oyster	Unknown	-	*Gymnodinium catenatum*
22 Dec., 1998 - 9 Mar., 1999	78	Coastal area of Yamaguchi Pref.	Sensaki Bay	Japanese oyster	Unknown	-	Unknown
20 Jan., 1994 - 28 Apr., 1994	99	Offshore island	Tsushima	Noble scallop	7.8	-	Unknown
9 Feb., 1996 - 25 May., 1996	106	Offshore island	Tsushima	Noble scallop	17.5	-	*Alexandrium catenella*
17 Dec., 1996 - 8 Feb., 1997	54	Offshore island	Tsushima	Noble scallop	33.9	-	Unknown
31 Mar., 1997 - 1 Apr., 1998	367	Offshore island	Tsushima	Bivalves such as oysters	135	-	Unknown

Source: Japan Fisheries Resource Conservation Association (JFRCA) (2001)

5 Status of recent HAB events and the associated environmental conditions

5.1 Status of red-tide events in 2006

5.1.1 Number of red-tide events

In 2006, a total of 40 red-tide events were recorded in the target sea area, in which 4 events induced fishery damage.

5.1.2 Number of red-tide events by month

Figure 5.1 shows the number of red-tide events that occurred in the target sea area by month. Red-tide events were recorded during February-March and May-November. The number of events was highest in July (15 events). Four events that occurred during July-August induced fishery damage.

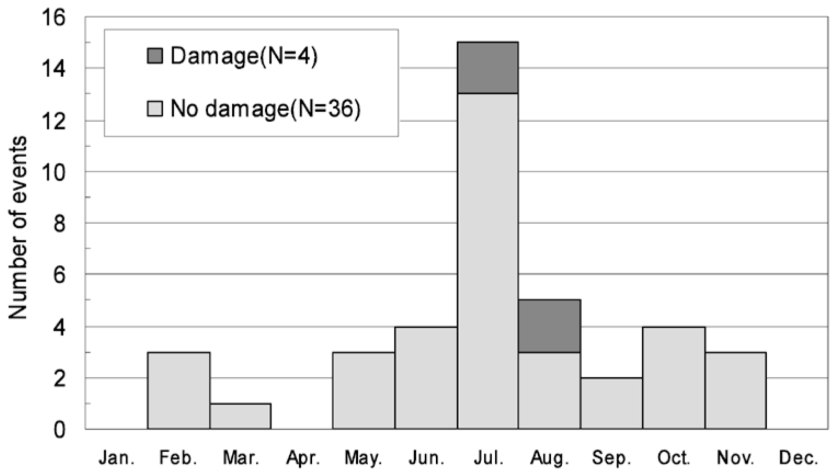


Figure 5.1 Number of red-tide events by month in the target sea area (2006)

Source:
Nagasaki Prefectural Institute of Fisheries (2007)
Saga Prefectural Genkai Fisheries Promotion Center (2007)
Fukuoka Fisheries and Marine Technology Research Center (2007)
Yamaguchi Prefectural Fisheries Research Center (2007)

5.1.3 Duration of red-tide events

Table 5.1 shows the number of red-tide events by duration (no. of days). Within the 39 events that were recorded in 2006 (the diatom red tide that occurred in July 2006 in Fukuoka Bay was excluded from the total as its duration was unknown), 20 events were under 5 days, 8 events between 6-10 days, 9 events between 11-30 days and 2 events were over 31 days. The longest duration was 45 days by *Heterosigma akashiwo*, which occurred in Ohumra Bay during May-June.

Table 5.1 Number of red-tide events by duration (2006)

Region	≤ 5 days	6-10 days	11-30 days	≥ 31 days	Total	Longest duration (days)
Coastal area of Yamaguchi Pref.	3	2(1)	1(1)		6(2)	23
Northern Kyushu	11	3	2(1)	1	17	21
Western Kyushu	5	2(1)	5	1	13(2)	45
Remote islands	1	1	1		3	12
Total	20	8(2)	9(2)	2	39 (4)	-

Note:
*1: The numbers in the parenthesis show the number of events that induced fishery damage
*2: The diatom red tide that occurred in July 2006 in Fukuoka Bay was excluded from the total as its duration was unknown
Source:
Nagasaki Prefectural Institute of Fisheries (2007)
Saga Prefectural Genkai Fisheries Promotion Center (2007)
Fukuoka Fisheries and Marine Technology Research Center (2007)
Yamaguchi Prefectural Fisheries Research Center (2007)

5.1.4 Location of red-tide events

Table 5.2 shows the number of red-tide events by sea area and the causative species. Figure 5.2 shows the location of the red-tide events and the causative species. Figure 5.3 shows the location of the red-tide events by months. In 2006, 6 events occurred in the coastal area of Yamaguchi Prefecture, 18 events in the north Kyushu sea area, 13 events in the west Kyushu sea area and 3 events in the remote islands. Red-tide events were particularly frequent in Imari Bay (north Kyushu sea area), Ohmura Bay and Kujyuku Island (both in west Kyushu sea area).

Table 5.2 Number of red-tide events by sea area (2006)

Year	Sea area		No. of events	Causative species	Note
	Region	Spot			
2006	Coastal area of Yamaguchi Pref.	Between the coast of Shimonoseki and Hagi City	6(2)	*Noctiluca scintillans, Noctiluca* sp. *Karenia mikimotoi, Mesodinium rubrum*	
	North Kyushu sea area	Fukuoka Bay	3	Diatoms	
		Karatsu Bay	2	*Mesodinium rubrum, Thalassiosira* sp.	
		Kariya Bay	1	*Skeletonema costatum*	
		Imari Bay	9(1)	*Ceratium furca, Karenia mikimotoi, Prorocentrum sigmoides, Prorocentrum triestinum*, Diatoms	
		Hirado (Usuka/Furue Bay)	1	*Cochlodinium polykrikoides*	
		Others	2	*Noctiluca scintillans, Karenia mikimotoi*	Chikuzen Sea, North Kyushu (Kanmon Straits)
	West Kyushu sea area	Ohmura Bay	7	Cryptophyceae, *Heterosigma akashiwo, Karenia mikimotoi , Prorocentrum sigmoides, Prorocentrum* spp.	
		Tachibana Bay	1	*Ceratium furca*	
		Kujuku Island	5(1)	*Strombidium* sp., *Prorocentrum* spp., *Mesodinium rubrum, Karenia mikimotoi, Prorocentrum minimum*	
	Remote islands	Goto Island	1	*Heterosigma akashiwo*	
		Tsushima	2	*Cochlodinium polykrikoides, Mesodinium rubrum*	
	Total		40(4)		

Note: The numbers in the parenthesis show the number of events that induced fishery damage
Source:
Nagasaki Prefectural Institute of Fisheries (2007)
Saga Prefectural Genkai Fisheries Promotion Center (2007)
Fukuoka Fisheries and Marine Technology Research Center (2007)
Yamaguchi Prefectural Fisheries Research Center (2007)

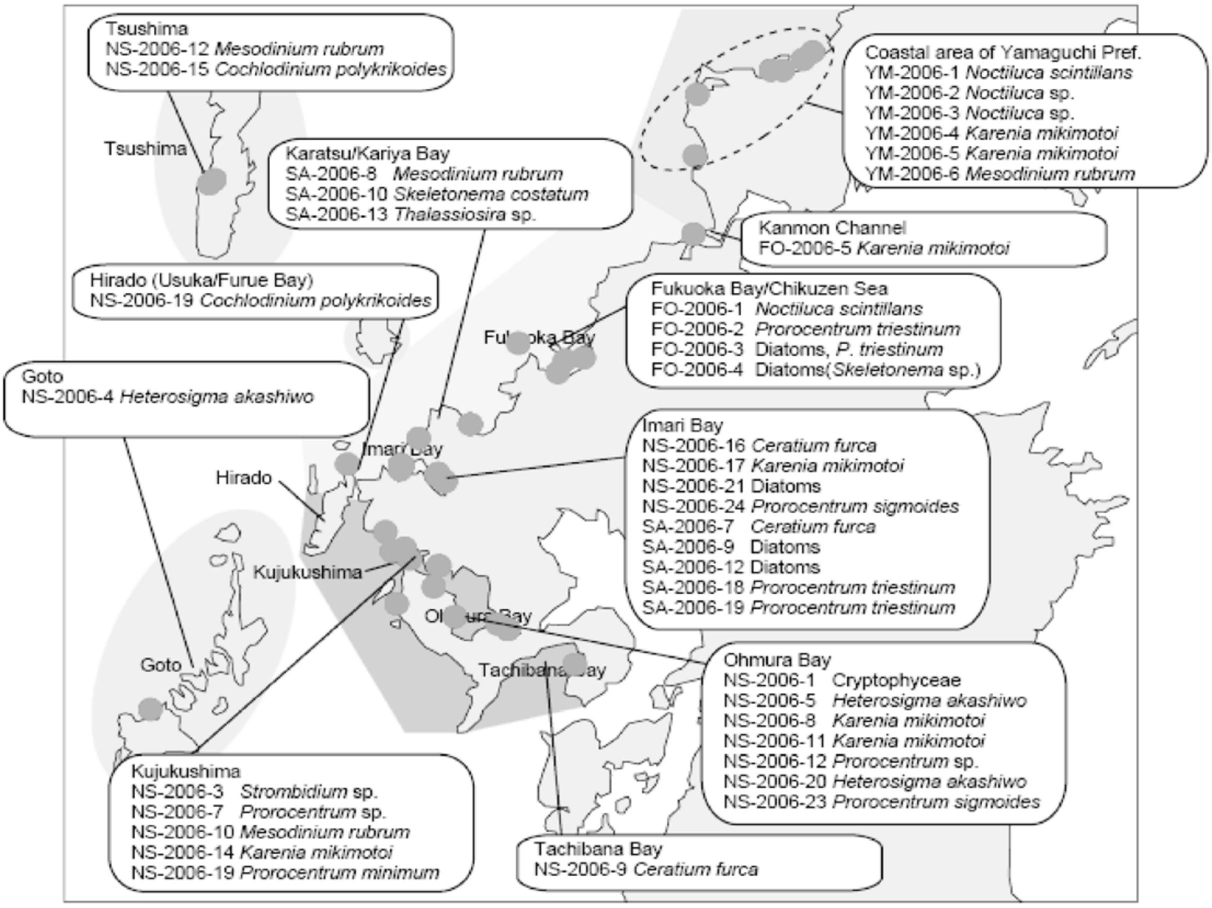
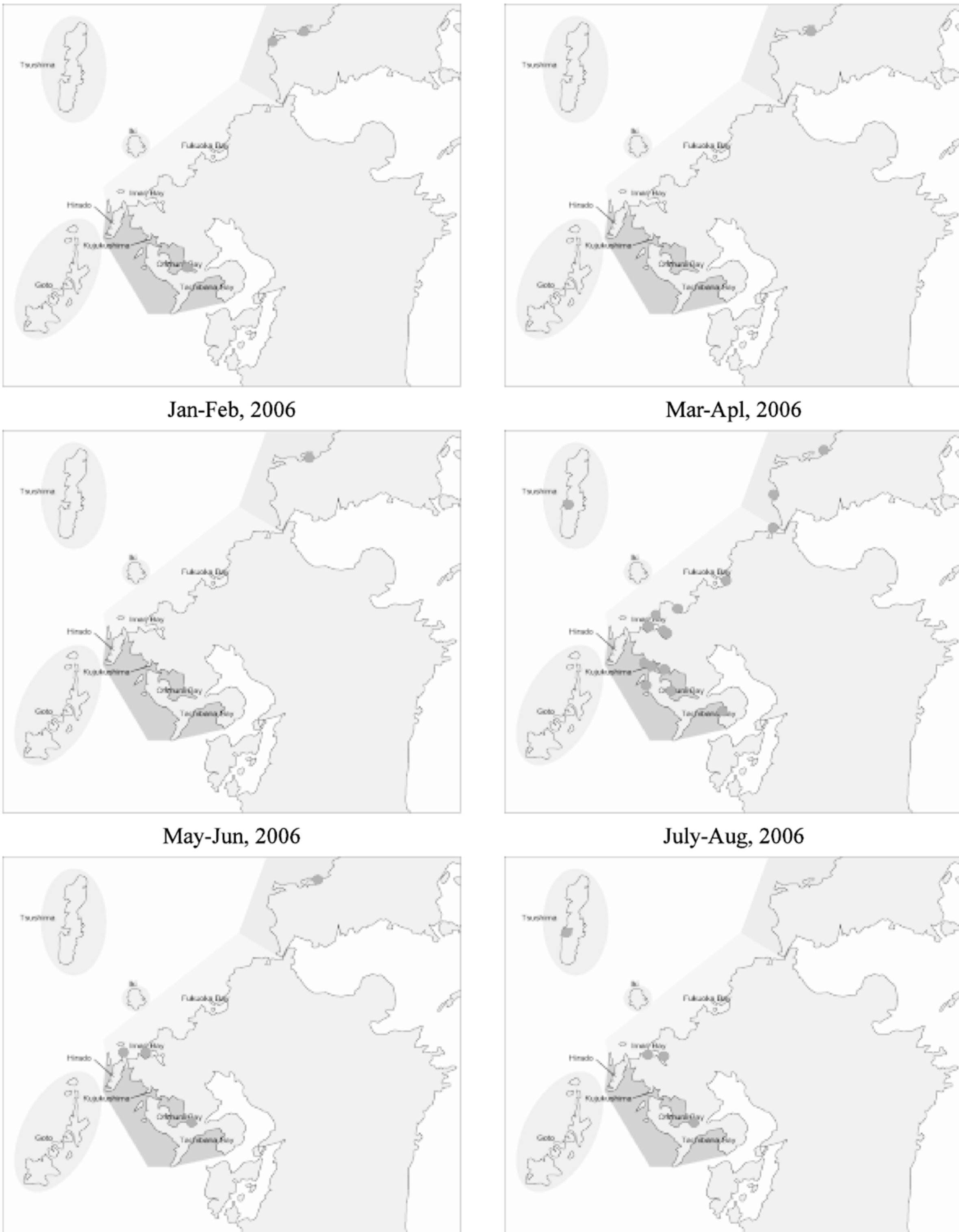


Figure 5.2 Location of red-tide events in 2006 (red dots show the location)



Jan-Feb, 2006 | Mar-Apl, 2006

May-Jun, 2006 | July-Aug, 2006

Sep-Oct, 2006 | Nov-Dec, 2006

Figure 5.3 Location of red-tide events by months in 2006
(red dots show the location)

5.1.5 Types of red-tide species

Table 5.3 shows the red-tide species that were recorded in the target sea area in 2006 and their frequency of occurrences. In 2006, a total of 15 red-tide species were recorded and were comprised from the following classes: Dinophyceae (9 species), Bacillariophyceae (2 species), Raphidophyceae (1 species) and others (3 species). Several red tides were caused by a mixture of diatom species. The most frequently recorded red-tide species were the dinoflagellate *Karenia mikimotoi* and diatom species. *Karenia mikimotoi* was also the only species that induced fishery damage in 2006.

Table 5.3 Red-tide species recorded in the target sea area and their frequency of occurrences (2006)

Genus and Species	Coastal area of Yamaguchi Pref.	North Kyushu sea area	West Kyushu sea area	Remote islands	Total
Dinophyceae					
Prorocentrum minimum			1		1
Prorocentrum sigmoides		1	1		2
Prorocentrum riestinum		3			3
Prorocentrum spp.			2		2
<u>*Cochlodinium polykrikoides*</u>		1		1	2
<u>*Karenia mikimotoi*</u>	2(2)	2(1)	3(1)		7(4)
Ceratium furca		2	1		3
Noctiluca scintillans	1	1			2
Noctiluca sp.	2				2
Bacillariophyceae					
Skeletonema costatum		1			1
Thalassiosira sp.		1			1
Diatoms (mixture of several spp.)		5			5
Raphidophyceae					
<u>*Heterosigma akashiwo*</u>			2	1	3
Others					
Cryptophyceae			1		1
Mesodinium rubrum	1	1	1	1	4
Strombidium sp.			1		1
合計	6(2)	18(1)	13(1)	3	40(4)

Note:
*1: The numbers in the parenthesis show the number of events that induced fishery damage
*2: The underlined species are known to cause fishery damage
Source:
Nagasaki Prefectural Institute of Fisheries (2007)
Saga Prefectural Genkai Fisheries Promotion Center (2007)
Fukuoka Fisheries and Marine Technology Research Center (2007)
Yamaguchi Prefectural Fisheries Research Center (2007)

5.1.6 Maximum cell concentration of red-tide events

Table 5.4 shows the maximum cell concentration of each red-tide event that occurred in the target sea area in year 2006. The highest maximum cell concentration was recorded in May 2006 at Ohmura Bay (west Kyushu sea area) by *Heterosigma akashiwo*, which reached up to 225,000 cells/mL.

Table 5.4 Maximum cell concentration of each red-tide event that occurred in the target sea area (2006)

Year	Event No.	Causative species	Density (cells or inds/mL)
2006	YM-2006-1	*Noctiluca scintillans*	2,150
2006	YM-2006-2	*Noctiluca* sp.	Unknown
2006	YM-2006-3	*Noctiluca* sp.	Unknown
2006	YM-2006-4	*Karenia mikimotoi*	57,500
2006	YM-2006-5	*Karenia mikimotoi*	4,900
2006	YM-2006-6	*Mesodinium rubrum*	68
2006	FO-2006-1	*Noctiluca scintillans*	200
2006	FO-2006-2	*Prorocentrum triestinum*	10,060
2006	FO-2006-3	*Skeletonema* sp. *Leptocylindrus* sp. *Chaetoceros* sp. other Diatom *Prorocentrum triestinum*	25,240 11,800 1,710 740 14,090
2006	FO-2006-4	*Skeletonema* sp. *Chaetoceros* sp. other Diatom	47,110 2,020 1,200
2006	FO-2006-5	*Karenia mikimotoi*	43,100
2006	SA-2006-7	*Ceratium furca*	340
2006	SA-2006-8	*Mesodinium rubrum*	1,180
2006	SA-2006-9	*Nitzschia* sp. *Thalassiosira* sp.	13,900 5,940
2006	SA-2006-10	*Skeletonema costatum*	11,140
2006	SA-2006-12	*Thalassiosira* sp. *Skeletonema costatum*	2520 1400
2006	SA-2006-13	*Thalassiosira* sp.	2,022
2006	SA-2006-18	*Prorocentrum triestinum*	7,240
2006	SA-2006-19	*Prorocentrum triestinum*	2,940
2006	NS-2006-1	Cryptophyceae	148,000
2006	NS-2006-3	*Strombidium* sp.	55
2006	NS-2006-4	*Heterosigma akashiwo*	11,800
2006	NS-2006-5	*Heterosigma akashiwo*	225,000
2006	NS-2006-7	*Prorocentrum* sp.	3,400
2006	NS-2006-8	*Karenia mikimotoi*	15,800
2006	NS-2006-9	*Ceratium furca*	6,650
2006	NS-2006-10	*Mesodinium rubrum*	13,570
2006	NS-2006-11	*Karenia mikimotoi*	92,200
2006	NS-2006-12	*Prorocentrum* spp.	721
2006	NS-2006-14	*Karenia mikimotoi*	8,504
2006	NS-2006-15	*Cochlodinium polykrikoides*	135
2006	NS-2006-16	*Ceratium furca*	667
2006	NS-2006-17	*Karenia mikimotoi*	16,100
2006	NS-2006-19	*Prorocentrum minimum*	12,800
2006	NS-2006-20	*Heterosigma akashiwo*	11,500
2006	NS-2006-21	Diatoms	16,220
2006	NS-2006-22	*Cochlodinium polykrikoides*	646
2006	NS-2006-23	*Prorocentrum sigmoides*	160
2006	NS-2006-24	*Prorocentrum sigmoides*	14,980
2006	NS-2006-25	*Mesodinium rubrum*	490

5.1.7 Status of red-tide induced fishery damage

Table 5.5 shows the fishery damages that were caused by the red tides in the target sea area in year 2006. Fishery damage occurred 4 times in 2006 and was all during July-August. All incidents were caused by *Karenia mikimotoi*. The fishery damages occurred in the coastal area of Yamaguchi Prefecture, Kujukuri Island (west Kyushu sea area) and Imari Bay (north Kyushu sea area). Cultured fish such as amberjack and puffer fish were affected and the financial losses ranged between 120,000-10,350,000 yen. Fishery damage by *Karenia mikimotoi* has also been reported from the Kanon Straits in July 2006 (Fukuoka Prefecture, 2007), but its details are unknown.

Table 5.5 Fishery damages caused by red-tides in the target sea area (2006)

Month/ Year	Event No.	Region	Spot	Causative Species	Fishery damage		
					Fish/Shellfish Species	Quantity	Economic loss (1,000 yen)
July, 2006	YM-2006-4	Coastal area of Yamaguchi Pref.	Coastline of Shimonoseki City	*Karenia mikimotoi*	Amberjack etc.	Amberjack 360 ind.	1,800
July, 2006	NS-2006-14	West Kyushu sea area	Kujuku island	*Karenia mikimotoi*	Puffer fish Red seabream	Puffer fish: 1,000 ind. Red seabream: 70 ind.	184
July, 2006	NS-2006-17	North Kyushu sea area	Imari Bay	*Karenia mikimotoi*	Puffer fish	6,900 ind.	10,350
Aug, 2006	YM-2006-5	Coastal area of Yamaguchi Pref.	Between Hagi City and Abu Town	*Karenia mikimotoi*	Kingfish	Kingfish 60 ind.	120

Source:
Nagasaki Prefectural Institute of Fisheries (2007)
Yamaguchi Prefectural Fisheries Research Center (2007)

5.2 Status of toxin-producing planktons and shipment stoppage in 2006

5.2.1 Status of toxin-producing planktons

Table 5.6 shows the concentration of PSP- and DSP-inducing species that were recorded in the target sea area in F.Y. 2006. The highest concentration of *Gymnodinium catenatum* was 1,211 cells/L, and was recorded in 17 January 2007 at Station 1 of Senzaki Bay. The highest concentration of *Alexandrium* spp. was 20,084 cells/L, and was recorded in May 30th, 2006 at Station 4 of Kariya Bay. The highest concentration of *Dinophysis* spp. was 512 cells/L, and was recorded in May 30th, 2006 at Station 1 of Kartsu Bay.

Table 5.6 Concentration of PSP- and DSP-inducing species that were recorded in the target sea area in F.Y. 2006 (Water depth: 0 m)

Monitoring date	Monitoring organization	Spot	Station	PSP-inducing species (cells/L)		DSP-inducing species (cells/L)
				Gymnodinium catenatum	*Alexandrium* spp.	*Dinophysis* spp.
2006.10.26	Yamaguchi .	Sensaki Bay	1	0	0	0
2006.11.6	Yamaguchi .	Sensaki Bay	1	16	0	0
2006.11.13	Yamaguchi .	Sensaki Bay	1	4	23	0
2006.11.27	Yamaguchi .	Sensaki Bay	1	164	152	0
2006.11.30	Yamaguchi .	Sensaki Bay	1	29	7	0
2006.12.6	Yamaguchi .	Sensaki Bay	1	114	0	0
2006.12.15	Yamaguchi .	Sensaki Bay	1	43	6	0
2006.12.22	Yamaguchi .	Sensaki Bay	1	77	0	0
2007.1.5	Yamaguchi .	Sensaki Bay	1	74	12	0
2007.1.12	Yamaguchi .	Sensaki Bay	1	0	4	0
2007.1.17	Yamaguchi .	Sensaki Bay	1	1211	115	0
2007.1.24	Yamaguchi .	Sensaki Bay	1	57	0	0
2007.1.31	Yamaguchi .	Sensaki Bay	1	12	0	0
2007.2.7	Yamaguchi .	Sensaki Bay	1	12	0	0
2007.2.19	Yamaguchi .	Sensaki Bay	1	0	0	0
2007.2.26	Yamaguchi .	Sensaki Bay	1	0	0	0
2006.10.26	Yamaguchi .	Sensaki Bay	2	0	0	0
2006.11.6	Yamaguchi .	Sensaki Bay	2	0	12	0
2006.11.13	Yamaguchi .	Sensaki Bay	2	4	10	0
2006.11.27	Yamaguchi .	Sensaki Bay	2	425	667	0
2006.11.30	Yamaguchi .	Sensaki Bay	2	341	216	0
2006.12.6	Yamaguchi .	Sensaki Bay	2	235	15	0
2006.12.15	Yamaguchi .	Sensaki Bay	2	32	0	0
2006.12.22	Yamaguchi .	Sensaki Bay	2	86	18	0
2007.1.5	Yamaguchi .	Sensaki Bay	2	58	14	0
2007.1.12	Yamaguchi .	Sensaki Bay	2	92	0	0
2007.1.17	Yamaguchi .	Sensaki Bay	2	16	0	0
2007.1.24	Yamaguchi .	Sensaki Bay	2	102	0	0
2007.1.31	Yamaguchi .	Sensaki Bay	2	39	0	0
2007.2.7	Yamaguchi .	Sensaki Bay	2	0	0	0
2007.2.19	Yamaguchi .	Sensaki Bay	2	0	0	0
2007.2.26	Yamaguchi .	Sensaki Bay	2	0	0	0
2006.4.11	Fukuoka .	Fukuoka Bay	1	0	0	1
2006.5.17	Fukuoka .	Fukuoka Bay	1	0	0	0
2006.6.7	Fukuoka .	Fukuoka Bay	1	0	0	0
2006.7.11	Fukuoka .	Fukuoka Bay	1	0	0	0
2006.8.10	Fukuoka .	Fukuoka Bay	1	0	0	0

2006.9.14	Fukuoka .	Fukuoka Bay	1	0	0	0
2006.10.12	Fukuoka .	Fukuoka Bay	1	0	0	37
2006.11.15	Fukuoka .	Fukuoka Bay	1	0	0	0
2006.12.12	Fukuoka .	Fukuoka Bay	1	0	0	70
2007.1.10	Fukuoka .	Fukuoka Bay	1	0	0	0
2007.2.9	Fukuoka .	Fukuoka Bay	1	0	0	36
2007.3.8	Fukuoka .	Fukuoka Bay	1	0	0	0
2006.4.11	Saga .	Karatsu Bay	1	0	0	0
2006.5.2	Saga .	Karatsu Bay	1	0	40	0
2006.5.23	Saga .	Karatsu Bay	1	0	4800	128
2006.5.30	Saga .	Karatsu Bay	1	0	0	512
2006.6.8	Saga .	Karatsu Bay	1	0	712	0
2006.8.8	Saga .	Karatsu Bay	1	0	296	0
2006.8.13	Saga .	Karatsu Bay	1	0	8	18
2006.8.20	Saga .	Karatsu Bay	1	10	58	0
2006.8.27	Saga .	Karatsu Bay	1	0	0	24
2006.7.3	Saga .	Karatsu Bay	1	0	0	80
2006.8.2	Saga .	Karatsu Bay	1	0	0	16
2006.9.4	Saga .	Karatsu Bay	1	0	0	0
2006.10.5	Saga .	Karatsu Bay	1	192	120	0
2006.11.2	Saga .	Karatsu Bay	1	48	0	0
2006.11.20	Saga .	Karatsu Bay	1	64	0	0
2006.12.1	Saga .	Karatsu Bay	1	0	32	40
2007.1.8	Saga .	Karatsu Bay	1	0	72	0
2007.1.16	Saga .	Karatsu Bay	1	0	48	0
2007.1.18	Saga .	Karatsu Bay	1	64	0	32
2007.1.22	Saga .	Karatsu Bay	1	0	0	48
2007.1.25	Saga .	Karatsu Bay	1	0	0	8
2007.2.2	Saga .	Karatsu Bay	1	0	0	56
2007.3.2	Saga .	Karatsu Bay	1	0	208	80
2006.10.2	Saga .	Nagoyaura	2	0	98	0
2006.11.1	Saga .	Nagoyaura	2	0	32	0
2006.12.4	Saga .	Nagoyaura	2	0	0	0
2007.1.4	Saga .	Nagoyaura	2	0	0	0
2007.1.12	Saga .	Nagoyaura	2	0	6488	0
2007.1.16	Saga .	Nagoyaura	2	0	1056	0
2007.1.18	Saga .	Nagoyaura	2	0	180	0
2007.1.22	Saga .	Nagoyaura	2	0	224	0
2007.1.25	Saga .	Nagoyaura	2	32	224	0
2007.2.2	Saga .	Nagoyaura	2	0	80	0
2007.3.1	Saga .	Nagoyaura	2	0	16	0
2006.10.2	Saga .	Kushiura	3	16	0	0
2006.11.1	Saga .	Kushiura	3	0	32	8
2006.12.4	Saga .	Kushiura	3	0	0	0
2007.1.4	Saga .	Kushiura	3	0	0	0
2007.1.16	Saga .	Kushiura	3	0	0	0
2007.1.18	Saga .	Kushiura	3	0	0	0
2007.1.22	Saga .	Kushiura	3	0	0	0
2007.1.20	Saga .	Kushiura	3	0	0	0
2007.2.1	Saga .	Kushiura	3	0	0	0
2007.3.1	Saga .	Kushiura	3	0	0	0
2006.5.24	Saga .	Kariya Bay	4	0	104	68
2006.5.30	Saga .	Kariya Bay	4	0	20084	16
2006.8.2	Saga .	Kariya Bay	4	0	788	16
2006.8.6	Saga .	Kariya Bay	4	0	72	8
2006.9.8	Saga .	Kariya Bay	4	0	0	0
2006.9.13	Saga .	Kariya Bay	4	0	0	8
2006.9.20	Saga .	Kariya Bay	4	0	0	0
2006.9.27	Saga .	Kariya Bay	4	0	0	0

2006.10.3	Saga .	Kariya Bay	4	88	40	0
2006.11.2	Saga .	Kariya Bay	4	0	0	48
2006.12.5	Saga .	Kariya Bay	4	0	0	0
2007.1.5	Saga .	Kariya Bay	4	0	0	0
2007.1.22	Saga .	Kariya Bay	4	0	0	0
2007.2.2	Saga .	Kariya Bay	4	0	8	0
2007.3.2	Saga .	Kariya Bay	4	0	0	8
2006.5.24	Saga .	Imari Bay	5	0	0	16
2006.5.30	Saga .	Imari Bay	5	0	0	16
2006.6.2	Saga .	Imari Bay	5	0	0	8
2006.6.8	Saga .	Imari Bay	5	0	0	0
2006.6.9	Saga .	Imari Bay	5	0	0	0
2006.6.13	Saga .	Imari Bay	5	0	0	24
2006.6.21	Saga .	Imari Bay	5	0	0	0
2006.10.2	Saga .	Imari Bay	5	0	0	0
2006.11.1	Saga .	Imari Bay	5	320	0	0
2006.12.4	Saga .	Imari Bay	5	0	0	0
2007.1.4	Saga .	Imari Bay	5	0	0	0
2007.1.22	Saga .	Imari Bay	5	0	0	18
2007.2.1	Saga .	Imari Bay	5	0	0	326
2007.3.1	Saga .	Imari Bay	5	0	0	0
2006.4.3	Saga .	Imari Bay	6	0	0	0
2006.5.1	Saga .	Imari Bay	6	0	0	0
2006.5.24	Saga .	Imari Bay	6	0	0	0
2006.5.30	Saga .	Imari Bay	6	0	0	0
2006.6.2	Saga .	Imari Bay	6	0	0	144
2006.6.8	Saga .	Imari Bay	6	0	24	32
2006.6.9	Saga .	Imari Bay	6	0	0	8
2006.6.13	Saga .	Imari Bay	6	0	0	72
2006.6.21	Saga .	Imari Bay	6	0	0	0
2006.6.28	Saga .	Imari Bay	6	0	0	0
2006.7.3	Saga .	Imari Bay	6	0	0	32
2006.8.1	Saga .	Imari Bay	6	0	0	0
2006.9.1	Saga .	Imari Bay	6	0	0	0
2006.12.5	Saga .	Imari Bay	6	0	0	8
2007.1.4	Saga .	Imari Bay	6	0	0	0
2007.1.22	Saga .	Imari Bay	6	0	0	24
2007.2.1	Saga .	Imari Bay	6	0	0	58
2007.3.1	Saga .	Imari Bay	6	0	0	96
2006.4.13	Nagasaki ..	Tsushima	Terashima	0	0	0
2006.5.16	Nagasaki ..	Tsushima	Terashima	0	0	0
2006.6.19	Nagasaki ..	Tsushima	Terashima	0	0	0
2006.7.12	Nagasaki ..	Tsushima	Terashima	0	0	0
2006.8.22	Nagasaki ..	Tsushima	Terashima	0	0	0
2006.9.19	Nagasaki ..	Tsushima	Terashima	0	0	0
2006.10.10	Nagasaki ..	Tsushima	Terashima	0	0	0
2006.11.13	Nagasaki ..	Tsushima	Terashima	0	0	0
2006.12.6	Nagasaki ..	Tsushima	Terashima	0	0	0
2007.1.15	Nagasaki ..	Tsushima	Terashima	0	0	0
2007.2.13	Nagasaki ..	Tsushima	Terashima	0	0	0
2007.3.12	Nagasaki ..	Tsushima	Terashima	0	0	0
2006.4.17	Nagasaki ..	Tsushima	Hetajima	0	0	0
2006.5.16	Nagasaki ..	Tsushima	Hetajima	0	0	0
2006.6.19	Nagasaki ..	Tsushima	Hetajima	0	0	0
2006.7.12	Nagasaki ..	Tsushima	Hetajima	10	0	0
2006.8.22	Nagasaki ..	Tsushima	Hetajima	0	0	0
2006.9.19	Nagasaki ..	Tsushima	Hetajima	4	0	0
2006.10.10	Nagasaki ..	Tsushima	Hetajima	0	2	0
2006.11.13	Nagasaki ..	Tsushima	Hetajima	0	0	0

2006.12.6	Nagasaki ..	Tsushima	Hetajima	0	0	0
2007.1.18	Nagasaki ..	Tsushima	Hetajima	0	0	0
2007.2.19	Nagasaki ..	Tsushima	Hetajima	0	0	0
2007.3.12	Nagasaki ..	Tsushima	Hetajima	0	0	0
2006.4.18	Nagasaki .	Tachibana Bay	South Kushiyama	0	2	0
2006.5.8	Nagasaki .	Tachibana Bay	South Kushiyama	0	0	0
2006.6.6	Nagasaki .	Tachibana Bay	South Kushiyama	0	0	0
2006.7.12	Nagasaki .	Tachibana Bay	South Kushiyama	0	0	0
2006.8.16	Nagasaki .	Tachibana Bay	South Kushiyama	0	0	0
2006.9.13	Nagasaki .	Tachibana Bay	South Kushiyama	0	0	0
2006.10.18	Nagasaki .	Tachibana Bay	South Kushiyama	0	0	6
2006.11.22	Nagasaki .	Tachibana Bay	South Kushiyama	0	0	0
2006.12.13	Nagasaki .	Tachibana Bay	South Kushiyama	0	0	0
2007.1.24	Nagasaki .	Tachibana Bay	South Kushiyama	0	0	0
2007.2.21	Nagasaki .	Tachibana Bay	South Kushiyama	0	0	0
2007.3.9	Nagasaki .	Tachibana Bay	South Kushiyama	0	0	0

Source:
Nagasaki Prefectural Institute of Fisheries (2007)
Saga Prefectural Genkai Fisheries Promotion Center (2007)
Fukuoka Fisheries and Marine Technology Research Center (2007)
Yamaguchi Prefectural Fisheries Research Center (2007)

5.2.2 Status of shipment stoppage

Table 5.7 shows the status of shipment stoppage by shellfish contamination in the target sea area in F.Y. 2006. Shipment of Japanese oyster was stopped in Senzaki Bay, Yamaguchi Prefecture from December 2006-February 2007. During the shipment stoppage, the toxin levels in the Japanese oyster's meat ranged between 6.18-12.2MU/g. The causative species was the PSP-inducing *Gymnodinium catenatum*, and its maximum cell density reached up to 1,211 cells/L during the shipment stoppage.

Table 5.7 Status of shipment stoppage by shellfish contamination in the target sea area (F.Y. 2006)

Date	Region	Spot	Affected Species	Toxin level (MU/g whole meet)		Causative species
				PSP	DSP	
26 Dec., 2006 - 21 Feb., 2007	Coastal area of Yamaguchi Pref.	Sensaki Bay	Japanese oyster	6.18 - 12.2	-	*Gymnodinium catenatum* (Max. concentration during shipment stoppage: 1,211 cells/L)

Source: Yamaguchi Prefectural Fisheries Research Center (2007)

5.3 Status of red-tide species that cause fishery damage in 2006

Monitoring organizations regularly monitor several red-tide species that are known to be particularly harmful to fisheries (refer to Section 2.2). Within the monitored species, the status of the following red-tide species is presented in this section, namely: the dinoflagellates *Karenia mikimotoi*, *Cochlodinium polykrikoides* and the Raphidophyceae *Heterosigma akashiwo*.

5.3.1 *Karenia mikimotoi*

In 2006, *Karenia mikimotoi* blooms were recorded 7 times and were all during July-August. The blooms occurred throughout the target sea area, such as: the coast of Shimonoseki City, the coast between Hagi City and Abu Town, Kanmon Straits, Imari Bay and Ohmura Bay. Figure 5.4 shows the locations of the *Karenia mikimotoi* blooms. The cell concentration during the blooms ranged between 8,504-92,200 cells/mL. Mortality of cultured fish was reported 4 times out of the 7 blooms.

5.3.2 *Cochlodinium polykrikoides*

In 2006, *Cochlodinium polykrikoides* blooms were recorded once each in July (Tsushima) and October (Hirato). Figure 5.4 shows the locations of the *Cochlodinium polykrikoides* blooms. The cell concentration during the blooms ranged between 135-646 cells/mL. There were no fishery damages reported through the *Cochlodinium polykrikoides* blooms.

5.3.3 *Heterosigma akashiwo*

In 2006, *Heterosigma akashiwo* blooms were recorded once each in May (Goto Islands), June and September (Ohmura Bay). Figure 5.4 shows the locations of the *Heterosigma akashiwo* blooms. The cell concentration during the blooms ranged between 11,500-225,000 cells/mL. There were no fishery damages reported through the *Cochlodinium polykrikoides* blooms.

Karenia mikimotoi

Cochlodinium polykrikoides

Heterosigma akashiwo

Figure 5.4 Location of blooms of harmful red-tide species in the target sea area in 2006 (blue dots show the location)

5.4 Environmental conditions during post red-tide monitoring

During the post red-tide monitoring, sea surface temperature (SST), salinity and DO are measured. Table 5.8 shows the SST, salinity and DO values obtained during the post red-tide monitoring in the target sea area in 2006. According to the monitoring results, SST ranged between 10.0-28.2 C°; salinity ranged between 26.3-34.9; and DO ranged between 5.2-14.5 mg/L.

Table 5.8 SST, salinity and DO values obtained during the post red-tide monitoring in the target sea area (2006)

Year	Event No.	Duration	Spot	SST	Salinity	DO
2006	YM-2006-1	2.20-2.27	Between Yuya Bay, Nagato City and the coast of Yoshimo, Shimonoseki City	10.0	-	-
2006	YM-2006-2	2.25-2.28	Coast of Nagato City (Sensaki Bay, Fukagawa Bay)	-	-	-
2006	YM-2006-3	3.27-3.29	Coast of Nagato City (Sensaki Bay)	-	-	-
2006	YM-2006-4	7.13-8.4	Coast of Shimonooseki City (Gaikai)	25.4	-	-
2006	YM-2006-5	8.2-8.11	Between Hagi City and the coast of Abu Town	28.2	-	-
2006	YM-2006-6	10.16-10.19	Nagato City (Nohase fishery port)	23.0	-	-
2006	FO-2006-1	6.5-6.12	West area of Chikuzen sea	-	-	-
2006	FO-2006-2	6.21-6.27	Fukuoka Bay	-	-	-
2006	FO-2006-3	6.29-?.?	Fukuoka Bay	-	-	-
2006	FO-2006-4	7.11-7.31	Fukuoka Bay	-	-	-
2006	FO-2006-5	7.18-7.26	Kanmon (North Kyushu)	-	-	-
2006	SA-2006-7	7.20-7.22	Imari Bay	-	-	-
2006	SA-2006-8	7.20-7.23	Karatsu Bay	-	-	-
2006	SA-2006-9	7.26-7.30	Imari Bay	-	-	-
2006	SA-2006-10	7.27-7.30	Kariya Bay	-	-	-
2006	SA-2006-12	8.21-8.25	Imari Bay	-	-	-
2006	SA-2006-13	8.22-8.23	Karatsu Bay	-	-	-
2006	SA-2006-18	11.20-11.22	Imari Bay	-	-	-
2006	SA-2006-19	11.27-11.28	Imari Bay	-	-	-
2006	NS-2006-1	2.24-3.15	Ohmura Bay	12.7	27.4	14.5
2006	NS-2006-3	5.1-5.2	Kujukushima	17.7	33.8	8.6
2006	NS-2006-4	5.15-5.26	Goto	19.5	27.0	9.5
2006	NS-2006-5	5.16-6.29	Ohmura Bay	-	-	-
2006	NS-2006-7	6.1-6.3	Kujukushima	-	-	-
2006	NS-2006-8	7.3-7.14	Ohmura Bay	-	-	-
2006	NS-2006-9	7.4-7.12	Tachibana Bay	-	-	-
2006	NS-2006-10	7.9-7.11	Kujukushima	-	-	-
2006	NS-2006-11	7.8-7.31	Ohmura Bay	-	-	-
2006	NS-2006-12	7.14-7.18	Ohmura Bay	25.3	29.1	8.1
2006	NS-2006-14	7.20-7.25	Kujukushima	-	-	-
2006	NS-2006-15	7.20-7.25	Tsushima	22.8	26.3	5.2
2006	NS-2006-16	7.21-7.23	Imari Bay	26.0	-	-
2006	NS-2006-17	7.25-8.11	Imari Bay	-	-	-
2006	NS-2006-19	8.21-8.25	Kujukushima	26.1	31.9	10.1
2006	NS-2006-20	9.6-9.21	Ohmura Bay	27.5	30.1	-
2006	NS-2006-21	9.22-9.26	Imari Bay	23.0	-	-
2006	NS-2006-22	10.11-10.13	Hirado(Usuka/Furue Bay)	23.0	33.0	7.9
2006	NS-2006-23	10.26-11.6	Ohmura Bay	-	-	-
2006	NS-2006-24	10.30-12.7	Imari Bay	-	-	-
2006	NS-2006-25	11.1-11.3	Tsushima	22.5	34.9	5.8

Source:
Nagasaki Prefectural Institute of Fisheries (2007)
Saga Prefectural Genkai Fisheries Promotion Center (2007)
Fukuoka Fisheries and Marine Technology Research Center (2007)
Yamaguchi Prefectural Fisheries Research Center (2007)

5.5 Environmental conditions during regular HAB monitoring

5.5.1 Environmental conditions during regular red-tide monitoring

During regular red-tide monitoring, water quality parameters such as transparency, nutrients and chlorophyll-a are measured in addition to the parameters (SST, salinity and DO) measured during post red-tide monitoring. Table 5.9 shows the water-quality values obtained during the regular red-tide monitoring in the target sea area in 2006.

In Fukuoka Prefecture, regular red-tide monitoring was conducted at Fukuoka Bay during April-December. In Saga Prefecture, regular red-tide monitoring was conducted at Imari Bay, Kariya Bay, Nagoyaura and Hokawazu Bay during June-October. In Nagasaki Prefecture, regular red-tide monitoring was conducted at Imari Bay and Ohmura Bay during June-October. The above regular red-tide monitoring were conducted approximately once a month.

Table 5.9 Water-quality values obtained during the regular red-tide monitoring in the target sea area in 2006 (Water depth: 0 m)

Monitoring date	Organization	Spot	Station	Transparency (m)	SST (C°)	Salinity	DO (mg/L)	DIN (μM)	NO3-N (μM)	NO2-N (μM)	NH4-N (μM)	PO4-P (μM)	Chl.a (μg/L)
2006.4.-	Fukuoka	Fukuoka Bay	-	-	14.6	27.9	-	19.46	-	-	-	0.32	-
2006.5.-	Fukuoka	Fukuoka Bay	-	-	17.6	31.1	-	30.35	-	-	-	0.53	-
2006.6.-	Fukuoka	Fukuoka Bay	-	-	21.7	31.3	-	19.59	-	-	-	0.09	-
2006.7.-	Fukuoka	Fukuoka Bay	-	-	23.8	31.6	-	10.93	-	-	-	0.46	-
2006.8.-	Fukuoka	Fukuoka Bay	-	-	30.1	29.9	-	10.92	-	-	-	0.10	-
2006.9.-	Fukuoka	Fukuoka Bay	-	-	24.4	29.9	-	16.06	-	-	-	0.57	-
2006.10.-	Fukuoka	Fukuoka Bay	-	-	22.5	31.6	-	11.42	-	-	-	0.12	-
2006.11.-	Fukuoka	Fukuoka Bay	-	-	17.6	32.3	-	13.30	-	-	-	0.22	-
2006.12.-	Fukuoka	Fukuoka Bay	-	-	14.3	32.2	-	36.34	-	-	-	0.65	-
2006.5.1	Saga	Imari Bay	1	4.3	16.9	32.0	8.4	5.41	2.01	0.91	2.49	0.09	1.7
2006.5.1	Saga	Imari Bay	2	4.1	17.0	31.6	8.2	2.17	0.61	0.22	1.33	0.05	1.9
2006.5.1	Saga	Imari Bay	3	4.5	17.2	31.7	8.9	1.73	0.69	0.18	0.86	0.09	2.2
2006.6.1	Saga	Imari Bay	1	5.7	21.5	31.7	7.9	2.47	1.45	0.06	0.96	0.15	1.2
2006.6.1	Saga	Imari Bay	2	3.9	21.9	31.4	8.1	2.13	0.67	0.06	1.40	0.11	4.1
2006.6.1	Saga	Imari Bay	3	4.7	21.4	31.4	8.4	1.79	0.85	0.07	0.87	0.08	1.2
2006.7.3	Saga	Imari Bay	1	2.9	25.6	25.0	8.9	4.03	2.40	0.09	1.54	0.12	8.9
2006.7.3	Saga	Imari Bay	2	2.8	25.6	25.2	8.4	2.26	0.83	0.09	1.34	0.25	7.3
2006.7.3	Saga	Imari Bay	3	2.8	25.2	25.3	8.3	1.79	0.67	0.07	1.05	0.12	10.3
2006.8.1	Saga	Imari Bay	1	4.8	29.9	26.3	7.8	1.29	1.28	0.01	0.00	0.06	2.1
2006.8.1	Saga	Imari Bay	2	4.5	29.9	26.6	7.8	0.77	0.74	0.03	0.00	0.04	1.9
2006.8.1	Saga	Imari Bay	3	3.9	29.7	27.0	8.1	0.59	0.57	0.02	0.00	0.06	1.5
2006.9.1	Saga	Imari Bay	1	7.3	26.8	30.1	6.9	4.10	1.32	0.02	2.76	0.05	3.9
2006.9.1	Saga	Imari Bay	2	6.6	26.9	29.2	6.5	4.81	1.68	0.13	3.01	0.24	1.5
2006.9.1	Saga	Imari Bay	3	7.8	28.5	29.6	6.3	6.42	4.30	0.06	2.05	0.24	1.3
2006.10.2	Saga	Imari Bay	1	4.7	23.4	30.9	6.3	2.82	1.79	0.09	0.94	0.19	5.9
2006.10.2	Saga	Imari Bay	2	3.8	23.3	30.9	6.0	1.29	58.00	0.11	0.60	0.23	7.1
2006.10.2	Saga	Imari Bay	3	4.2	23.1	30.1	6.9	5.27	1.37	0.08	3.83	0.07	2.8
2006.5.8	Saga	Kariya Bay	A	7.5	16.9	32.2	8.0	6.48	2.24	0.50	3.74	0.10	3.3
2006.6.2	Saga	Kariya Bay	A	4.8	20.3	32.7	9.1	4.79	3.10	0.08	1.61	0.11	7.3
2006.7.4	Saga	Kariya Bay	A	6.0	23.7	24.7	8.3	23.51	20.98	0.30	2.23	0.09	6.9
2006.8.2	Saga	Kariya Bay	A	8.5	29.1	28.8	8.2	7.52	7.08	0.11	0.32	0.07	2.8
2006.9.4	Saga	Kariya Bay	A	2.7	27.2	26.5	9.1	11.82	7.39	0.13	4.30	0.00	7.9
2006.10.3	Saga	Kariya Bay	A	5.2	23.0	31.2	5.7	6.81	2.26	0.34	4.21	0.12	9.2
2006.5.15	Saga	Nagoyaura	4	8.6	16.8	31.6	8.2	10.66	8.17	0.49	2.00	0.26	1.0
2006.6.1	Saga	Nagoyaura	4	6.2	19.4	33.7	9.2	5.84	1.19	0.11	4.55	0.16	1.6
2006.7.3	Saga	Nagoyaura	4	7.9	23.0	31.0	7.2	12.30	9.37	0.25	2.67	0.26	2.6
2006.8.1	Saga	Nagoyaura	4	7.5	26.7	29.0	8.4	7.01	5.94	0.17	0.90	0.11	2.9

2006.9.1	Saga	Nagoyaura	4	10.6	25.1	31.6	6.4	3.66	1.41	0.09	2.16	0.20	0.6
2006.10.2	Saga	Nagoyaura	4	6.7	23.1	31.7	6.1	5.26	3.62	0.21	1.44	0.07	5.2
2006.5.1	Saga	Sototsu	5	6.0	16.9	32.8	9.0	2.28	1.02	0.23	1.03	0.31	3.1
2006.6.1	Saga	Sototsu	5	5.5	20.8	33.4	8.6	1.54	0.49	0.08	0.97	0.11	3.7
2006.7.3	Saga	Sototsu	5	3.9	24.0	39.1	8.5	24.64	20.28	0.25	4.11	0.09	4.3
2006.8.2	Saga	Sototsu	5	6.2	28.0	31.8	9.1	3.29	2.30	0.09	0.90	0.05	2.2
2006.9.4	Saga	Sototsu	5	4.3	26.4	31.2	7.3	3.94	2.46	0.08	1.40	0.07	2.7
2006.10.3	Saga	Sototsu	5	5.1	23.3	31.0	7.1	7.05	5.61	0.22	1.22	0.18	3.6
2006.6.21	Nagasaki	Imari Bay	1	9.0	22.0	33.4	5.0	0.66	0.25	0.01	0.40	0.01	0.9
2006.6.21	Nagasaki	Imari Bay	3	5.0	23.5	32.7	5.0	0.26	0.04	0.03	0.19	0.06	1.5
2006.6.21	Nagasaki	Imari Bay	4	6.0	23.5	32.7	5.2	0.41	0.05	0.06	0.30	0.02	1.6
2006.7.18	Nagasaki	Imari Bay	1	8.0	24.1	32.7	5.2	-	-	-	-	-	2.7
2006.7.18	Nagasaki	Imari Bay	3	7.0	26.8	31.8	4.7	-	-	-	-	-	2.1
2006.7.18	Nagasaki	Imari Bay	4	7.0	25.9	32.3	4.9	-	-	-	-	-	2.3
2006.8.7	Nagasaki	Imari Bay	1	7.5	29.3	32.2	5.6	1.75	1.37	0.07	0.31	0.02	2.0
2006.8.7	Nagasaki	Imari Bay	3	7.0	30.1	31.0	5.1	0.70	0.24	0.05	0.41	0.03	0.6
2006.8.7	Nagasaki	Imari Bay	4	7.0	28.6	31.7	5.4	0.44	0.08	0.04	0.32	0.03	1.0
2006.10.18	Nagasaki	Imari Bay	1	5.0	23.5	33.1	5.0	0.96	0.23	0.06	0.67	0.07	4.8
2006.10.18	Nagasaki	Imari Bay	3	3.5	22.9	32.8	4.7	0.37	0.05	0.04	0.28	0.13	6.3
2006.10.18	Nagasaki	Imari Bay	4	4.5	22.7	32.9	4.8	0.95	0.67	0.06	0.22	0.07	4.0
2006.8.29	Nagasaki	Ohmura Bay	b	2.5	28.0	30.1	4.5	0.52	0.19	0.04	0.29	0.05	3.9
2006.8.29	Nagasaki	Ohmura Bay	c	3.0	28.5	30.0	4.2	1.65	0.17	0.07	1.41	0.04	2.7
2006.8.29	Nagasaki	Ohmura Bay	P	3.0	30.2	29.6	5.3	1.41	0.10	0.07	1.24	0.07	3.1
2006.8.29	Nagasaki	Ohmura Bay	Z	3.0	29.5	29.7	4.9	0.44	0.04	0.07	0.33	0.12	3.0
2006.9.20	Nagasaki	Ohmura Bay	b	3.5	25.6	29.5	5.0	4.65	3.98	0.34	0.33	0.07	18.7
2006.9.20	Nagasaki	Ohmura Bay	c	3.5	26.5	31.0	5.0	0.73	0.23	0.05	0.45	0.06	3.7
2006.9.20	Nagasaki	Ohmura Bay	P	5.0	26.5	31.6	4.5	0.99	0.39	0.12	0.48	0.17	3.9
2006.9.20	Nagasaki	Ohmura Bay	Z	4.5	26.5	31.6	4.6	1.24	0.42	0.24	0.58	0.22	9.5

Note:
1*: The values of Fukuoka Prefecture are the average of 6 monitoring stations.
2*: The nutrient concentration units of Saga Prefecture are in μg/L.

Source:
Nagasaki Prefectural Institute of Fisheries (2007)
Saga Prefectural Genkai Fisheries Promotion Center (2007)
Fukuoka Fisheries and Marine Technology Research Center (2007)

5.5.2 Environmental conditions during regular toxin-producing plankton monitoring

Table 5.10 shows the water-quality values obtained during the regular toxin-producing plankton monitoring in the target sea area in 2006.

Table 5.10 Water-quality values obtained during the regular toxin-producing plankton monitoring in the target sea area in 2006 (Water depth: 0 m)

Monitoringdate	Organiz-atoin	Spot	Survey point	Trans parency (m)	SST (C°)	Salinity	DO (mg/L)	DIN (μM)	NO3-N (μM)	NO2-N (μM)	NH4-N (μM)	PO4-P (μM)	Chl.a (μg/L)
2006.10.26	Yamaguchi	Sensaki Bay	1	-	20.5	32.8	-	-	-	-	-	-	-
2006.11.6	Yamaguchi	Sensaki Bay	1	-	20.0	32.6	-	-	-	-	-	-	-
2006.11.13	Yamaguchi	Sensaki Bay	1	-	17.9	31.1	-	-	-	-	-	-	-
2006.11.27	Yamaguchi	Sensaki Bay	1	-	17.2	32.8	-	-	-	-	-	-	-
2006.11.30	Yamaguchi	Sensaki Bay	1	-	17.4	33.1	-	-	-	-	-	-	-
2006.12.6	Yamaguchi	Sensaki Bay	1	-	15.0	33.2	-	-	-	-	-	-	-
2006.12.15	Yamaguchi	Sensaki Bay	1	-	15.3	33.3	-	-	-	-	-	-	-
2006.12.22	Yamaguchi	Sensaki Bay	1	-	14.8	33.5	-	-	-	-	-	-	-
2007.1.5	Yamaguchi	Sensaki Bay	1	-	13.5	33.9	-	-	-	-	-	-	-
2007.1.12	Yamaguchi	Sensaki Bay	1	-	13.3	33.8	-	-	-	-	-	-	-
2007.1.17	Yamaguchi	Sensaki Bay	1	-	13.3	33.9	-	-	-	-	-	-	-
2007.1.24	Yamaguchi	Sensaki Bay	1	-	13.6	34.3	-	-	-	-	-	-	-
2007.1.31	Yamaguchi	Sensaki Bay	1	-	9.1	28.9	-	-	-	-	-	-	-
2007.2.7	Yamaguchi	Sensaki Bay	1	-	12.5	33.6	-	-	-	-	-	-	-
2007.2.19	Yamaguchi	Sensaki Bay	1	-	13.3	34.1	-	-	-	-	-	-	-
2007.2.26	Yamaguchi	Sensaki Bay	1	-	12.5	33.7	-	-	-	-	-	-	-
2006.10.26	Yamaguchi	Sensaki Bay	2	-	21.1	33.1	-	-	-	-	-	-	-
2006.11.6	Yamaguchi	Sensaki Bay	2	-	20.0	32.7	-	-	-	-	-	-	-
2006.11.13	Yamaguchi	Sensaki Bay	2	-	18.9	33.2	-	-	-	-	-	-	-
2006.11.27	Yamaguchi	Sensaki Bay	2	-	17.8	33.1	-	-	-	-	-	-	-
2006.11.30	Yamaguchi	Sensaki Bay	2	-	16.8	32.8	-	-	-	-	-	-	-
2006.12.6	Yamaguchi	Sensaki Bay	2	-	15.0	33.2	-	-	-	-	-	-	-
2006.12.15	Yamaguchi	Sensaki Bay	2	-	15.2	32.9	-	-	-	-	-	-	-
2006.12.22	Yamaguchi	Sensaki Bay	2	-	14.4	33.4	-	-	-	-	-	-	-
2007.1.5	Yamaguchi	Sensaki Bay	2	-	13.9	33.9	-	-	-	-	-	-	-
2007.1.12	Yamaguchi	Sensaki Bay	2	-	13.2	33.9	-	-	-	-	-	-	-
2007.1.17	Yamaguchi	Sensaki Bay	2	-	13.4	33.9	-	-	-	-	-	-	-
2007.1.24	Yamaguchi	Sensaki Bay	2	-	13.0	34.1	-	-	-	-	-	-	-
2007.1.31	Yamaguchi	Sensaki Bay	2	-	12.5	34.1	-	-	-	-	-	-	-
2007.2.7	Yamaguchi	Sensaki Bay	2	-	12.9	34.2	-	-	-	-	-	-	-
2007.2.19	Yamaguchi	Sensaki Bay	2	-	13.2	34.0	-	-	-	-	-	-	-
2007.2.26	Yamaguchi	Sensaki Bay	2	-	13.3	34.2	-	-	-	-	-	-	-
2006.4.11	Fukuoka	Fukuoka Bay	1	-	14.4	33.0	-	-	-	-	-	-	-
2006.5.17	Fukuoka	Fukuoka Bay	1	-	18.0	30.3	-	-	-	-	-	-	-
2006.6.7	Fukuoka	Fukuoka Bay	1	-	21.9	32.3	-	-	-	-	-	-	-
2006.7.11	Fukuoka	Fukuoka Bay	1	-	24.1	32.5	-	-	-	-	-	-	-
2006.8.10	Fukuoka	Fukuoka Bay	1	-	30.6	30.4	-	-	-	-	-	-	-
2006.9.14	Fukuoka	Fukuoka Bay	1	-	24.0	28.6	-	-	-	-	-	-	-
2006.10.12	Fukuoka	Fukuoka Bay	1	-	23.2	32.0	-	-	-	-	-	-	-
2006.11.15	Fukuoka	Fukuoka Bay	1	-	17.4	32.8	-	-	-	-	-	-	-
2006.12.12	Fukuoka	Fukuoka Bay	1	-	13.8	32.3	-	-	-	-	-	-	-
2007.1.10	Fukuoka	Fukuoka Bay	1	-	10.2	33.6	-	-	-	-	-	-	-
2007.2.9	Fukuoka	Fukuoka Bay	1	-	11.7	33.7	-	-	-	-	-	-	-
2007.3.8	Fukuoka	Fukuoka Bay	1	-	11.3	33.8	-	-	-	-	-	-	-
2006.4.11	Saga	Karatsu Bay	1	7.9	14.1	32.6	8.2	1.20	0.60	0.20	0.49	0.04	-
2006.5.2	Saga	Karatsu Bay	1	7.8	15.7	33.0	8.0	1.99	0.60	0.37	1.02	0.13	-
2006.7.3	Saga	Karatsu Bay	1	4.0	23.1	32.0	7.9	2.10	0.37	0.11	1.62	0.08	3.7
2006.8.2	Saga	Karatsu Bay	1	8.0	27.2	32.4	8.5	3.40	1.29	0.07	2.04	0.03	0.7

2006.9.4	Saga	Karatsu Bay	1	5.0	27.2	29.4	8.3	1.07	0.27	0.05	0.76	0.09	12.6
2006.11.2	Saga	Karatsu Bay	1	5.0	21.4	33.3	7.7	3.41	1.15	0.02	2.25	0.03	1.9
2006.12.1	Saga	Karatsu Bay	1	3.0	17.2	33.5	7.1	11.97	5.90	1.78	4.31	0.56	1.3
2007.1.8	Saga	Karatsu Bay	1	3.0	13.1	33.8	8.5	7.01	4.14	1.23	1.05	0.28	1.0
2007.2.2	Saga	Karatsu Bay	1	8.5	12.2	32.1	7.9	3.25	1.10	0.79	1.36	0.13	0.6
2007.3.2	Saga	Karatsu Bay	1	3.0	12.5	33.6	8.6	4.01	1.63	0.68	1.71	0.20	1.2
2006.10.2	Saga	Nagoyaura	2	8.7	23.1	31.7	8.1	5.26	3.62	0.21	1.44	0.07	5.2
2006.11.1	Saga	Nagoyaura	2	4.8	21.8	32.3	8.5	2.51	0.83	0.37	1.31	0.11	3.1
2006.12.4	Saga	Nagoyaura	2	8.5	18.0	32.7	8.1	6.72	2.70	1.38	2.80	0.30	1.0
2007.1.4	Saga	Nagoyaura	2	7.5	15.6	33.1	7.1	4.85	1.86	0.88	1.91	0.29	0.7
2007.3.1	Saga	Nagoyaura	2	7.8	13.9	32.8	8.1	3.92	1.78	0.55	1.58	0.14	0.7
2006.10.2	Saga	Kushiura	3	4.5	22.9	31.5	8.0	5.33	2.07	0.32	2.04	0.20	1.2
2006.11.1	Saga	Kushiura	3	4.0	21.8	32.2	8.4	9.59	3.28	0.72	5.61	0.20	1.3
2006.12.4	Saga	Kushiura	3	5.7	17.8	32.9	8.4	5.17	2.58	1.47	1.14	0.32	1.6
2007.1.4	Saga	Kushiura	3	5.7	15.7	33.3	7.1	9.99	3.33	1.19	6.47	0.30	0.6
2007.2.1	Saga	Kushiura	3	5.4	13.3	33.1	7.2	6.84	2.33	1.12	3.18	0.30	0.5
2007.3.1	Saga	Kushiura	3	6.6	13.9	33.1	8.2	8.70	3.17	0.51	5.02	0.64	0.6
2006.10.3	Saga	Karitya Bay	4	4.3	22.6	29.9	7.3	-	-	-	-	-	-
2006.11.2	Saga	Karitya Bay	4	5.2	20.8	30.9	7.2	9.41	6.71	0.15	2.56	3.78	3.8
2006.12.5	Saga	Karitya Bay	4	7.1	16.4	32.0	7.4	-	-	-	-	-	-
2007.1.5	Saga	Karitya Bay	4	7.5	13.4	32.3	7.5	10.82	6.15	2.39	2.28	0.87	0.9
2007.2.2	Saga	Karitya Bay	4	8.0	12.1	32.6	7.7	4.81	2.20	1.00	1.61	1.78	1.8
2007.3.2	Saga	Karitya Bay	4	8.7	14.1	32.5	8.2	2.30	1.50	0.43	0.37	0.95	1.0
2006.10.2	Saga	Imari Bay	5	4.7	23.4	30.0	8.3	2.82	1.79	0.09	0.94	0.19	6.0
2006.11.1	Saga	Imari Bay	5	3.8	21.3	31.5	8.1	1.74	0.49	0.03	1.22	0.17	4.2
2006.12.4	Saga	Imari Bay	5	6.8	14.4	31.9	8.9	8.79	2.33	0.49	3.97	0.37	2.2
2007.1.4	Saga	Imari Bay	5	7.5	11.6	31.4	8.6	1.60	0.15	0.87	0.79	0.13	0.8
2007.2.1	Saga	Imari Bay	5	8.5	11.8	32.5	7.7	4.57	1.68	0.81	2.08	0.17	1.3
2007.3.1	Saga	Imari Bay	5	11.6	12.8	32.5	8.3	2.86	0.93	0.37	1.68	0.14	0.5
2007.1.4	Saga	Imari Bay	6	9.0	15.4	32.8	7.6	-	-	-	-	-	-
2007.2.1	Saga	Imari Bay	6	8.9	13.3	32.8	7.4	-	-	-	-	-	-
2007.3.1	Saga	Imari Bay	6	11.0	13.6	32.9	8.1	-	-	-	-	-	-
2006.4.13	Nagasaki	Tsushima	Terashima	9.2<	14.7	34.6	-	-	-	-	-	-	-
2006.5.16	Nagasaki	Tsushima	Terashima	8.0	16.5	34.7	-	-	-	-	-	-	-
2006.6.19	Nagasaki	Tsushima	Terashima	5.0	20.6	34.0	-	-	-	-	-	-	-
2006.7.12	Nagasaki	Tsushima	Terashima	2.5	22.5	31.7	-	-	-	-	-	-	-
2006.8.22	Nagasaki	Tsushima	Terashima	4.0	27.2	32.0	-	-	-	-	-	-	-
2006.9.19	Nagasaki	Tsushima	Terashima	4.0	24.3	31.5	-	-	-	-	-	-	-
2006.10.10	Nagasaki	Tsushima	Terashima	5.5	22.8	34.5	-	-	-	-	-	-	-
2006.11.13	Nagasaki	Tsushima	Terashima	8.0	20.1	35.2	-	-	-	-	-	-	-
2006.12.6	Nagasaki	Tsushima	Terashima	10.1	17.7	35.6	-	-	-	-	-	-	-
2007.1.15	Nagasaki	Tsushima	Terashima	9.0	15.5	35.8	-	-	-	-	-	-	-
2007.2.13	Nagasaki	Tsushima	Terashima	9.9<	14.6	34.3	-	-	-	-	-	-	-
2007.3.12	Nagasaki	Tsushima	Terashima	9.4<	13.9	34.3	-	-	-	-	-	-	-
2006.4.17	Nagasaki	Tsushima	Hetajima	9.5	14.6	34.3	-	-	-	-	-	-	-
2006.5.16	Nagasaki	Tsushima	Hetajima	7.0	16.6	34.8	-	-	-	-	-	-	-
2006.6.19	Nagasaki	Tsushima	Hetajima	10.0	20.9	33.6	-	-	-	-	-	-	-
2006.7.12	Nagasaki	Tsushima	Hetajima	2.5	22.2	31.1	-	-	-	-	-	-	-
2006.8.22	Nagasaki	Tsushima	Hetajima	8.0	26.6	31.5	-	-	-	-	-	-	-
2006.9.19	Nagasaki	Tsushima	Hetajima	1.3	24.9	31.2	-	-	-	-	-	-	-
2006.10.10	Nagasaki	Tsushima	Hetajima	9.0	23.1	34.5	-	-	-	-	-	-	-
2006.11.13	Nagasaki	Tsushima	Hetajima	11.0	20.9	35.1	-	-	-	-	-	-	-
2006.12.6	Nagasaki	Tsushima	Hetajima	19.0	18.9	35.5	-	-	-	-	-	-	-
2007.1.18	Nagasaki	Tsushima	Hetajima	12.0	16.0	35.7	-	-	-	-	-	-	-
2007.2.19	Nagasaki	Tsushima	Hetajima	11.5	15.3	34.2	-	-	-	-	-	-	-
2007.3.12	Nagasaki	Tsushima	Hetajima	5.0	14.7	34.3	-	-	-	-	-	-	-
2006.4.18	Nagasaki	Tachibana Bay	South Kushiyama	11.0	16.2	33.6	-	-	-	-	-	-	-
2006.5.8	Nagasaki	Tachibana Bay	South Kushiyama	12.0	17.9	33.4	-	-	-	-	-	-	-

2006.6.6	Nagasaki	Tachibana Bay	South Kushiyama	11.0	20.9	33.0	-	-	-	-	-	-	-
2006.7.12	Nagasaki	Tachibana Bay	South Kushiyama	9.0	24.5	31.1	-	-	-	-	-	-	-
2006.8.16	Nagasaki	Tachibana Bay	South Kushiyama	8.0	29.2	30.6	-	-	-	-	-	-	-
2006.9.13	Nagasaki	Tachibana Bay	South Kushiyama	7.0	24.8	33.0	-	-	-	-	-	-	-
2006.10.18	Nagasaki	Tachibana Bay	South Kushiyama	11.0	23.3	33.2	-	-	-	-	-	-	-
2006.11.22	Nagasaki	Tachibana Bay	South Kushiyama	6.0	20.0	33.6	-	-	-	-	-	-	-
2006.12.13	Nagasaki	Tachibana Bay	South Kushiyama	9.0	17.7	34.4	-	-	-	-	-	-	-
2007.1.24	Nagasaki	Tachibana Bay	South Kushiyama	11.0	13.6	34.7	-	-	-	-	-	-	-
2007.2.21	Nagasaki	Tachibana Bay	South Kushiyama	10.0	13.5	34.8	-	-	-	-	-	-	-
2007.3.9	Nagasaki	Tachibana Bay	South Kushiyama	10.0	13.4	34.9	-	-	-	-	-	-	-

Note: The nutrient concentration units of Saga Prefecture are in μg/L.

Source:
Nagasaki Prefectural Institute of Fisheries (2007)
Saga Prefectural Genkai Fisheries Promotion Center (2007)
Fukuoka Fisheries and Marine Technology Research Center (2007)

5.6 Meteorological conditions during regular red-tide monitoring

The reports of the monitoring organizations of Saga and Nagasaki Prefectures provide information on the meteorological conditions observed during the regular red-tide monitoring. Table 5.11 shows the meteorological conditions observed during the regular red-tide monitoring in the target sea area in 2006.

Table 5.11 Meteorological conditions observed during the regular red-tide monitoring in the target sea area (2006)

Monitoring date	Organi-zation	Spot	Survey point	Observation time	Weather	Cloud cover	Wind direction	Wind speed (Beaufort scale)
2006.5.1	Saga	Imari Bay	1	9:45	Cloudy	10	SW	1
2006.5.1	Saga	Imari Bay	2	9:55	Cloudy	10	SW	1
2006.5.1	Saga	Imari Bay	3	10:10	Cloudy	10	SW	3
2006.6.1	Saga	Imari Bay	1	9:41	Cloudy	10	N	1
2006.6.1	Saga	Imari Bay	2	9:55	Cloudy	10	N	1
2006.6.1	Saga	Imari Bay	3	10:11	Cloudy	10	N	1
2006.7.3	Saga	Imari Bay	1	9:25	Rainy	10	SW	1
2006.7.3	Saga	Imari Bay	2	9:36	Rainy	10	SW	1
2006.7.3	Saga	Imari Bay	3	9:49	Cloudy	10	NW	1
2006.8.1	Saga	Imari Bay	1	9:10	Sunny	1	NW	1
2006.8.1	Saga	Imari Bay	2	9:25	Sunny	1	N	1
2006.8.1	Saga	Imari Bay	3	9:37	Sunny	1	N	1
2006.9.1	Saga	Imari Bay	1	9:20	Cloudy	8	NE	1
2006.9.1	Saga	Imari Bay	2	9:35	Cloudy	10	NE	2
2006.9.1	Saga	Imari Bay	3	9:46	Cloudy	10	NE	2
2006.10.2	Saga	Imari Bay	1	9:12	Sunny	7	N	2
2006.10.2	Saga	Imari Bay	2	9:23	Sunny	5	N	1
2006.10.2	Saga	Imari Bay	3	9:35	Sunny	5	N	2
2006.5.8	Saga	Kariya Bay	A	10:14	Cloudy	10	NE	1
2006.6.2	Saga	Kariya Bay	A	10:18	Cloudy	10	E	2
2006.7.4	Saga	Kariya Bay	A	10:03	Cloudy	10	S	1
2006.8.2	Saga	Kariya Bay	A	10:10	Sunny	8	NW	1
2006.9.4	Saga	Kariya Bay	A	10:11	Sunny	4	NE	1
2006.10.3	Saga	Kariya Bay	A	9:58	Sunny	3	NE	2
2006.5.15	Saga	Nagoyaura	4	11:20	Cloudy	10	SW	1
2006.6.1	Saga	Nagoyaura	4	11:50	Cloudy	10	NE	1
2006.7.3	Saga	Nagoyaura	4	11:30	Cloudy	10	NE	1
2006.8.1	Saga	Nagoyaura	4	11:05	Sunny	1	N	1
2006.9.1	Saga	Nagoyaura	4	11:07	Sunny	7	N	1
2006.10.2	Saga	Nagoyaura	4	11:04	Sunny	2	NE	1
2006.5.1	Saga	Sototsu	5	11:40	Cloudy	10	SW	2
2006.6.1	Saga	Sototsu	5	11:11	Cloudy	10	NW	1
2006.7.3	Saga	Sototsu	5	11:01	Cloudy	10	NE	1
2006.8.2	Saga	Sototsu	5	10:42	Sunny	8	NW	1
2006.9.4	Saga	Sototsu	5	10:38	Sunny	7	N	1
2006.10.3	Saga	Sototsu	5	10:53	Sunny	4	NE	2
2006.6.21	Nagasaki	Imari Bay	1	8:31	Cloudy	10	SW	4
2006.6.21	Nagasaki	Imari Bay	3	10:56	Sunny	7	W	4
2006.6.21	Nagasaki	Imari Bay	4	11:04	Sunny	6	SW	3
2006.7.18	Nagasaki	Imari Bay	1	11:57	Cloudy	10	SW	3
2006.7.18	Nagasaki	Imari Bay	3	13:22	Cloudy	10	SW	5
2006.7.18	Nagasaki	Imari Bay	4	13:04	Cloudy	10	SW	4
2006.8.7	Nagasaki	Imari Bay	1	13:42	Sunny	2	N	5
2006.8.7	Nagasaki	Imari Bay	3	16:39	Sunny	3	NW	4
2006.8.7	Nagasaki	Imari Bay	4	16:53	Sunny	3	N	6
2006.10.18	Nagasaki	Imari Bay	1	11:32	Sunny	5	NE	2

2006.10.18	Nagasaki	Imari Bay	3	14:54	Sunny	5	NW	5
2006.10.18	Nagasaki	Imari Bay	4	15:08	Sunny	5	N	5
2006.8.29	Nagasaki	Ohmura Bay	b	9:47	Cloudy	10	SW	2
2006.8.29	Nagasaki	Ohmura Bay	c	10:45	Sunny	7	NE	2
2006.8.29	Nagasaki	Ohmura Bay	P	12:30	Sunny	7	SW	6
2006.8.29	Nagasaki	Ohmura Bay	Z	13:36	Cloudy	8	E	1
2006.9.20	Nagasaki	Ohmura Bay	b	10:26	Sunny	1	-	-
2006.9.20	Nagasaki	Ohmura Bay	c	10:51	Sunny	1	-	-
2006.9.20	Nagasaki	Ohmura Bay	P	11:32	Sunny	2	-	-
2006.9.20	Nagasaki	Ohmura Bay	Z	12:05	Sunny	2	-	-

Source:
Nagasaki Prefectural Institute of Fisheries (2007)
Saga Prefectural Genkai Fisheries Promotion Center (2007)
Fukuoka Fisheries and Marine Technology Research Center (2007)
Yamaguchi Prefectural Fisheries Research Center (2007)

6 Monitoring with satellite remote sensing images

6.1 Satellite remote sensing data used in this study

The following satellite remote sensing data were obtained and analyzed in this study referring to Eutrophication Monitoring Guidelines by Remote Sensing for the NOWPAP Region (2007).

Period	Parameter	Resolution	Sensor	Satellite	Data source
Jan 1, 2006 to Dec 31, 2006	Chlorophyll-a concentration	1Km	MODIS	Aqua and Terra	Marine Environmental Watch
	Chlorophyll-a concentration	500m	MODIS	Aqua and Terra	MODIS Near Real Time Database of JAXA
	True color image	10m	AVNIR-2	ALOS	JAXA

6.2 Utilization status of satellite remote sensing images

Several organizations in the target sea area provide SST images, which are mainly for the local fishermen.

Yamaguchi Prefecture provides SST images of its sea areas (Sea of Japan side) through the following website <http://www.pref.yamaguchi.lg.jp/gyosei/suisan-s/uminari/satelite/index.htm>. The SST data are from NOAA's satellites, and are received at Japan Fisheries Information Service Center (JAFIC).

Fukuoka Prefecture provides NOAA's SST images through the following website: <http://www.sea-net.pref.fukuoka.jp/eisei/eisei_jpn.htm>

Since 2004, Yamaguchi Prefecture has been developing red-tide monitoring methods by using satellite chlorophyll-a images (Yamaguchi Prefecture, 2007).

Figure 6.1 shows the distribution of chlorophyll-a concentration in the coastal area of Yamaguchi Prefecture before and during a *Karenia mikimotoi* bloom in August 2006, which was estimated from satellite remote sensing images. Areas of high chlorophyll-a concentration were confirmed on the coast of Hohoku Town and along the coast between Hagi City and Abu Town, which incidentally was where red-tide warnings were announced during the above *Karenia mikimotoi* bloom.

Satellite chlorophyll-a images used in the above analysis were obtained from the website of JAXA's Earth Observation Research Center (EORC). The satellite chlorophyll-a images were processed from the sea-color data measured by the Aqua/Terra-MODIS. The MODIS data are received and processed at the Tokai University Research & Information Center and JAXA/EOC (Yamaguchi Prefecture, 2007).

Another example of the use of satellite remote sensing images is Miyahara et al. (2005). In this paper, the movement of *Cochlodinium Polylrikoides* blooms was traced by referring to the satellite images of chlorophyll-a concentration observed by MODIS. Field measurements verified that the high chlorophyll-a concentration in the satellite images was predominantly due to *Cochlodinium Polylrikoides*.

Thus, monitoring of transportation of high chlorophyll-a concentration (algal blooms) by satellite remote sensing is becoming feasible in recent years. In the near future, it is expected that satellite images will become a useful tool for forecasting of harmful algal bloom.

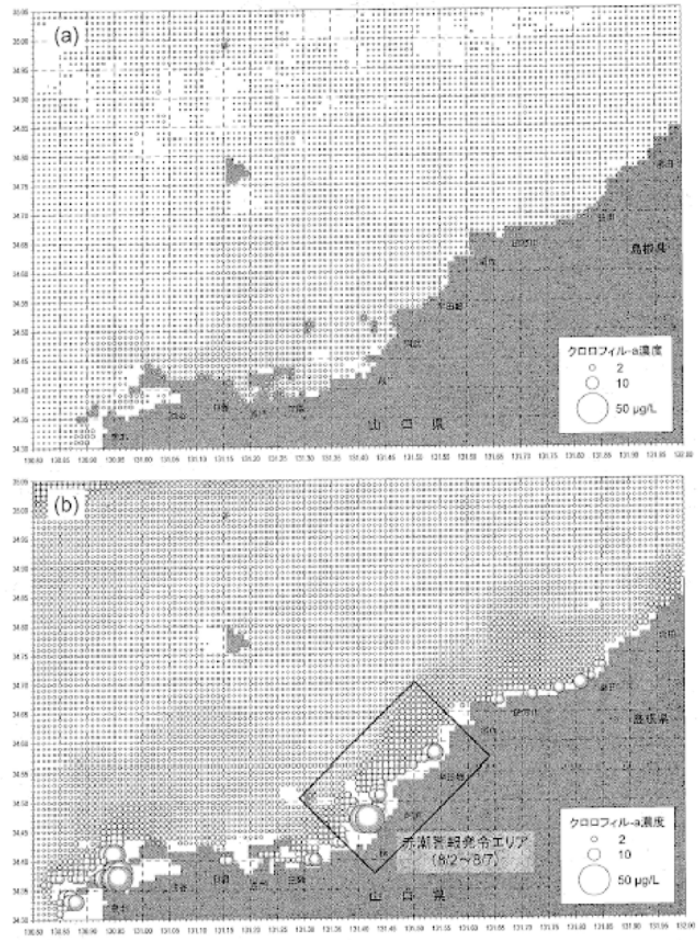


Figure 6.1 Distribution of chlorophyll-a concentration in the coastal area of Yamaguchi Prefecture before and during a *Karenia mikimotoi* bloom in August 2006 (estimated from satellite remote sensing images)

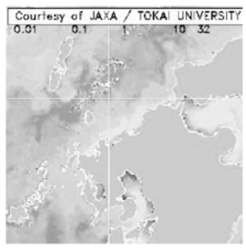
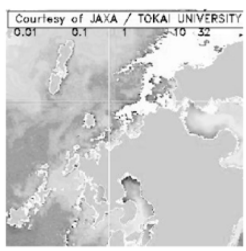
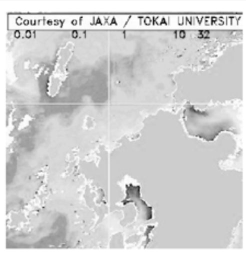
Source: Yamaguchi Prefectural Fisheries Research Center (2007)

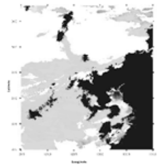
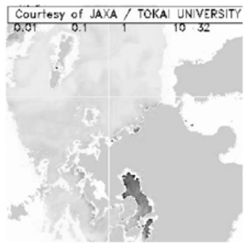
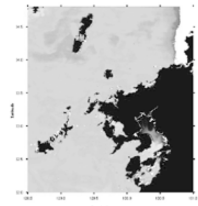
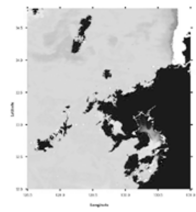
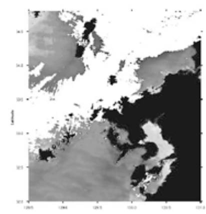
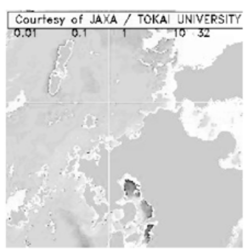
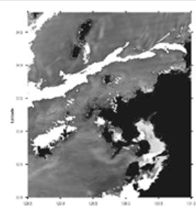
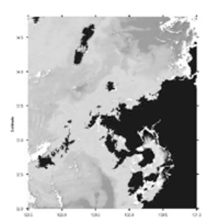
6.3 Satellite remote sensing images of HAB events

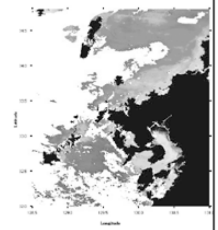
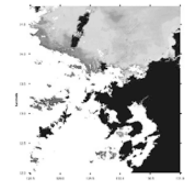
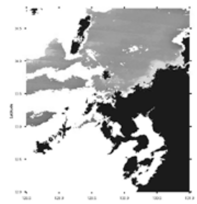
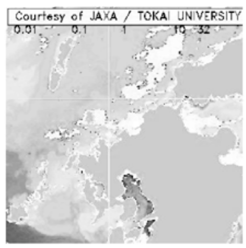
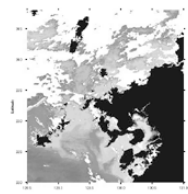
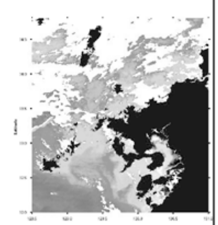
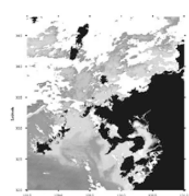
Table 6.2 shows the best visible satellite remote sensing images during past HAB events. Satellite images of some HAB events could not be obtained due to cloud cover.

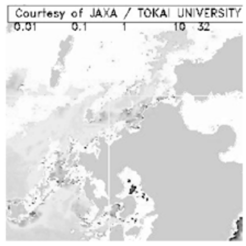
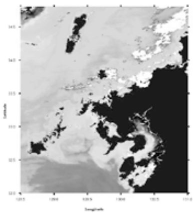
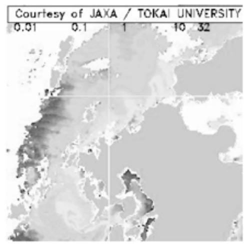
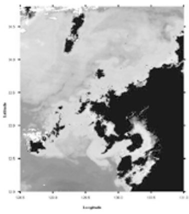
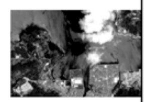
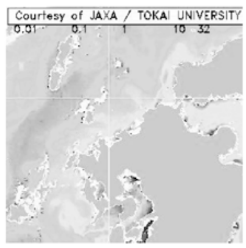
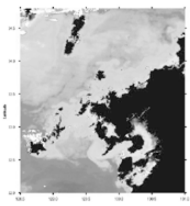
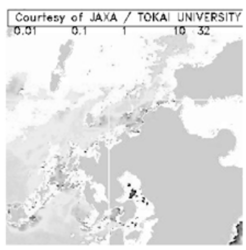
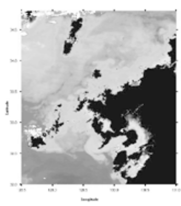
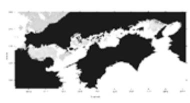
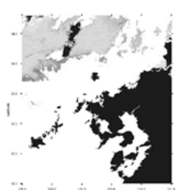
Chlolophyll-a concentration images in northwest sea area of Kyushu region obtained from Marine Environmental Watch Project and JAXA MODIS Near real time were studied to see chlorophyll-a concentration distribution around HAB events area, and enlarged images were cutout to see spatial distribution of HAB events. High resolution true color satellite images obtained by AVNIR-2 onbord ALOS were also analyzed to spatial distribution of HABs.

Table 6.1 Satellite remote sensing images during HAB events in the target sea area

Year	Event No.	Duration	Spot	Chlorophyll-a images (Marine Environmental Watch Project Homepage)	Chlorophyll-a images (MODIS Near real time)	Enlarged chlorophyll-a images	High resolution true color satellite images (ALOS)
2006	YM-2006-1	2.20-2.27	Between Yuya Bay, Nagato City and the coast of Yoshimo, Shimonoseki City	 2/21	Not available		Not available
2006	NS-2006-1	2.24-3.15	Ohmura Bay	 3/4	Not available		Not available
2006	YM-2006-2	2.25-2.28	Coast of Nagato City (Sensaki Bay, Fukagawa Bay)	Not available	Not available		Not available
2006	YM-2006-3	3.27-3.29	Coast of Nagato City (Sensaki Bay)	 3/29	Not available		Not available

2006	NS-2006-3	5.1-5.2	Kujukushima	Not available	 5/2 Terra		Not available
2006	NS-2006-4	5.15-5.26	Goto	 5/20	 5/20 Terra		Not available
2006	NS-2006-5	5.16-6.29	Ohmura Bay	 5/24	 5/20 Terra		Not available
2006	NS-2006-7	6.1-6.3	Kujukushima	Not available	 6/3 Terra		Not available
2006	FO-2006-1	6.5-6.12	West area of Chikuzen sea	 6/9	 6/6 AQUA  6/9 AQUA		Not available

2006	FO-2006-2	6.21-6.27	Fukuoka Bay	Not available	 6/21 Terra		Not available
2006	FO-2006-3	6.29-	Fukuoka Bay	 7/2	 6/29 AQUA  7/2 Terra		Not available
2006	NS-2006-8	7.3-7.14	Ohmura Bay	 7/13	 7/9 Terra		Not available
2006	NS-2006-9	7.4-7.12	Tachibana Bay	Not available	 7/9 Terra		Not available
2006	NS-2006-10	7.9-7.11	Kujukushima	Not available	 7/9 Terra		Not available

2006	NS-2006-11	7.8-7.31	Ohmura Bay	 7/16	 7/13 AQUA		
2006	FO-2006-4	7.11-7.31	Fukuoka Bay	 7/26	 7/14 Terra		
2006	YM-2006-4	7.13-8-4	Shimonoseki	 7/27	 7/14 Terra		Not available
2006	NS-2006-12	7.14-7.18	Ohmura Bay	 7/16	 7/14 Terra		Not available
2006	FO-2006-5	7.18-7.26	Kanmon (North Kyushu)	Not available	 7/22 AQUA		Not available
2006	SA-2006-7	7.20-7.22	Imari Bay	Not available	Not available		Not available
2006	SA-2006-8	7.20-7.23	Karatsu Bay	Not available	Not available		Not available
2006	NS-2006-14	7.20-7.25	Kujukushima	Not available	Not available		Not available
2006	NS-2006-15	7.20-7.25	Tsushima	Not available	 7/22 AQUA		Not available
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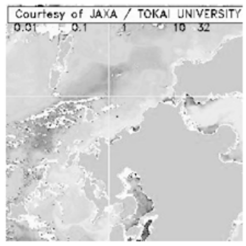
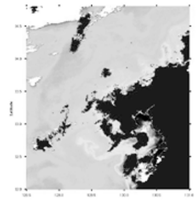
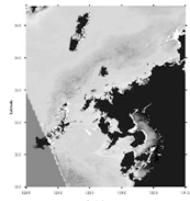
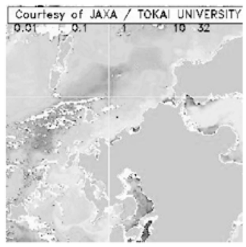
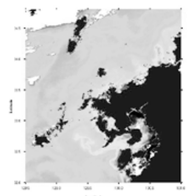
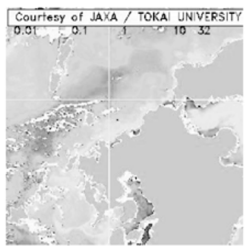
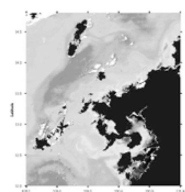
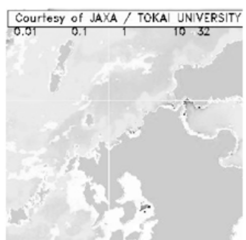
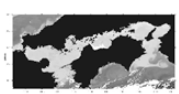
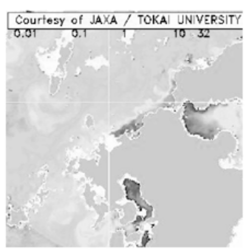
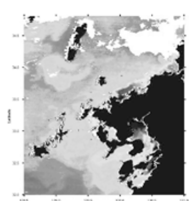
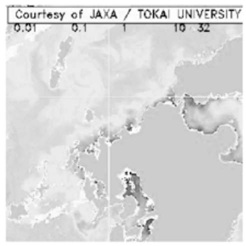
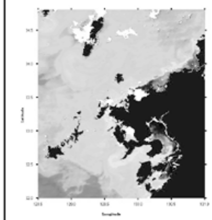
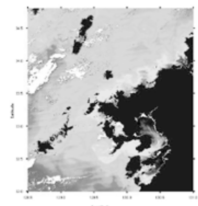
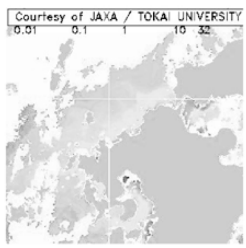
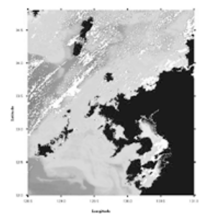
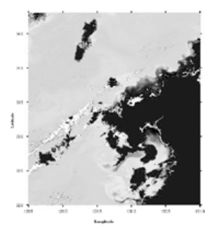
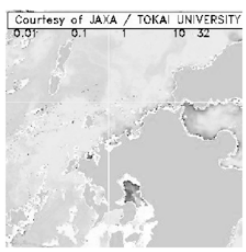
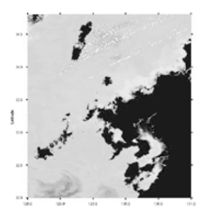
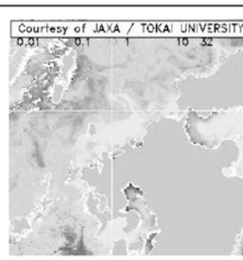
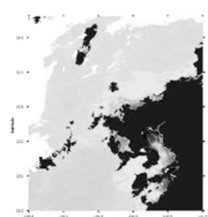
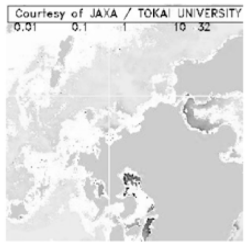
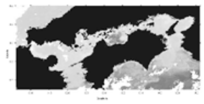
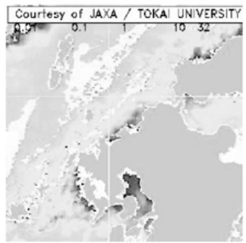
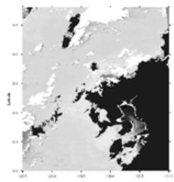
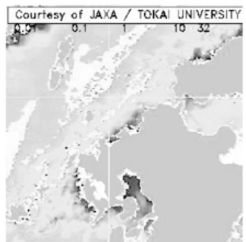
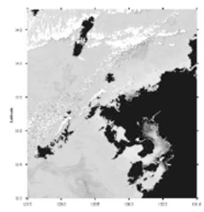
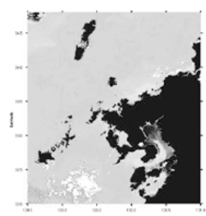
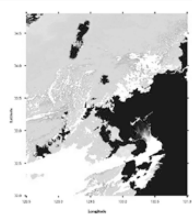
2006	NS-2006-17	7.25-8.11	Imari Bay	 7/29	 7/26 AQUA  7/30 AQUA		Not available
2006	SA-2006-9	7.26-7.30	Imari Bay	 7/29	 7/26 AQUA		Not available
2006	SA-2006-10	7.27-7.30	Kariya Bay	 7/29	 7/27 AQUA		Not available
2006	YM-2006-5	8.2-8.11	Between Hagi City and the coast of Abu Town	 8/3	 8/3 Terra		
2006	SA-2006-12	8.21-8.25	Imari Bay	 8/21	 8/21 Terra		Not available

2006	NS-2006-19	8.21-8.25	Kujukushima	 8/24	 8/21 AQUA		Not available
2006	SA-2006-13	8.22-8.23	Karatsu Bay	Not available	 8/23 AQUA		Not available
2006	NS-2006-20	9.6-9.21	Ohmura Bay	 9/8	 9/7 Terra  9/19 AQUA		Not available
2006	NS-2006-21	9.22-9.26	Imari Bay	 9/22	 9/23 Terra		Not available
2006	NS-2006-22	10.11-10.13	Hirado(Usuka/Furue Bay)	 10/14	 10/12 AQUA		Not available

2006	YM-2006-6	10.16-10.19	Nagato City (Nohase fishery port)	 10/18	 10/17 Terra		Not available
2006	NS-2006-23	10.26-11.6	Ohmura Bay	 10/31	 10/27 AQUA		Not available
2006	NS-2006-24	10.30-12.7	Imari Bay	 10/31	 10/31 AQUA		Not available
2006	NS-2006-25	11.1-11.3	Tsushima	Not available	 11/3 Terra		Not available
2006	SA-2006-18	11.20-11.22	Imari Bay	Not available	 11/21 Terra		Not available
2006	SA-2006-19	11.27-11.28	Imari Bay	Not available	Not available		Not available

Source:

Marine Environmental Watch Project (http://www.nowpap3.go.jp/jsw/jpn/callender/index.html)

JAXA MODIS Near real time homepage (http://kuroshio.eorc.jaxa.jp/ADEOS/mod_nrt_new/index.html)

7 Conclusion

7.1 Status of recent HAB events in the target sea area

During the recent years, there have been no major variations in the number of red-tide events in the target sea area, with around 50 red-tide events occurring each year. Fishery damages by red-tide events have also occurred every year.

Since monitoring started in 1979, around four (20 events/5 year) *Karenia mikimotoi* blooms have been recorded every year, and is still one of the major species that cause fishery damage. Apart from *Karenia mikimotoi*, blooms of *Cochlodinium polykrikoides*, *Heterocapsa circularisquama*, *Chattonella antique*, *Chattonella marina* and *Heterosigma akashiwo* have also been occurring continuously. Within these species, *Cochlodinium polykrikoides* is considered as a high priority species in the NOWPAP region; and websites and pamphlets have been developed specifically for this species. *Cochlodinium polykrikoides* does not only bloom and remain in the coastal area but is reported to transport to other regions with the ocean currents (NOWPAP CEARAC, 2005). It is therefore necessary to continue the observations on *Cochlodinium polykrikoides*.

During 1978-1999, shipment of shellfish has been stopped 10 times due to contamination by toxin-producing planktons; shipment was stopped once in 2006. Although shipment stoppage in the target sea area is less frequent than it is in the Hokkaido and Tohoku regions, toxin-producing planktons are still recorded every year in the target sea area. Prior to the 1980's, shellfish contamination was not a common event in the target sea area; however, despite yearly variations, shipment stoppage has become more frequent since the 1980's. Therefore it is necessary to continue with the information collection activities on shellfish contamination and the causative toxin-producing planktons.

Monitoring organizations of each prefecture monitor planktons that cause significant fishery damage such as *Karenia mikimotoi*, *Cochlodinium polykrikoides*, *Heterosigma akashiwo*, *Chattonella antique*, *Chattonella marina* and *Heterocapsa circularisquamai*, and notify the local fishermen when the cell concentration of these species exceeds the set warning/action standards. PSP- and DSP-inducing speceis (*Dinophysis* spp., *Alexandrium* spp., and *Gymnodinium catenatum*) are also monitored regularly. These species should also be considered as high priority species as in the case with *Cochlodinium polykrikoides*, and information should be collected and shared among the NOWPAP members.

7.2 Environmental conditions during HAB events

During post red-tide survey, SST, salinity and DO are measured to understand the environmental conditions during red-tide events. Regular red-tide monitoring is also conducted in addition to the post red-tide monitoring. During regular red-tide monitoring, red-tide related environmental parameters such as nutrients and chlorophyll-a are also measured in addition to SST, salinity and DO. However, the reports of the monitoring organizations have not made any detailed analysis on the relationship between red-tide events and the measured environmental conditions.

Data on HABs in the target sea area will be collected continuously through the HAB case study and are planned to be presented in an integrated manner. The collected and integrated data should hopefully then be useful for the understanding of HAB mechanisms in the target sea area. For future activities, it is necessary to collect and share information (e.g. scientific literatures) that investigates the relationship between HAB events and environmental conditions.

7.3 Monitoring with satellite remote sensing images

To assist the local fishermen, several monitoring organizations in the target sea area provide daily satellite images of SST. The use of satellite chlorophyll-a images has been limited for studying large-scale red tides due to its relatively low resolution (around 1 km). However, as described in 6.2, utilization of satellite images for monitoring of red-tide is becoming feasible and expected to be more useful in the near future. Particularly, some*Cochlodinium polykrikoides* blooms that occur in the Chugoku region of Japan were suspected to originate from the *Cochlodinium polykrikoides* blooms in the Korean coastline (Miyahara, 2005). To understand the transport processes of *Cochlodinium polykrikoides* from Korea to Japan, satellite chlorophyll-a images are most effective tool. Further research and trials will be required for forecasting red-tide events..

The satellite images of JAXA/ALOS satellite have a spatial resolution of 10 m (see Figure 7.1), which is sufficient even for identifying the spatially small-scale red tides less than 1km that occur in Japan. However, since ALOS does not orbit the same path every day, only three ALOS satellite images for comparison were available for the periods that red tides occurred in 2006. Despite some limitations, the high-resolution ALOS satellite images should become an effective option for monitoring and forecasting spatially small-scale red-tide events in the future.

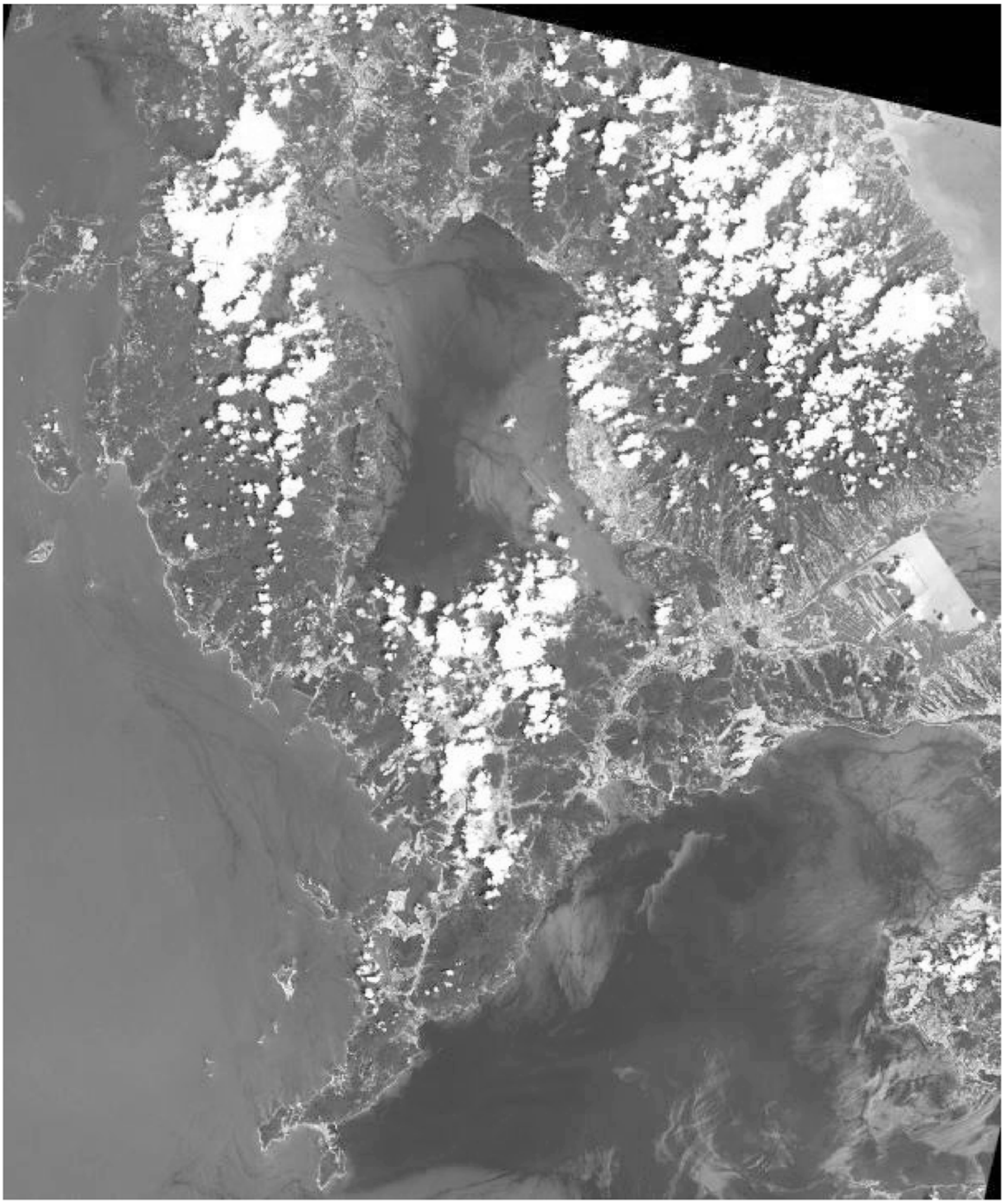


Figure 7.1 ALOS images of Nagasaki Prefecture sea area (July 27th)

7.4 Information sharing among the NOWPAP members

The target sea area is located close to the HAB hot spots of East China Sea and southern coast of Korea. Recent HAB events in the target sea area are known to be partly triggered by the transboundary transport of HAB species from the above mentioned HAB hot spots. Therefore, in order to advance measures against HABs in the target sea area, it is necessary to understand the status of HAB events in the other sea areas of the NOWPAP region. Finally, it is hoped that information sharing of HAB events will be promoted through the HAB case studies, and consequently lead to the reduction of HAB events in not only the target sea area, but the whole NOWPAP region as well.

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Annex1 Proposed format for recording of HAB events

Event No.			Duration(Start)			Duration(End)			Continuous days	Locatio of occurrence		Causative species	Maximum density (cells･inds./mL)	Fishery damage			Environmental parameters			Size of bloom (km^2)	備考
Pref. Code	Year	No.	Year	Month	day	Year	Month	day		Region	Location			Fish/Shellfish species	Quantity	Economic loss (1,000 yen)	Temp. (℃)	Salinity	DO (mg/L)		
YM	2006	1?	2006	2	20	2006	2	27	8	Coastal area of Yamaguchi	長門市油谷湾から下関市吉母沿岸	Noctiluca scintillans	2,150				10.0	-	-	-	
YM	2006	2?	2006	2	25	2006	2	28	4	Coastal area of Yamaguchi	長門市沿岸（仙崎湾、深川湾）	Noctiluca sp.	?				-	-	-	-	
YM	2006	3?	2006	3	27	2006	3	29	3	Coastal area of Yamaguchi	長門市沿岸（仙崎湾）	Noctiluca sp.	?				-	-	-	0.3	
YM	2006	4?	2006	7	13	2006	8	4	23	Coastal area of Yamaguchi	下関市沿岸（外海）	Karenia mikimotoi	57,500	養殖ハマチ 畜養魚（イカ、イサキ、アワビ）	養殖ハマチ 370尾	1,800	25.4	-	-	50.0	
YM	2006	5?	2006	8	2	2006	8	11	10	Coastal area of Yamaguchi	萩市から阿武町沿岸	Karenia mikimotoi	4,900	養殖ヒラマサ	60尾	120	28.2	-	-	-	
YM	2006	6?	2006	10	16	2006	10	19	4	Coastal area of Yamaguchi	長門市野波瀬漁港	Mesodinium rubrum	68				23.0	-	-	0.0001	
FO	2006	1?	2006	6	5	2006	6	12	8	North Kyushu	筑前海西部	Noctiluca scintillans	200				?	?	?	?	
FO	2006	2?	2006	6	21	2006	6	27	7	North Kyushu	福岡湾	Prorocentrum triestinum	10,060				?	?	?	?	
FO	2006	3?	2006	6	29	2006	?	?	?	North Kyushu	福岡湾	Skeletonema sp. Leptocylindrus sp. Chaetoceros sp. other Diatom Prorocentrum triestinum	25240 11800 1710 740 14090				?	?	?	?	
FO	2006	4?	2006	7	11	2006	7	31	21	North Kyushu	福岡湾	Skeletonema sp. Chaetoceros sp. other Diatom	47110 2020 1200				?	?	?	?	
FO	2006	5?	2006	7	18	2006	7	26	9	North Kyushu	関門北九州	Karenia mikimotoi	43,100	あり（詳細不明）			?	?	?	?	
SA	2006	7	2006	7	20	2006	7	22	3	North Kyushu	伊万里湾	Ceratium furca	340				-	-	-	-	
SA	2006	8	2006	7	20	2006	7	23	4	North Kyushu	唐津湾	Mesodinium rubrum	1,180				-	-	-	-	
SA	2006	9	2006	7	26	2006	7	30	5	North Kyushu	伊万里湾	Nitzschia sp. Thalassiosira sp.	13900 5940				-	-	-	-	佐賀県全海域
SA	2006	10	2006	7	27	2006	7	30	4	North Kyushu	仮屋湾	Skeletonema costatum	11,140				-	-	-	-	
SA	2006	12	2006	8	21	2006	8	25	5	North Kyushu	伊万里湾	Thalassiosira sp. Skeletonema costatum	2520 1400				-	-	-	-	佐賀県全海域
SA	2006	13	2006	8	22	2006	8	23	2	North Kyushu	唐津湾	Thalassiosira sp.	2,022				-	-	-	-	
SA	2006	18	2006	11	20	2006	11	22	3	North Kyushu	伊万里湾	Prorocentrum triestinum	7,240				-	-	-	-	
SA	2006	19	2006	11	27	2006	11	28	2	North Kyushu	伊万里湾	Prorocentrum triestinum	2,940				-	-	-	-	
NS	2006	1	2006	2	24	2006	3	15	20	West Kyushu	大村湾	Cryptophyceae	148,000				12.7	27.4	14.5	-	
NS	2006	3	2006	5	1	2006	5	2	2	West Kyushu	九十九島	Strombidium sp.	55				17.7	33.8	8.6	0.00005	
NS	2006	4	2006	5	15	2006	5	26	12	Remote Is.	五島	Heterosigma akashiwo	11,800				19.5	27.0	9.5	0.005	
NS	2006	5	2006	5	16	2006	6	29	45	West Kyushu	大村湾	Heterosigma akashiwo	225,000				-	-	-	-	
NS	2006	7	2006	6	1	2006	6	3	3	West Kyushu	九十九島	Prorocentrum sp.	3,400				-	-	-	0.0001	
NS	2006	8	2006	7	3	2006	7	14	12	West Kyushu	大村湾	Karenia mikimotoi	15,800				-	-	-	-	
NS	2006	9	2006	7	4	2006	7	12	9	West Kyushu	橘湾	Ceratium furca	6,650				-	-	-	0.44	
NS	2006	10	2006	7	9	2006	7	11	3	West Kyushu	九十九島	Mesodinium rubrum	13,570				-	-	-	-	
NS	2006	11	2006	7	8	2006	7	31	24	West Kyushu	大村湾	Karenia mikimotoi	92,200				-	-	-	-	
NS	2006	12	2006	7	14	2006	7	18	5	West Kyushu	大村湾	Prorocentrum spp.	721				25.3	29.1	8.1	0.5	
NS	2006	14	2006	7	20	2006	7	25	6	West Kyushu	九十九島	Karenia mikimotoi	8,504	トラフグ マダイ	トラフグ1000尾 マダイ70尾	184	-	-	-	-	
NS	2006	15	2006	7	20	2006	7	25	6	Remote Is.	対馬	Cochlodinium polykrikoides	135				22.8	26.3	5.2	-	
NS	2006	16	2006	7	21	2006	7	23	3	North Kyushu	伊万里湾	Ceratium furca	667				26.0	-	-	-	
NS	2006	17	2006	7	25	2006	8	11	18	North Kyushu	伊万里湾	Karenia mikimotoi	16,100	トラフグ	トラフグ 6900尾	10,350	-	-	-	-	
NS	2006	19	2006	8	21	2006	8	25	5	West Kyushu	九十九島	Prorocentrum minimum	12,800				26.1	31.9	10.1	-	
NS	2006	20	2006	9	6	2006	9	21	16	West Kyushu	大村湾	Heterosigma akashiwo	11,500				27.5	30.1	-	-	
NS	2006	21	2006	9	22	2006	9	26	5	North Kyushu	伊万里湾	Diatoms	16,220				23.0	-	-	-	
NS	2006	22	2006	10	11	2006	10	13	3	North Kyushu	平戸 (Usuka/Furue Bay)	Cochlodinium polykrikoides	646				23.0	33.0	7.9	0.25	
NS	2006	23	2006	10	26	2006	11	6	12	West Kyushu	大村湾	Prorocentrum sigmoides	160				-	-	-	5.3	
NS	2006	24	2006	10	30	2006	12	7	39	North Kyushu	伊万里湾	Prorocentrum sigmoides	14,980				-	-	-	2.1	
NS	2006	25	2006	11	1	2006	11	3	3	Remote Is.	対馬	Mesodinium rubrum	490				22.5	34.9	5.8	-	

National Report on HAB case study in Korea

Yang Soon Kang

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1. Introduction

1.1. Objective

The objective of conducting the HAB case study in the southeastern sea area of Korea is to establish the most effective and laborsaving ways for sharing among the NOWPAP member states, information on HAB events and associated oceanographic and meteorological conditions. Furthermore, common HAB issues within the NOWPAP region will be identified through the case study. In the case study, red-tide and toxin-producing planktons will be referred as HAB species.

1.2. Definitions and rules used in the HAB case study

Mention that in general, the scientific names in the 'Integrated Report' and 'Booklet on Countermeasures' will be used in this cas e study.

1.3. Overview of the target sea area

1.3.1. Location and boundary

The target sea area (longitude : 34°35′43″-34°57′54″, latitude: 127°30′11″-128°56′60″) is located in the eastern part of South Sea, Korea, which faces East China sea. The Bay surrounded by Goseong-jaran Bay, and Jinju Bay has shellfish farms including oyster and *Mytilus edulis* and fish farms shown in right and left below of Fig. 1.

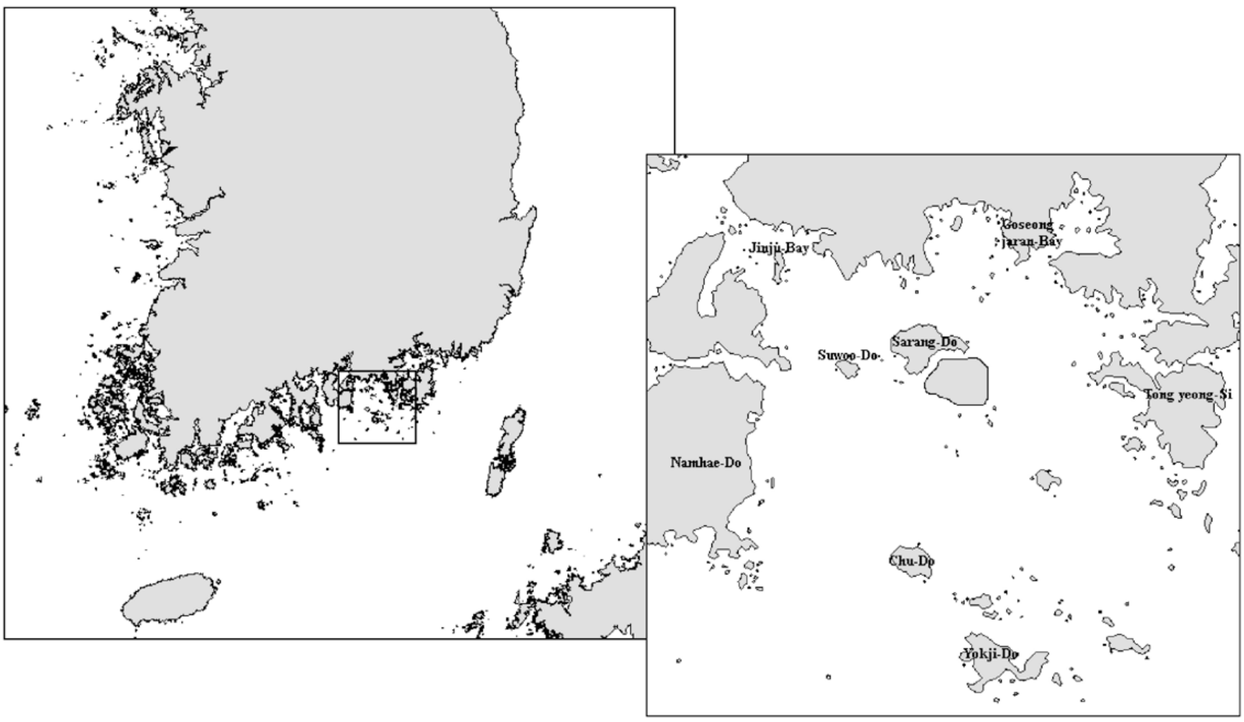


Figure 1. Target sea area for the case study of Korea

1.3.2. Environmental/geographical characteristics

Three sides of the target sea is surrounded by land such as Tongyeong-Si, Namhae-Si, Goseong-Si. Its south is opened to offshore and has long ria coast with irregular coast line. The depth of water is generally less than 10 m and the area has a less wave due to geographic characters of deeper depth of water in offshore. While, this area is directly affected by a Tsushima warm current with abundant nutrient supply and smooth current flow. Therefore, fishery industry including fish farming has been developed in this area. However, since 1995, *Cochlodinium polykrikoides* blooms have occurred in this area in every August and September, causing numerous fishery damages.

2. Methodology used in the case study of southeastern sea of Korea

2.1. Methodology used in the case study

HABs and dominant species are regularly investigated during March to November by NFRDI's personnel. HAB species is identified and reported to NFRDI by local fishery stations whenever HABs occur in waters. However, Once HAB initiate, all relevant agency conducts their daily HAB monitoring using vessel and helicopter. National Maritime Police Agency is responsible for HAB monitoring by helicopter. NFRDI's personnel monitor all southern coasts for forecasting occurrences and dispersal of HABs during July to September. All the collected data from field survey, meteorology and remote sensing by NOAA and MODIS are sent to HAB emergency center under NFRDI.

2.2. Warning/action standards against HAB events

HABs monitoring system covering whole Korean waters was established for minimization of fishery damages. HAB species, its abundances and economic damages are monitored by the system, and these data were sent to fishers and relative institutes through ARS(automated telephone response system), SMS service, satellite TV, facsimile, and internet web site (http://www.nfrdi.re.kr). To give previous attention to fishermen and aquaculturists, NFRDI deploy alert system. It consists of Red Tide Attention, Red Tide Alert and Warning Lift. The notice of attention and alert are issued when the density of *C. polykrikoides* exceed 300 cells/mL and 1,000cells/mL, respectively as in Table 1. When HAB attention and Alert issues, we lead the way to withdraw feeding, supply the liquid oxygen and disperse of yellow clay.

Table 1. HAB warning/action standards of Korea

Waring Class	Scale	Cell density(cells/mL)
Red tide attention	HAB blooms and over radius 2-5km (12-79 ㎢) and potential fishery damages	○Dinoflagellates: depends on cell size and toxicity - *Chattonella* sp. : over 50 - *Cochlodinium* sp. : over 300 - *Gyrodinium* sp. : over 500 - *Karenia mikimotoi*: over 1,000 - Etc. : over 30,000 ○Diatom: over 50,000 ○Mixed blooms: over 40,000 cells (over 50%) of dinoflagellate
Red tide Alert	HAB blooms and over radius 5km (79㎢) and fishery damages	○ Dinoflagellates: depends on cell size and toxicity - *Chattonella* sp. : over 100 - *Cochlodinium* sp. : over 1,000 - *Gyrodinium* sp. : over 2,000 - *Karenia mikimotoi*: over 3,000 - Etc. : over 50,000 ○Diatom : over 100,000 ○Mixed blooms : over 80,000 cells (over 50%) of dinoflagellate
Warning Lift	HABs are extinct, no risk of fisheries damages	

- The president of NFRDI can authorize red tide attention in case of alarming potential bloom damages regardless cell densities.

Source: National Fisheries research and Development Institute (http://portal.nfrdi.re.kr/redtide/index.jsp)

In NFRDI, harvested shellfish are routinely monitored to confirm the presence of algal toxins. Safety limits are established by the Government, which are 80μg/100g for PSP. So, NFRDI notifies fisherman not to harvest the shellfish when the toxin level exceeds over 80μg/100g meat.

2.3. Target HAB species

Dinoflagellates such as *Prorocentrum minimum, P. dentatum, Heterosigma akashiwo, Akashiwo saguineum, Ceratium furca* and *Cochlodinium polykrikoides* were found to be the major dinoflagellates in the case study area. They exclusively formed monospecific bloom of high density in the summer season. Besides, it reveals that some cyst-forming dinoflagellate species makes the bloom at the same place and same time (Kim et al., 1990).

C. polykrikoides is a major causative organism of HABs for fishery damages in Korea. Major blooms occurred in end of July to end of September, its blooms have caused mortality of farming fish every year. Other than *C. polykrikoides*, fish kills have not been reported by organisms listed in Table 2. In addition, *Chattonella* spp. causing fishery damages in Japan have occurred in Korean waters but no fish kills occurred.

Table 2. Target HAB species in this case study (NFRDI)

	Harmful Red-tide causative species	Toxin-Producing Plankton
Dinophyceae		
Akashiwo sanguinea	○	
Cochlodinium polykrikoides	○	
Prorocentrum dentatum	○	
Prorocentrum minimum	○	
Ceratium furca	○	
Raphidophyceae		
Heterosigma akashiwo	○	

Source: National Fisheries research and Development Institute (http://portal.nfrdi.re.kr/redtide/index.jsp)

3. Monitoring framework and parameters of HAB

3.1. Monitoring framework

In NFRDI of Korea, HABs have been regularly monitored to prevent HABs induced fishery damage. The routine monitoring has been conducted by National Fisheries Research and Development Institute(NFRDI)'s personnel. Also, focused HAB monitoring survey has been conducted by each fishery station located in Korean-wide. The detailed monitoring on HABs is conducted by NFRDI, SFRDI, Aquaculture environment research center. Monitoring areas are shown in Table 3.

Table 3. Monitoring organization and monitored sea areas

Monitoring organization	Monitored sea area
National Fisheries Research and Development Institute	Southeastern Sea
South Sea Fisheries Research and Development Institute (SSFRDI), Aquaculture environment research center	South Sea, Tongyeong, Geoje
Tongyeong fishery station(TFS)	Mireuk Do, SarangDo
Sacheon fishery station(SFS)	Jinju Bay
Goseong fishery station(GFS)	Goseong Bay, Saran Bay
Geoje fishery station(GEFS)	Geoje Do
Namhae fishery station(NFS)	Namhae Do, Changsun Do

Source: National Fisheries research and Development Institute (http://portal.nfrdi.re.kr/redtide/index.jsp)

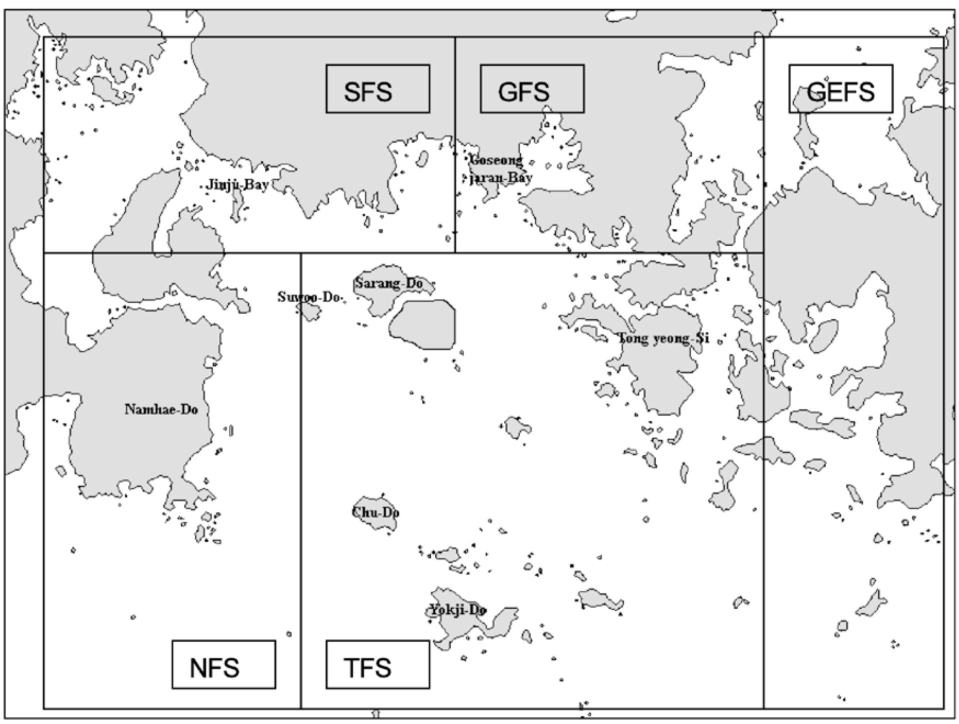


Figure 2. Monitores sea area in the case study of southeastern sea of Korea

3.2. Monitoring parameters

In the eastern part of South Sea area of Korea, the following three types of HAB related surveys are conducted: regular HAB monitoring survey, focused HABs monitoring survey, HABs in South Sea investigation. Regular HAB coastal monitoring has been carried out monthly at 90 stations from March to November by NFRDI to investigate the status of water quality and outbreaks of HAB. Most of the coastal environmental parameters are monitored simultaneously. Focused HABs monitoring survey is conducted when water discoloration, HAB event or fishery damage occur. HABs in South Sea investigation is conducted during early HAB's blooms to their extinction and used for HAB's warning. Regular shell-fish poisoning survey is conducted regularly at fixed locations. Table 4 shows the objective and monitoring parameters of each survey.

This case study will focus mainly on the results of the focused HABs monitoring survey, which monitors HAB causative species, cell density, affected area, fishery damage, water temperature and salinity.

Table 4 Objectives and monitoring parameters of each HAB survey

Survey type	Main objectives	Monitoring parameter				Monitoring frequency
		HAB	Water quality	Meteorology	Others	
Regular HAB monitoring survey	To check presence of HAB spp.	-All HAB species -Cell density -Water color	-Water temp. -Salinity -DO -Transparency -Nutrients -Chl.a	none		9/year (March - December)
Focused HABs monitoring survey	Monitoring of HAB spp.	-HAB species (dominant/causative spp.) -Cell density -Bloom area -Water color	-Water temp. -Salinity	-Weather -Cloud cover -Wind direction/speed		Immediately after water discoloration is reported
HABs in South Sea investigation	To check presence of HAB in waters, changes in species compositions	-Species that induce shellfish poisoning -Cell density -Water color	-Water temp. -Salinity -DO -Transparency -Nutrients -Chl.a			6-7/year (each other week)
Regular shellfish-poisoning survey	To check presence of HAB spp. that induce shellfish poisoning Contamination of shellfish products	-Species that induce shellfish poisoning -Cell density -Water color	-Water temp. -Salinity -DO		Shellfish contamination	30/year (4/month)

Source: National Fisheries research and Development Institute (http://portal.nfrdi.re.kr/redtide/index.jsp)

3.3. Data and information used

All the collected data are sent to HAB emergency center in NFRDI, immediately. Table 5 shows the monitoring parameters that will be referred in the HAB case study. HAB's species, cell density, and bloom areas are investigated for early warning blooms, and water quality is investigated for distribution of HABs. When the *C. polykrikoides* bloom is outbroken, it gradually develops into plume like patch and get enlarged around plume in slightly eutrophic water. Their movement and distribution is dependent on the wind direction and tidal current. The bloom approaches the coast at flood current and wind. So, we investigated all parameter such as water quality and meteorology in HABs in South Sea investigation. Total data for HAB's monitoring is used for warning and predicting HAB's migration and dispersal.

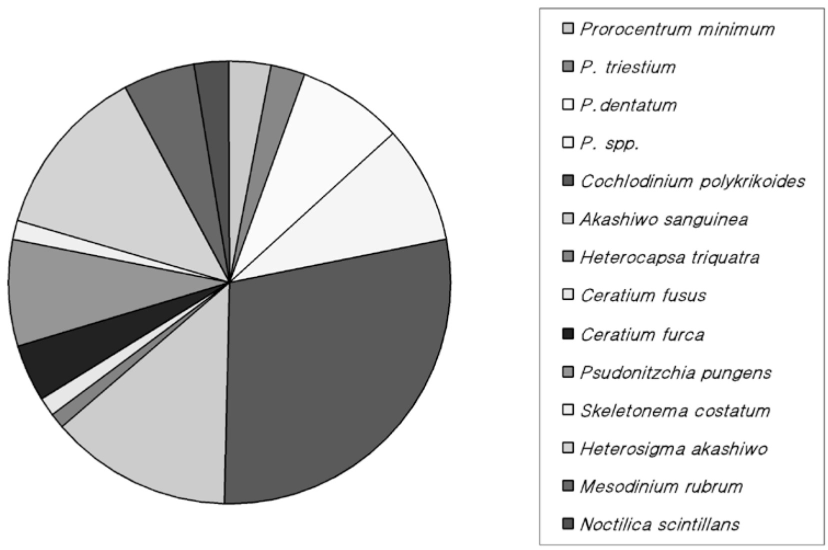
Table 5 Monitoring parameters referred in the HAB case study

	Monitoring parameter	Survey type
HAB	- HAB species (dominant/causative spp.) - Cell density - Bloom area	Focused HABs monitoring survey HABs in South Sea investigation
Water quality	- Water temp. - Salinity - DO	Focused HABs monitoring survey
Others	- Water quality Transparency, Nutrients, Chl.a - Meteorology Weather, Cloud cover, Wind, direction/speed	Regular HAB monitoring survey HABs in South Sea investigation

4. Status of HAB events

4.1. Status of HAB events from year 1995-2007

From year 1995-2007, a total of 795 HAB events were recorded, in which 181 events induced fishery damage in Korea. Especially, a total of 169 HAB events were recorded, in which 47 events induced fishery damage in the case study area. This frequency of HAB is determined from data of local fishery office, and a bloom occurrence in each territory was counted as a single HAB occurrence and additional HAB event was added if the dominant species is changed to other organism. The most frequently observed HAB species was *Heterosigma akashiwo, Prorocentrum dentatum, Akashiwo sanguinea* and *C. polykrikoides,* which was recorded 181 times. HAB species that inflicted the most fishery damage *was C. polykrikoides* .



4.2. Yearly trends of HAB events

During the 13 years between 1995 and 2007, a total of 169 HAB events were recorded, in which 47 events induced fishery damage in HAB case study area(Figure 2). Since 2005, non-harmful red tide occurrences have been decreased, and the non-harmful red tide occurred only 1-2 times during 2005-2007. While harmful red tide occurred 2-5 times. Total frequency of HAB has decreased in general.

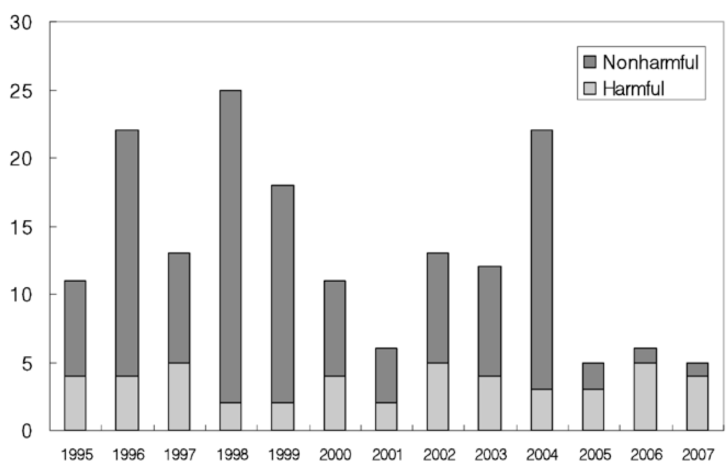


Figure 2. Number of HAB events in case study area (1995-2007)

4.3. Yearly trends of HAB season

According to the HAB data from 1995-2007, the highest peak season was high temperature season from June to September, of total red tide occurrences, 57% blooms occurred in August. And Fishery damage occurred most frequently during August. The Majority of the events during the high water temperature season were attributed to the *C. polykrikoides* blooms.

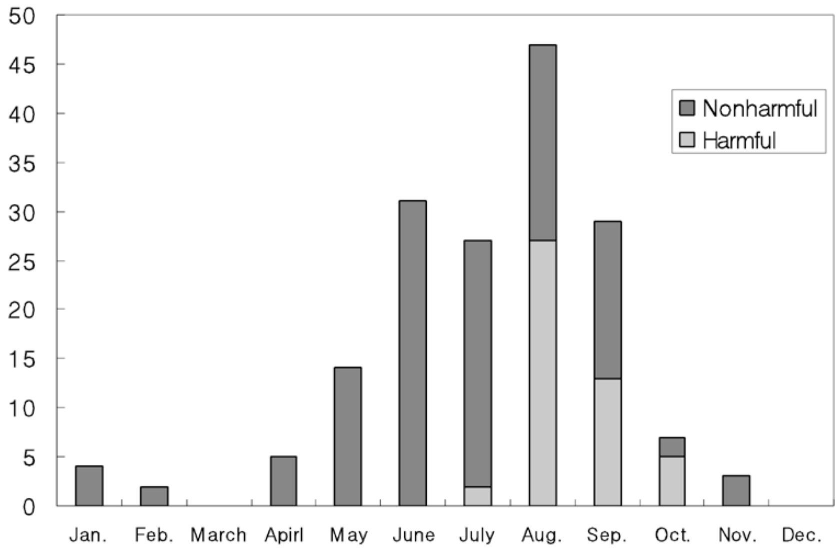


Figure 3. Number of HAB events by month in southeastern sea of Korea(1995-2007)

4.4. Yearly trends of causative species

Table 6 shows the HAB species that were recorded in eastern part of South Sea between 1995-2007 and their frequency of occurrences. A total of HAB species were recorded and the most frequent species were dinoflagellates such as *C. polykrikoides, Akashiwo sanguinea*, and *Heterosigma akashiwo* etc. The organism causes fishery damages is *C. polykrikoides*. HAB by dinoflagellates are much more frequent than by diatoms. HAB, in general, begins to occur from January to February almost every year, and shows its peak from August and September during which *C. polykrikoides* makes its blooms.

Table 6 HAB species recorded in the in southeastern sea of Korea between 1995-2007 and their frequency of occurrences

Genus and Species	1995-1997	1998-2000	2001-2003	2004-2006	2007 onwards	Total
Dinophyceae						
Prorocentrum minimum	2	3				5
P. triestium	1	1	2			4
P.dentatum	2		3	8		13
P. spp.		8	5	1		14
Cochlodinium polykrikoides	13	8	11	11	4	47
Akashiwo sanguinea	6	8	4	3	1	22
Heterocapsa triquatra	1	1				2
Ceratium fusus	1		1			2
Ceratium furca	1	6				7

Bacillariophyceae						
Pseudo-nitzchia pungens	2		3	8		13
Skeletonema costatum	1	1				2
Diatoms	1					1
Raphidophyceae						
Chattonella antiqua						
C. marina						
Heterosigma akashiwo	4	11	3	3	0	21
Others						
Mesodinium rubrum	1	3		5		9
Noctilica scintillans		3		1		4
Others	1	11	1	5		18
Total	37	64	33	45	5	184

Note: The underlined species caused significant fishery damage

5. Status of recent HAB events and results of environmental monitoring

5.1. Number of HAB events

Records of HAB events in 2007 are provided in Appendix. In 2007, a total of 38 HAB events were recorded, in which 21 events induced fishery damage. The most frequently observed HAB species was *C. polykrikoides* and *Chattonella* spp. In the case study area, a total of 6 HAB events were recorded, in which 5 events induced fishery damage. The organism causes fishery damages was *C. polykrikoides*.

5.2. Period of HAB events

According to the HAB data in 2007, it occurred from April to November, HAB occurred during July to October, and 60% of HABs occurred in July and August (Figure 4). The blooms in this case study area mostly occurred in July and August and fishery damage occurred most frequently during August.

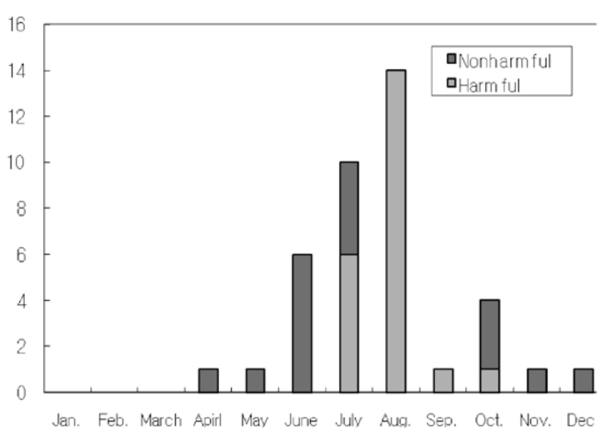


Figure 4. Number of HAB events by month in Korea(2007)

5.3. Duration of HAB events

Table 7 shows the number of events by duration (no. of days) in 2007. *Chattonella* blooms in West Sea lasted for 10days, while *Chochlodinium* blooms lasted for 30 days in the same waters. In the case study area in southeastern Sea, HABs lasted for the whole bloom seasons. In Tongyeong covering wide areas, HAB originated from Yeosu was dispersed to other areas after 3-5 days. The other blooms not causing fishery damages became extinct after 7-10 days. However, the duration of HAB by *C.*

polykrikoides is much longer, range from 1-2months.

Table 7. Numbers of HAB events caused fishery damages by duration (no. of days)

	Duration	Organism
Yeosu	42	*C. polykrikoides*
Namhae	42	"
Tongyeong	35	"
Geoje	35	
Goseong	29	
Sacheon	3	
Taean(West Sea)	10	*Chattonella* spp.

Source: National Fisheries research and Development Institute (http://portal.nfrdi.re.kr/redtide/index.jsp)

5.4.Location of HAB events

Table 8 shows the number of red tide occurrences in the case study area in 2007. Figures 4 and 5 show the location of the HAB events. In 2007, *C. polykrikoides* blooms were dominant except for 1 event, one bloom event occurred in Mizo, South Sea for 42 days, and HABs occurred in Tongyeong, Kosoung, and Jinju Bay. In this year, the number of HAB event was low but the blooms dispersed to other areas and high density blooms resulted in numerous fishery damages.

Table 8. Number of HAB events by area

Year	Sea area		No. of events	Causative species
	Sub-area	Spot		
2007	Tongyeong	Tongyeong Dosan	1	*Akashiwo sangunea*
	Tongyeong-Namhae	Namhae Mizo	1	*Cochlodinium polykrikoides*
		Tongyeong Sarang Suyou-do	1	
		Goseong Bay	1	
		Jinju bay	1	
		Upper Sarang-do	1	
	Total		5	

Source: National Fisheries research and Development Institute (http://portal.nfrdi.re.kr/redtide/index.jsp)

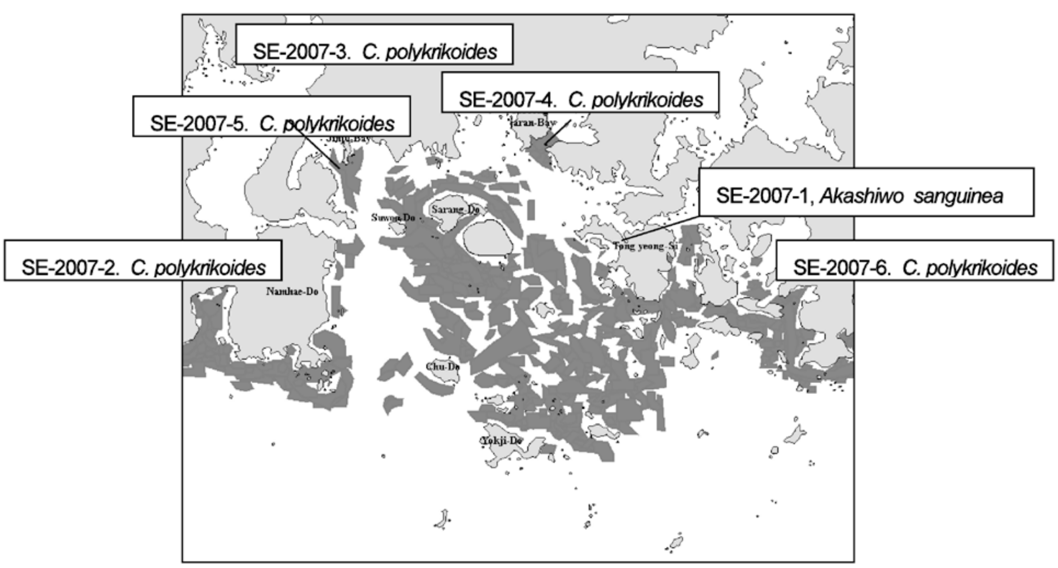
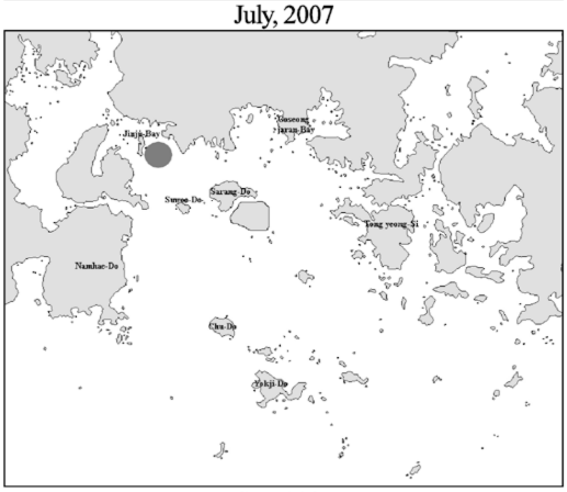


Figure 4. Location of HAB events (event no. and causative species)

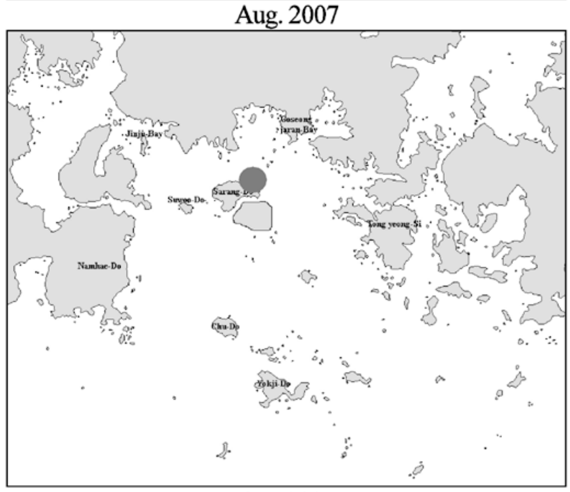
Note : Red one is dispersal area of HAB

July, 2007

Aug. 2007



Sep. 2007



Oct. 2007

Figure 5. Location of HAB events by months (red dots show the location of HAB event)

5.5.Causative species

Table 9 shows the HAB species that were recorded in eastern part of South Sea. A total of HAB species were recorded and the most frequent species were dinoflagellates such as *Akashiwo sanguinea* and *C. polykrikoides*. HAB occurred in Tongyeong became extinct on 17th September and then the blooms re-occurred in upper Sarang-do and became extinct.

Table 9. HAB species recorded in southeastern Sea of Korea in 2007 and their frequency of occurrences

Genus and Species	2006 onwards (2006 Nagasaki)	Total
Dinophyceae		
Cochlodinium polykrikoides	5	5
Akashiwo sanguinea	1	1
Total	6	6

Note: The underlined species caused significant fishery damage

Source: National Fisheries research and Development

5.6.Maximum density of each HAB event

Table 10 shows the maximum density of each HAB event that occurred in the case study in year 2007. Within these HAB events, maximum densities peaked on 4th September at 32,500 cells/mL in Namhaedo and dominant species was *C. polykrikoides.*The usual number of maximum cell density in Korea remains at the level of several thousands cells/mL.

Table 10. Maximum density of HAB events that occurred in southeastern Sea of Korea

Year	Event No.	Causative species	Maximum density (cells or inds/mL)	Affected Area (km^2)
2007	SE-2007-1	*Akashiwo sanguinea*	500	No info.
2007	SE-2007-2	*C. polykrikoides*	32,500	50
2007	SE-2007-3	*C. polykrikoides*	23,000	70
2007	SE-2007-4	*C. polykrikoides*	4,000	3
2007	SE-2007-5	*C. polykrikoides*	2,000	2
2007	SE-2007-6	*C. polykrikoides*	2,130	2.

5.7.Status of HAB induced fishery damage

Table 11 shows the fishery damage caused by HAB in eastern part of South Sea in year 2007. Large fishery damages occurred in South and East Seas due to HABs in offshore. *C. polykrikoides* blooms occurred and caused fishery damages in the mid August. Approximately 10 million U.S. dollar losses and 25 million fish kills (Rockfish, parrot fish etc.) in farms were estimated during the blooms.

Table 11. Fishery damage caused by HAB in southeastern Korea in year 2007

Month/ Year	Event No.	Sub-area	Spot	Causative Species	Fishery damage		
					Fish/Shellfish Species	Quantity(million ind.)	Economic loss (1,000 won)
Aug. 2007	SE-2006-3	Tongyeong	Tongyeong Sarangdo	*C. polykrikoides*	Rockfish, Parrot fish etc.	Rockfish, 2, Parrot fish 1 , etc. 1.9	7,337
Aug, 2007	SE-2006-2	Namhae-Do	Namhae-Do Mizo	*C. polykrikoides*	Red sea bream, Bass, Rockfish, parrot fish	Rockfish, 0. 688, Red sea bream 0.389, Parrot fish 0.15, Bass 0.61, Sea bastes 0.149	3,664

Source: National Fisheries research and Development Institute

5.8.Status of target species

- In previous year, *Prorocentrum*, *Heterosigam*, *Akashio sanguinea* blooms were dominant in Bay and *Noctiluca* blooms occurred in Yokjido. While *A. sanguinea* and *C. polykrikoides* blooms occurred in eastern part of South Sea. *A. sanguinea* blooms lasted for short time but *C. polykrikoides* blooms occurred over 40 days. High density blooms lasted for long time since blooms were dispersed to other areas through wind or current. Blooms in eastern part of South Sea occurred at high density and lasted for long time occurring from the end of July, which is early than last year blooms occurred in mid August.
-

5.9.Environmental monitoring results during HAB events

During the focused HABs monitoring survey, water temperature and salinity are measured. Table 12 shows the data obtained for each HAB event. During the HAB events, water temperature ranged between 22.4-26.5C°, salinity between 31.1-33.2.

Table 12 Data of focused HABs monitoring surveys in the southeastern sea of Korea

Year	Event No.	Duration	Spot	Water temp.(C°)	Salinity
2007	SE-2007-1	7. 24	Tongyeong	22.4-22.5	33.2
2007	SE-2007-2	8.6-9.15	Namhae	23.3-25.7	32.0
2007	SE-2007-3	8.9-9.12	Tongyeong	24.0	32.6
2007	SE-2007-4	8.11-9.1	Goseong	26.5	31.1
2007	SE-2007-5	9.3-9.9	Sacheon	23.7	30.9
2007	SE-2007-6	10.19-10.29	Tongyeong	23.0	33.2

5.10. Water quality parameters of regular HAB monitoring survey

Table 13 shows the results of the regular HAB monitoring survey

Table 13 Water quality data obtained during regular HAB monitoring survey in southeastern sea of Korea

Survey date	Spot	survey point	Water temp.	Salinity	pH	DO (mg/L)	NH_4-N (mg/L)	NO_2-N (mg/L)	NO_3-N (mg /L)	DIP (mg/L)	SIO2-SI (mg/L)	Chl-a (μg/L)	Trans parency (m)
Jun-07	Tongyeong	3	20.5	33.4	8.06	6.69	0.059	0.006	0.021	0.053	0.182	9.3	3.0

Jun-07		4	21.6	33.5	8.08	6.72	0.019	0.001	0.018	0.082	0.150	2.3	5.0
Jun-07	Goseong-Jaran Bay	5	23.0	25.9	7.96	6.04	0.057	0.001	0.011	0.059	0.545	4.0	3.0
Jun-07		6	22.8	33.5	7.95	5.57	0.018	0.001	0.011	0.063	0.973	1.9	5.0
Jun-07	Sachun	7	21.5	33.5	8.05	7.76	0.013	0.002	0.016	0.051	0.413	5.3	4.0
Jun-07	Jinju Bay	8	21.4	33.4	7.91	6.26	0.033	0.010	0.065	0.064	0.480	2.6	3.0
Jun-07		9	23.6	33.3	7.94	7.56	0.031	0.002	0.016	0.063	0.253	7.1	3.0
Jun-07	Tongyeong off shore	10	20.7	33.5	8.12	7.65	0.022	0.003	0.015	0.049	0.208	0.5	16.0
Jun-07		11	20.7	33.7	8.08	7.73	0.016	0.015	0.016	0.058	0.403	3.4	5.0
Jun-07		12	19.0	33.7	8.12	6.66	0.034	0.005	0.026	0.089	0.298	2.2	5.0
Jul-07	Tongyeong	3	24.6	32.5	8.12	8.92	0.016	0.002	0.071	0.004	0.066	14.0	2.0
Jul-07		4	25.5	32.7	8.06	6.86	0.017	0.002	0.060	0.006	0.278	15.3	6.0
Jul-07	Goseong-Jaran Bay	5	27.4	31.4	8.29	8.32	0.020	0.002	0.035	0.013	0.814	1.3	3.0
Jul-07		6	26.3	31.8	8.10	7.73	0.018	0.002	0.036	0.038	0.052	12.8	6.0
Jul-07	Sachun	7	24.1	32.3	8.11	8.39	0.018	0.004	0.054	0.007	0.095	1.7	3.0
Jul-07	Jinju Bay	8	25.7	31.1	8.27	8.10	0.020	0.007	0.121	0.007	0.139	2.7	3.0
Jul-07		9	26.3	31.1	8.27	7.23	0.020	0.002	0.066	0.000	0.019	0.7	2.0
Jul-07	Tongyeong off shore	10	24.1	32.9	8.08	7.48	0.017	0.001	0.077	0.008	0.126	0.3	11.0
Jul-07		11	24.8	32.5	8.06	7.40	0.020	0.003	0.040	0.014	0.054	0.2	9.0
Jul-07		12	23.6	32.9	8.03	7.73	0.019	0.004	0.071	0.009	0.056	1.0	4.0
Aug-07	Tongyeong	3	22.7	32.8	8.01	7.77	0.010	0.001	0.038	0.010	0.015	12.6	3.0
Aug-07		4	25.0	32.6	7.88	7.49	0.010	0.022	0.012	0.023	0.013	4.0	4.0
Aug-07	Goseong-Jaran Bay	5	25.7	32.0	7.70	7.34	0.010	0.003	0.031	0.013	0.036	8.8	3.0
Aug-07		6	24.0	32.1	7.93	9.03	0.008	0.000	0.026	0.007	0.023	5.2	6.0
Aug-07	Sachun	7	23.5	32.2	7.96	7.41	0.009	0.002	0.038	0.025	0.083	6.0	4.0
Aug-07	Jinju Bay	8	24.5	32.3	7.80	7.10	0.007	0.002	0.033	0.033	0.032	2.4	2.5
Aug-07		9	26.1	31.3	8.00	7.52	0.012	0.011	0.040	0.062	0.047	4.3	3.0
Aug-07	Tongyeong off shore	10	23.7	32.5	8.08	6.95	0.008	0.013	0.120	0.019	0.050	2.6	4.0
Aug-07		11	24.1	32.6	7.97	8.10	0.006	0.000	0.042	0.009	0.015	2.2	5.0
Aug-07		12	23.1	33.0	8.10	8.30	0.015	0.008	0.038	0.016	0.020	5.0	4.0
Sep-07	Tongyeong	3	24.6	30.0	8.12	8.31	0.006	0.008	0.033	0.027	0.024	23.9	1.8
Sep-07		4	24.8	30.9	8.06	6.60	0.010	0.003	0.034	0.007	0.018	7.8	4.0
Sep-07	Goseong-Jaran Bay	5	24.8	30.7	8.19	7.91	0.010	0.006	0.008	0.005	0.178	4.9	1.5
Sep-07		6	24.8	30.8	8.08	7.17	0.020	0.008	0.006	0.010	0.338	2.4	5.0
Sep-07	Sachun	7	24.2	30.0	8.00	6.29	0.016	0.019	0.075	0.036	0.746	4.9	2.0
Sep-07	Jinju Bay	8	24.2	26.6	8.00	6.52	0.030	0.031	0.308	0.035	1.390	8.2	1.2
Sep-07		9	24.8	21.2	8.69	8.50	0.012	0.015	0.027	0.026	0.966	42.0	1.0
Sep-07	Tongyeong off shore	10	24.8	30.5	8.15	6.16	0.012	0.009	0.008	0.005	0.234	4.0	6.5
Sep-07		11	24.8	30.9	8.00	7.77	0.017	0.011	0.006	0.013	0.396	6.8	4.0
Sep-07		12	24.4	30.5	8.11	8.10	0.010	0.018	0.010	0.005	0.336	16.3	3.0

Source: National Fisheries research and Development Institute

5.11. Meteorological observation parameters

NFRDI uses data of wind direction, wind speed, solar irradiance, amount of precipitation, typhoon etc. from KMA for predicting HABs. Wind and current affect HABs dispersal to East Sea. Weather forecast is important for predicting HABs occurrence and dispersal because environmental factors such as amount of precipitation are related to diatom blooms causing changes in dominant species and harmful blooms extinction.

6. Eutrophication monitoring with satellite image

6.1. Framework of Satellite image monitoring

The following remote sensing data are available for the HAB case study:

- NFRDI has been receiving SST images derived from NOAA series, ocean color (chlorophyll-a and suspended sediment) images derived from SeaWiFS and MODIS for HABs prediction, respectively.

Observation parameters: sea surface temperature (SST), chlorophyll-a (Chl-a), suspended sediment (SS) etc.

Available data period (SST, Chl-a SS etc) see table 14.

Observation frequency: 6-8 per a day (NOAA/AVHRR), 1-2 per a day (SeaWiFS and MODIS)

Resolution: 1 km x 1 km, 4 km x 4 km and 9 km x 9 km, respectively.

NOAA/AVHRR has been receiving from 1989 by NFRDI. The data opened to the public via the internet homepage in NFRDI. MODIS data has been receiving from May 2001 by NFRDI. NFRDI also has SeaWiFS data with LAC (local area coverage) spatial resolution supported by KEOC (Korea Earth Observation Center) from 1999. OCM (Ocean Color Monitor) of IRS-P4 Chl-a concentration data has been received from May 2001 through October 2004 in NFRDI. IRS-P4 OCM Launched 26 may 1999 from India. OCM Chl-a data are processed by NASA OC2 algorithm.

6.2. Parameters of satellite image monitoring

Table 14 shows available remote sensing data for the HAB case study.

Table 14. Remote sensing data available for the HAB case study

Organization	Name of system	Monitoring Parameters	Data Set available					
			Sensor	Period of data	Unit of data set	Resolution	Product data level	Processing algorithm
NFRDI	Satellite Ocean Information Lab.	SST (MCSST)	AVHRR (NOAA)	1989.11-continue	Pass	1 km	Level 0	McClain et al (1985) MCSST algorithm
NFRDI	Satellite Ocean Information Lab.	Chlorophyll-a, Suspended sediment (SS)	SeaWiFS (Orbview-2)	1998.9-2007.12	Pass	1 km	Level 0	OC2 algorithm
NFRDI	Satellite Ocean Information Lab.	Chlorophyll-a	OCM (IRS-P4)	2001.5-2004.10	Pass	360m	Level 0	OC2 algorithm
NFRDI	Satellite Ocean Information Lab.	SST, Chlorophyll-a, Suspended sediment (SS)	MODIS (Aqua)	2002. 5-present	Pass	1 km	Level 0	OC3 Chl-a Algorithm, MCSST
			MODIS (Terra)	2001. 7-present	Pass	1 km	Level 0	OC3 Chl-a algorithm

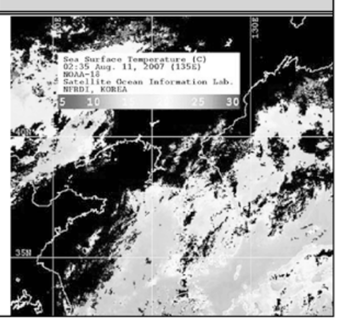
Organization	Name of system	Monitoring Parameters	Data Set available					
			Sensor	Period of data	Unit of data set	Resolution	Product data level	Processing algorithm
NASA	Ocean Color Web	Chlorophyll a	CZCS (SeaStar)	1978.11-1986.6	Daily, 8-Day, Monthly, Seasonal, Annual	4 km	Level 3	OC4 Chl-a algorithm
						9 km		
			OCTS (ADEOS)	1996.8-1997.7	Daily, 8-Day, Monthly, Seasonal, Annual	9 km	Level 3	
			SeaWiFS (Orbview-2)	1997.9-2004.12	Daily	1 km	Level 2	
					Daily, 8 Day, Monthly, Seasonal, Annual	9 km	Level 3	
					Daily, 8 Day, Monthly, Seasonal, Annual	4 km	Level 13	
						9 km		

6.3. Results of satellite image monitoring

The case study will provide the following information:

- The amounts of cells and dispersal in South Sea are monitored with SST and Chl-a measured by satellite remote sensing.
- The following table shows satellite images during HAB events.
-

Table 15. Satellite images during HAB events in Korea waters

Year	Event No.	Duration	Spot	SST (from Marine Calendar)
2007	SE-2007-2	2007. 8.11	Korea	

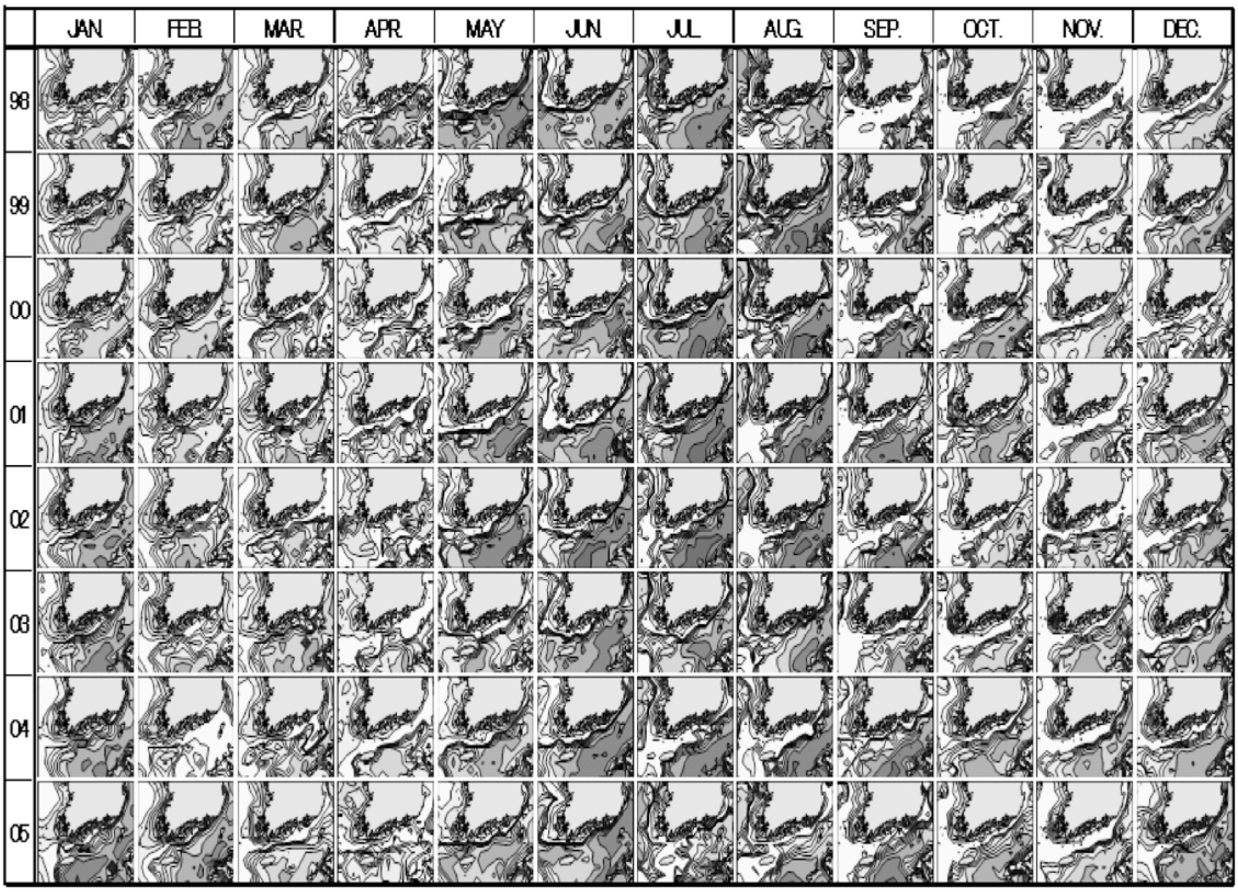


Figure 6. Monthly average SeaWiFS Chl-a imagies in the South Sea of Korea from 1998 to 2005.

7. Conclusion

For the last two decades, the economic impact of HABs on fisheries has increased with the increase of scale of HABs in Korea. Particularly, the blooms by fish killing *Cochlodinium polykrikoides* have been the direct and severe impacts on the coastal aquaculture industries in Korea and Japan. Therein, there is growing concerns to minimize fisheries damage by establishing early warning system from the initial stage and take emergent action against the blooms.

In 2007, *C. polykrikoides* blooms lasted for long time in Korean waters, and high density blooms occurred in South Sea. Approximately 10 million U.S. dollar losses and 25 million fish kills (Rockfish, parrot fish etc.) in farms were estimated during the blooms. The reason is that Tsushima current water was weak in the end of July and early August but strong Tsushima current water after mid August resulted in extinction of cold water column in Geoje-Do and dispersal of HABs in South Sea to East Sea. Fishery damages mainly occurred in South and East Seas. Phytoplankton species succession occurred due to heavy rainfall and nutrient increase, and remained HABs were extinct because of direct/indirect effects of typhoon. Therefore Tsushima current water, thermocline, wind direction, wind intensity, and amount of precipitation need to be investigated. HABs in South Sea were dispersed to East Sea by wind direction, wind intensity, and Tsushima current water. These factors also influence a large scale blooms and cell density. Species succession between *C. polykrikoides* and diatom due to nutrient supply from heavy rainfall at the end of red tide occurrences resulted in extinction of HABs. All parameters of HAB are the same in each country.

Herein, information on the bloom for the species would be essential to countermeasure against the blooms. In addition, collaborative research program to get scientific knowledge and networking for the monitoring and prediction of HABs among

NOWPAP member countries would be very beneficial in resolving the problems. The information of HABs by collaboration among NOWPAP member countries monitor and control land-based pollutants which might play a key role in accelerating blooms in coastal areas of NOWPAP member countries. Thus, it is highly encouraged to develop Korea appropriate policies and technologies to minimize the loading of land-based pollutants into the sea of NOWPAP area.

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Appendix

Records of HAB events in southeastern sea of Korea

Event No.			Duration (Start)			Duration(End)			Continuous days	Location of occurrence		Causative species	Maximum density (cells,inds/mL)	Fishery damage			Environmental parameters		Affected Area
Pref. cod	Year	No.	Year	Month	Day	Year	Month	Day		Sub-area	Spot			Fish/Shellfish Species	Quantity (million ind.)	Economic loss (1,000 won)	Water temp.(C°)	Salinity	Size of bloom(km2)
SE	2007	1	2007	7	24	2007	7	30	7	Tongyeong	Tongyeong Dosan	*Akashiwo sanguinea*	500				22.4-22.5	33.2	No info.
SE	2007	2	2007	8	6	2007	9	15	42	Namhae	Namhae Mizo	*C. polykrikoides*	32,500	Red sea bream, Bass, Rockfish, parrot fish	Rockfish, 0. 688, Red sea bream 0.389, Parrot fish 0.15, Bass 0.61, Sea bastes 0.149	3,664	23.3-25.7	32	50
SE	2007	3	2007	8	9	2007	9	12	35	Tongyeong	Tongyeong Sarang Suyou-do	*C. polykrikoides*	23,000	Rockfish, Parrot fish etc.	Rockfish, 2, Parrot fish 1 , etc. 1.9	7,337	24	32.6	70
SE	2007	4	2007	8	11	2007	9	1	29	Tongyeong	Goseong Bay	*C. polykrikoides*	4,000				26.5	31.1	3
SE	2007	5	2007	9	3	2007	9	9	6	Tongyeong	Jinju bay	*C. polykrikoides*	2,000				23.7	30.9	2
SE	2007	6	2007	10	19	2007	10	29	10	Tongyeong	Upper Sarang-do	*C. polykrikoides*	2,130				23	33.2	2

Report of HAB Case Studies in Amurskii Bay, Russia

Tatiana ORLOVA

Session 3

Review of Procedures for Assessment of Eutrophication Status Including Evaluation of Land Based Sources of Nutrients for the NOWPAP Region

Interim review and refinement of Draft Procedures for assessment of eutrophication status including evaluation of land based sources of nutrients for the NOWPAP region and a case study in Toyama Bay

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ABSTRACT

Eutrophication in the Northwest Pacific region (hereinafter referred as NOWPAP region) is a major environmental issue, as population and industries continue to grow in this region. In order to solve eutrophication issues in the NOWPAP region, it is important at first to understand and assess its current eutrophication status. However, at the moment, there are no established eutrophication assessment procedures that could be commonly applied to the NOWPAP region.

In order to help address eutrophication issues in the region, CEARAC proposed a new activity to develop procedures for assessment of eutrophication status including evaluation of land based sources of nutrients for the NOWPAP Region for the 2008-2009 biennium. The proposal was approved at the 12th NOWPAP Inter-Governmental Meeting.

Northwest Pacific Region Environmental Cooperation Centre (NPEC), hosting body of CEARAC, has conducted a case study in Toyama Bay and developed the 'Draft procedures for assessment of eutrophication status including evaluation of land based sources of nutrients (Draft Procedures) (Appendix 1)' by referring to existing approaches in other region. Summary of the case study in Toyama Bay is attached to this abstract as appendix 2.

For the purpose of sharing of common procedures for assessment of eutrophication status among the NOWPAP member states, the Draft Procedures are being reviewed and refined by the nominated experts in China, Korea and Russia. An interim progress of review and refinement work of China, Korean and Russia will be reported during the workshop.

Appendix 1

Draft procedures for assessment of eutrophication status including evaluation of land-based sources of nutrients for the NOWPAP region

(as of August 7, 2008)

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1. Introduction

1-1. Background

1.1. Development of the 'Draft procedures for assessment of eutrophication status including evaluation of land-based sources of nutrients for the NOWPAP region (Draft Procedures)' was proposed and approved at the 5th CEARAC Focal Point Meeting (FPM).

1.2. As part of the development processes of the Draft Procedures, NPEC has implemented a case study in Toyama Bay (Toyama Bay case study), by referring to the 'Common Procedure for the Identification of the Eutrophication Status of the OSPAR Maritime Area'. An interim progress of the Toyama Bay case study was presented at the 5th CEARAC FPM and First Coastal Environment Assessment Workshop held in Toyama from March 6-8, 2008.

1-2. Objectives of the Draft Procedures

1.3. The objectives of the Draft Procedures are to enable each NOWPAP member state to assess the status and impacts of eutrophication in their respective sea areas, by using data/information obtained through existing monitoring activities. The assessment results could hopefully then be utilized by each NOWPAP member state for consideration and development of monitoring systems and countermeasures against eutrophication. Figure 1 schematically shows the concept of the Draft Procedures.

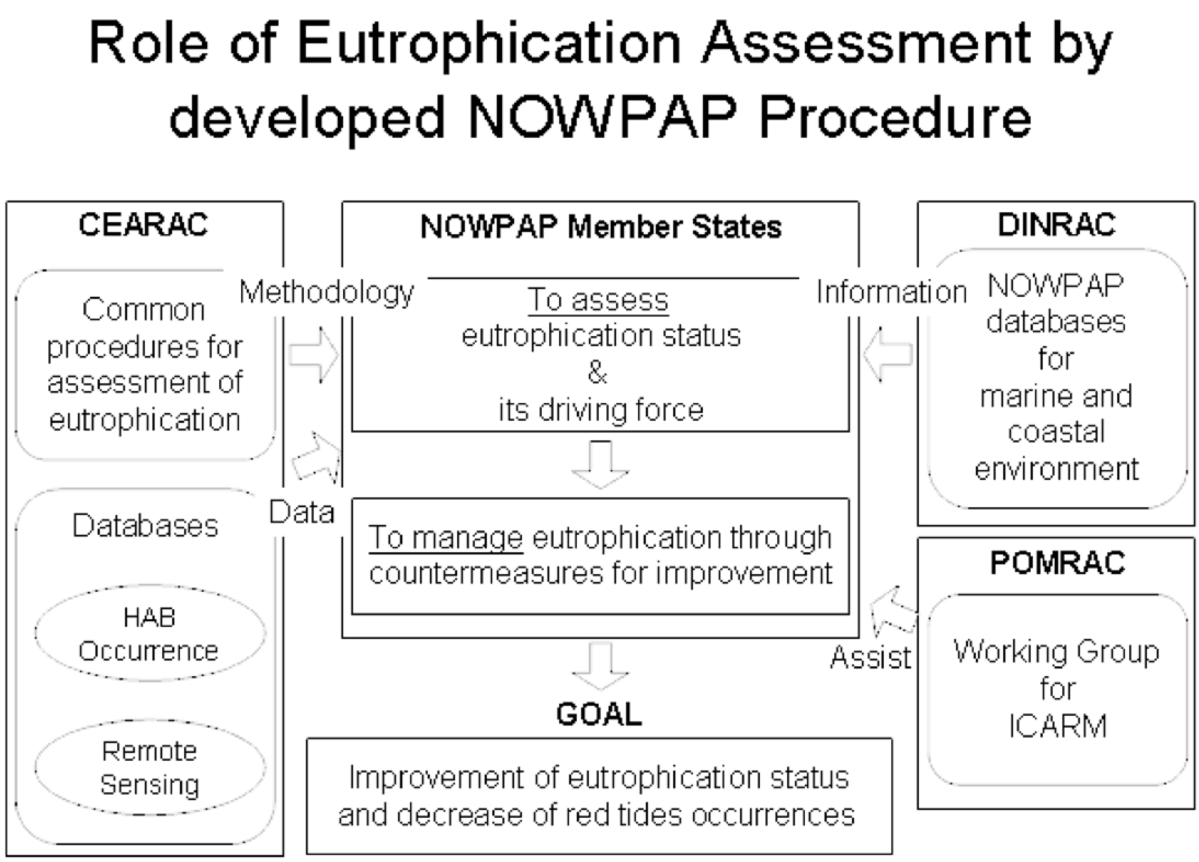

Figure 1 Concept of the Draft Procedures

1-3. Characteristics of the Draft Procedures

1.4. The Draft Procedures was developed based on the following principles:

i) It should be adaptable to various types of sea areas in the NOWPAP region.
ii) Remote Sensing data should be used in the assessment procedure.
iii) Eutrophication status is assessed through a holistic approach by integrating the following eutrophication aspects: degree of nutrient enrichment, direct/indirect effects of nutrient enrichment and other possible effects of nutrient enrichment.
iv) In general, eutrophication status is assessed in relative ways within the whole assessment area.

1-4. Overall structure

1.5. The assessment procedure is broadly separated into six parts, namely i) scope of assessment, ii) data processing, iii) setting of assessment criteria iv) assessment process and results, v) verification of results and vi) conclusion/recommendation. In the 'scope of assessment' part, an assessment area and parameters are selected. In the 'data processing' part, raw data are processed into data sets for the assessment. In the 'setting of assessment criteria' part, assessment criteria are set. In the 'assessment process and results' part, eutrophication status of the assessment area is identified. In the 'verification of results' part, the assessment results are reviewed and verified by new monitoring techniques such as remote sensing. In the 'conclusion/recommendation' part, future issues and actions are identified on the basis of the assessment results. Figure 2 shows the implementation flow of the Draft Procedures.

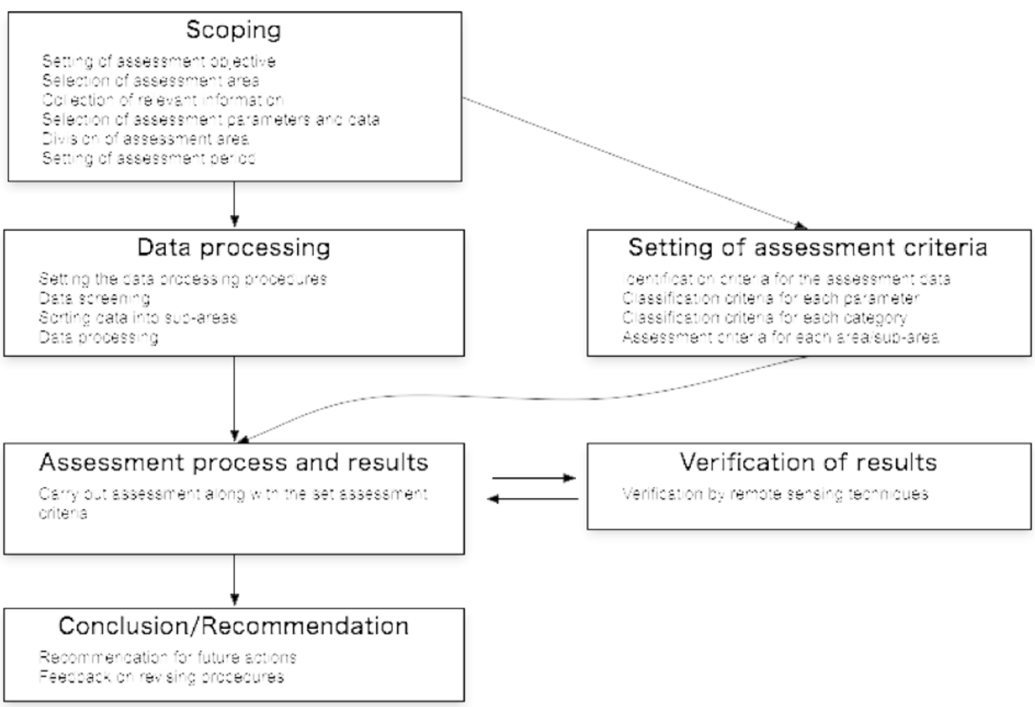

Figure 2 Basic flow of the Draft Procedures

2. Scope of assessment

2-1. Setting of assessment objective

2.1. State the objectives of the assessment.

2.2. In order to facilitate the understanding of the assessment results, clarify the preconditions and limitations involved in the assessment.

2.3. State any scientific uncertainties that future users of the assessment results should take note of, such as:

i) Application of the assessment results for forecasting environmental changes could be inappropriate.

ii) The assessment results may become less reliable/valid when scientific data/information are updated.

2-2. Selection of assessment area

2.4. Select an area that can be considered as a single sea area.

2.5. An assessment area should be an area that has ongoing environmental monitoring and assessment programs.

2.6. An assessment area must be an area that has ongoing water quality monitoring and assessment programs.

2-3. Collection of relevant information

2.7. Collect information on the assessment area such as, status of water quality monitoring (locations, frequency, parameters), ocean observations by satellite remote sensing, status of wastewater treatment, status of coastal use (e.g. location of recreational beaches), population of catchment area, land use and industrial activities (e.g. industries that have potential impacts on eutrophication).

2.8. Collect data from organizations that monitor chemical, biological and physical parameters that directly or indirectly relate to eutrophication. The following are some relevant organizations:

i) Organizations that monitor water quality for environmental conservation purposes
ii) Organizations that observe ocean with satellite remote sensing
iii) Organizations that monitor harmful algal blooms for protection of fishery resources
iv) Organizations that monitor shellfish poisoning for food safety
v) Organizations that have other relevant information such as ocean current and water temperature.

2.9. Collect existing survey data/information from the above organizations as in Table 1.

Table 1 Survey data/information collected from monitoring organizations

Survey area	Governing organization	Survey title	Aim	Survey period	Main survey parameters	Survey frequency	No. of survey points

2.10. Select the most appropriate data source for the assessment process in section 5.

2.11. Types of data sources which should not be used for the assessment procedure:

i) Surveys conducted at very limited frequency
ii) Data that are not directly related to eutrophication
iii) Surveys that are not conducted at regular locations and frequency
iv) Surveys that are not conducted for monitoring water quality and aquatic organisms
v) Surveys that employ uncommon analytical methods

2-4. Selection of assessment parameters and data

2-4-1. Categorization of monitored/surveyed parameters

2.12. Categorize all eutrophication related parameters that are monitored/surveyed within the assessment area into one of the following 4 assessment categories:

i) Category I Parameters that indicate degree of nutrient enrichment
ii) Category II Parameters that indicate direct effects of nutrient enrichment
iii) Category III Parameters that indicate indirect effects of nutrient enrichment
iv) Category IV Parameters that indicate other possible effects of nutrient enrichment

2-4-2. Selection of assessment parameters for each assessment category

2.13. After the categorization process, select assessment parameters that are applicable for the assessment procedure on the basis of their data reliability and continuity (e.g. data collected at fixed locations and at regular frequencies). The selected assessment parameters should also have established methods of analysis.

2.14. In principle, all surveyed/monitored parameters related to eutrophication should be selected for the assessment procedure. If certain parameters are to be excluded from the assessment procedures, the reasons must be stated.

2.15. Table 2 shows examples of assessment parameters that are relevant to the 4 categories.

Table 2 Examples of assessment parameters

Category		Assessment parameter
I	Degree of nutrient enrichment	Riverine input (T-N, T-P)
		Total nitrogen/Total phosphorus (T-N, T-P)
		Winter DIN/DIP concentration
		Winter N/P ratio (DIN/DIP)
II	Direct effects of nutrient enrichment	Chlorophyll-a concentration (field data)
		Chlorophyll-a concentration (remote sensing data)
		Sea area ratio with high chlorophyll-a concentration (remote sensing data)
		Red-tide events (diatom species)
III	Indirect effects of nutrient enrichment	Dissolved oxygen (DO)
		Abnormal fish kill incidents
		Chemical oxygen demand (COD)
IV	Other possible effects of nutrient enrichment	Red-tide events (*Noctiluca* sp.)
		Shellfish poisoning incidents

2-4-3. Setting of assessment value

2.16. In order to understand the interannual trends of eutrophication, assessment should be basically conducted with annual values.

2.17. Set the assessment values (e.g. annual mean, annual max., annual number of events) to be used for each assessment parameter.

2-4-4. Selection of data source for the assessment

2.18. Select the data source to be applied for each assessment parameter.

2-5. Division of assessment area into sub-areas

2.19. In order to understand and assess the causes and direct/indirect effects of eutrophication at more localized scales, the assessment area may be divided into sub-areas.

2.20. When dividing the assessment area into sub-areas, factors such as location of riverine input, monitoring locations, fishery activities, underwater topography, salinity distribution, ocean/tidal currents and red-tide events should be considered.

2-6. Setting of assessment period

2.21. Set the assessment period in accordance with the assessment objectives and availability of reliable data.

3. Data processing

3-1. Setting of data processing procedure

3.1. Based on the set assessment values, establish a common data processing method for each assessment parameter.

3-2. Data screening

3.2. Within the selected data source, exclude data that are not suitable for the assessment.

3.3. If data are excluded in the above process, state the reasons for their exclusion. Possible reasons could be related to survey location, data reliability and so on.

3-3. Sorting data into sub-areas

3.4. If the assessment area is divided into sub-areas, the data used for the assessment of each sub-area should be sorted by the location of survey/monitoring sites.

3-4. Data processing of assessment parameters

3.5. Based on the set data processing method, process the collected data.

3.6. In principal, data should be processed by each survey/monitoring site.

3.7. Data sets should be prepared for each assessment parameter and sorted by survey/monitoring site.

4. Setting of assessment criteria

4.1. In order to assess the eutrophication status of an assessment area, identification criteria for each assessment data* and classification criteria for each assessment parameter, category and assessment criteria for area/sub-area must be set.

*Assessment data: data to be used for the following identification process, which is calculated by assessment value.

4-1. Setting of identification criteria for the assessment data

4.2. The eutrophication status of each assessment parameter is assessed by its current status and future trend. The current status and future trend of an assessment parameter are identified by its assessment data with the following identification tools. Combination of these identification tools must be applied for each assessment parameter.

i) Identification by comparison (identifies current status): The eutrophication status is identified by comparing the assessment data with either the value established by environmental standards or background value set by the values measured in an area that have had negligible influence from anthropogenic activities. This identification tool is used for assessment parameters that can be represented in terms of concentration or ratio.

ii) Identification by occurrence (identifies current status): The eutrophication status is identified by occurrence or non-occurrence of events. This identification tool is used for assessment parameters that can be represented in terms of number or frequency of occurrence.

iii) Identification by trend (identifies future trend): The eutrophication status is identified by predicting future trends. This identification tool is used for all parameters.

4.3. The basis behind the set identification criteria must be stated clearly and objectively.

4-2. Setting of classification criteria for each assessment parameter

4.4. Set the classification criteria of each assessment parameter based on the current status and future trend identified by the combination of the identification tools.

4.5. Table 3 shows an example of identification tools applied to each assessment parameter.

Table 3 Examples of identification tools applied to each assessment parameter

Category	Assessment parameter	Assessment value	Identification tools[1)]			Remarks
			Comparison	Occurrence	Trend	
I	Riverine input (T-N, T-P)	Annual mean			✓	
	Total nitrogen/Total phosphorus (T-N, T-P)	Annual mean	✓		✓	
	Winter DIN/DIP concentration	Winter mean	✓		✓	
	Winter N/P ratio (DIN/DIP)	Winter mean	✓		✓	
II	Chlorophyll-a concentration (field data)	Annual max. Annual mean	✓		✓	
	Chlorophyll-a concentration (remote sensing data)	Annual max. Annual mean	✓		✓	
	Sea area ratio with high chlorophyll-a concentration (remote sensing data)	Annual max. Annual mean			✓	
	Red-tide events (diatom species)	Annual occurrences		✓	✓	
III	Dissolved oxygen (DO)	Annual min.	✓		✓	
	Abnormal fish kill incidents	Annual occurrences		✓	✓	
	Chemical oxygen demand (COD)	Annual mean	✓		✓	
IV	Red-tide events (*Noctiluca* sp.)	Annual occurrences		✓	✓	
	Shellfish poisoning incidents	Annual occurrences		✓	✓	

1) Comparison: comparison with environmental standard or background value
Occurrence: occurrence or non-occurrence
Trend: degree of increase/decrease

4.6. The proposed classification criteria for each assessment parameter are as follows. The identification result of the current status is classified as either 'high status' or 'low status', and future trend is classified as 'decrease trend', 'no trend' or 'increase trend'. Classification results of the current status and future trend are then integrated and classified into 6 eutrophication groups shown in Table 4. If the assessment parameter can only be assessed by the trend method, the assessment parameter will be classified as either ‘decrease trend’, ‘no trend’ or ‘increase trend’.

4.7. Table 4 shows the classification criteria for the assessment parameter.

Table 4 Classification criteria of assessment parameter

Classification	Identification result
HI (High status and Increase Trend)	Current status high and increasing trend
HN (High status and No Trend)	Current status high but no increasing or decreasing trend
HD (High status and Decrease Trend)	Current status high but decreasing trend
LI (Low status and Increase Trend)	Current status low but increasing trend
LN (Low status and No Trend)	Current status low but no increasing or decreasing trend
LD (Low status and Decrease Trend)	Current status low and decreasing trend

Classification by trend only

Classification	Assessment result
I (Increase Trend)	Increasing trend
N (No Trend)	No increasing or decreasing trend
D (Decrease Trend)	Decreasing trend

4-3. Setting of classification criteria for the assessment category

4.8. Set the classification criteria of each assessment category based on the classification results of the assessment parameters.

4.9. Classify the assessment category by selecting one classification result of the assessment parameters within the assessment category that most appropriately represents the eutrophication status of the area. However, if the classification results among the assessment parameters in the assessment category are contradictory, and therefore it is unreasonable to select a representative classification result, this assessment category can be excluded from the classification procedure with its reasons stated.

4-4. Setting of assessment criteria for the assessment area/sub-area

4.10. Set holistic assessment criteria for the assessment area/sub-area so as to diagnostically explain classification results of each assessment parameter and category.

5. Assessment process and results

5.1. The eutrophication status of the assessment area should be assessed, on the basis of the identification results of the assessment data and classification results of each parameter and parameter's categories.

5.2. Identify the eutrophication status of the assessment data of each monitoring site based on the set identification criteria.

5.3. Classify each assessment parameter based on the identification results of the assessment data. If there are multiple monitoring sites in each sub-area, the identification results from all the monitoring sites should be taken into account.

5.4. Classify each assessment category based on the classification results of assessment parameters.

5.5. The eutrophication status of each area/sub-area should be assessed based on the classification results of each assessment parameter and category.

6. Verification of results

6.1. The assessment report should have all necessary information required for review.

6.2. Use of remote sensing is recommended for the verification of the assessment results.

7. Conclusion and recommendation

7.1. Based on the assessment results, provide recommendations for future actions.

7.2. The results of each classification process should be clearly presented, so that policy makers etc. can consider the most appropriate monitoring or countermeasures against eutrophication.

Appendix 2

Summary of Phase 1 of Toyama Bay case study

Aug 7, 2008

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I Introduction

1 Background and objective

Eutrophication in the Northwest Pacific region (hereinafter referred as NOWPAP region) is a major environmental issue, as population and industries continue to grow in this region. In order to solve eutrophication issues in the NOWPAP region, it is important to first understand and assess its current eutrophication status. However, at the moment, there are no established eutrophication assessment procedures that could be commonly applied to the NOWPAP region.

Assessment methods for eutrophication have developed by OSPAR Commission, NOAA and Mediterranean Action Plan of UNEP. Among these, the procedure developed in OSPAR (OSPAR procedure) seemed to be the most suitable reference material for the NOWPAP region in respect that it has been already implemented by many of the OSPAR countries, and that the selection of assessment parameters and their assessment levels for the uses in the eutrophication assessment and final judgment on the eutrophication status are entrusted to each country.

In order to develop an objective eutrophication assessment procedure for the NOWPAP region, the Northwest Pacific Region Environmental Cooperation Centre (NPEC) has conducted a case study in Toyama Bay (Toyama Bay case study) and developed the 'Draft procedures for assessment of eutrophication status including evaluation of land-based sources of nutrients (Draft Procedures)' by referring to the OSPAR procedure.

While remote sensing data are considered as a supplementary tool in the OSPAR procedure, the Toyama Bay case study incorporated remote sensing data into the assessment and verification processes. The aim was to establish an effective assessment and verification tool for eutrophication by utilizing remote sensing techniques.

2 Implementation processes of the Toyama Bay case study

In F.Y. 2007, the Toyama Bay case study was implemented to examine the validity of the Draft Procedures (Phase 1 of Toyama Bay case study).

As part of Phase 1, the assessment procedures set out in the OSPAR procedure were reviewed by using data obtained in Toyama Bay, and an appropriate assessment method for eutrophication in Toyama Bay was considered in the process.

The progress of the Toyama Bay case study was reviewed by experts of the following committees established by NPEC: Red tide and HAB National Review Committee, Ocean Remote Sensing National Review Committee and Toyama Bay Project Review Committee.

Based on the experiences gained in Phase 1, the Draft Procedures has being completed. The Draft Procedures will be finalized after being reviewed further by the experts of the NOWPAP member states.

3 Structure of the Toyama Bay case study

The Toyama Bay case study broadly consists of six parts, namely i) scope of assessment, ii) data processing, iii) setting of assessment criteria iv) assessment process and results, v) verification of results and vi) conclusion/recommendation. In the 'scope of assessment' part, assessment area and parameters were selected. In the 'data processing' part, raw data were processed into data sets for the assessment. In the 'setting of assessment criteria' part, assessment criteria were set. In the 'assessment process and results' part, eutrophication status of the assessment area/sub-areas was identified. In the 'verification of results' part, the assessment results were reviewed and verified by remote sensing. In the 'conclusion/recommendation' part, future issues and actions were identified. Figure I-3-1 shows the structure of the Toyama Bay case study. Also necessary feedback was made to update and improve the contents and methodologies of each part.

Details of each part are described from Chapter II.

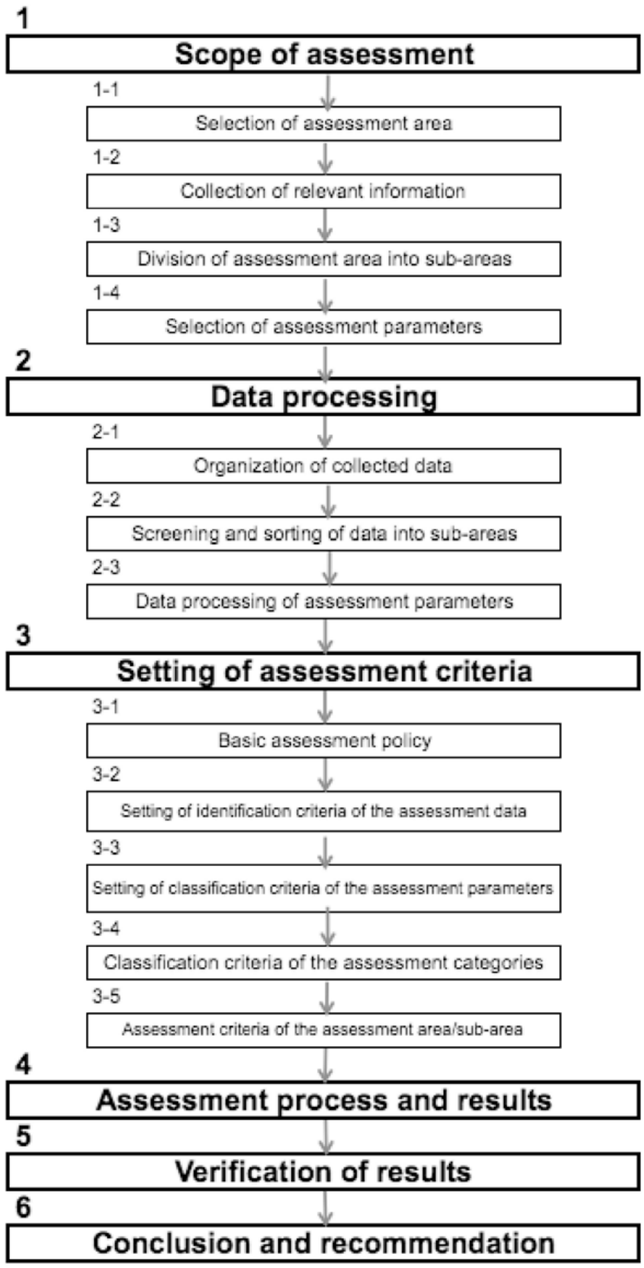

Figure I-3-1. Structure of the Toyama Bay case study.

4 Assessment results of the Toyama Bay case study

Since the primary focus of the Toyama Bay case study was to establish a common assessment procedure for various types of sea areas, the assessments conducted in the case study were based on uncertain assumptions and assessment criteria. Therefore, it is necessary to note the possibility that the obtained assessment results may not be an accurate reflection of the eutrophication status of Toyama Bay.

In F.Y. 2008, eutrophication status of Toyama Bay will be re-assessed by re-implementing the Toyama Bay case study (Phase 2 of Toyama Bay case study) with an improved assessment procedure.

II Toyama Bay case study

1 Scope of assessment

1-1 Selection of assessment area

In the OSPAR procedure, for the assessment of eutrophication, it is recommended to select an assessment area by considering factors such as oceanographic characteristics, availability of existing water quality monitoring and assessment programs.

In the Toyama Bay case study, the area for the assessment was selected by referring to existence and reliability of data/ information related to eutrophication.

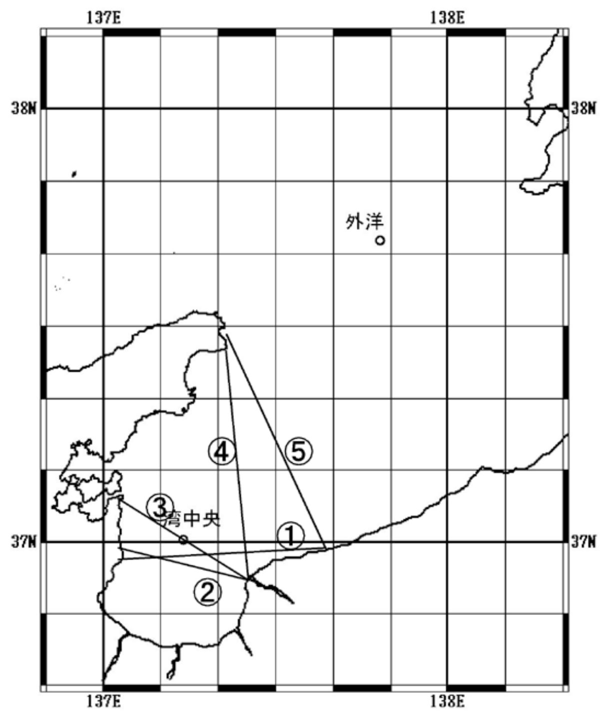

Figure II-1-1-1. Scopes of Toyama Bay sea area.

1-2 Collection of relevant information

In Toyama Bay, under the Water Pollution Control Law, the environmental department of the Toyama Prefecture government conducts monthly water quality monitoring in its public waters. From F.Y. 1997, to understand the status of eutrophication in Toyama Bay, the environmental department has supplemented the above monitoring program by adding new monitoring parameters and sites. Surveys and researches related to eutrophication have also been conducted in Toyama Bay. Water pollution incidents such as oil spills and abnormal fish kills have also been recorded.

To monitor and protect the fishing grounds in Toyama Bay, the fisheries department of the Toyama Prefecture government conducts monitoring of fishing ground (e.g. water quality, red tides, marine organisms) in the coastal areas of Toyama Bay. Oceanographic conditions are also monitored at fixed locations along the coast.

Table II-1-2-1 summarizes the monitoring and research programs related to eutrophication in Toyama Bay.

Table II-1-2-1. Monitoring and research programs related to eutrophication in Toyama Bay.

Survey type	Organization	Survey title		Aim	Survey period	Main parameters	Frequency	No. of survey sites (as of 2005)
Water quality monitoring	Toyama Pref., Dept. of Environmental Conservation	Water quality monitoring of public waters (sea area)		Monitoring of water quality	F.Y. 1976- F.Y. 1997- (T-N/T-P)	DO, COD, T-N, T-P	1/month	23 Coast: 10 Jintsu River: 7 Oyabe River: 6
	Toyama Pref., Dept. of Environmental Conservation	Supplementary water quality monitoring in Toyama Bay		Monitoring of eutrophication	F.Y 1997-	DIN, DIP, Chlorophyll-a, T-N, T-P	1/month	9
	Toyama Pref., Dept. of Environmental Conservation	Reporting of water pollution		To understand the status of water pollution	F.Y. 1975-	Pollution location/area/casues, impact on fish	Ad hoc	
Environment related survey/research	Toyama Pref., Dept. of Environmental Conservation	Basic survey for simulation model development		To improve the accuracy of simulation model	F.Y. 2005	Riverine input (T-N, T-P) (1985-2004)	1 year	5 rivers
	Toyama Pref., Dept. of Environmental Conservation/ Japan Coast Guard	Joint environmental survey of Toyama Bay	Water quality survey (Dept. of Environment	To understand diffusion of COD, nitrogen, phosphrous through river inflow	F.Y. 2004-2005	COD, T-N, T-P, DIN, DIP, Chlorophyll-a, transparency	Rivermouth: 4/year Toyama Bay: Once in 2005	Jintzu rivermouth: 10 sites Oyabe rivermouth: 10 sites Toyama Bay: 10
			Ocean current survey	To understand current movement in rivermouth area		Current direction/speed, Water temp., salinity	Once in 2005	ADCP: 48 sites Toyama Bay: 44 sites
	Toyama Prefectural Environmental Science Research Center	Reseach on water pollution mechanism in Toyama Bay		To understand the pollution mechanism of CDOM	F.Y. 2005-2007	CDOM, R-DOM, chlorophyll-a	4/year	7
	NPEC, TESC, Toyama Uni., Nagasaki Uni., etc.	Survey to promote NOWPAP activities (Toyama Bay project)		To verify the applicability of remote sensing in ocean monitoring	F.Y. 2003-	DIN, DIP, chlorophyll-a, SS, DO, T-N, T-P, transparency,	1/month	11
	NPEC	Development of current analysis program for Toyama Bay		Development of current simulation program by water temp. distribution	F.Y. 2003-2005 Analysis period: F.Y. 2002-2004	Remote sensing: chlorophyll-a, SST Fiedl survey: surface current direction, current speed, water temp.	Remote sensing: all year Field survey: May 10-13, 2005	136°E30´-136°E30´, 36°N40´-38°N40´
Water quality monitoring by fisheries department	Toyama Pref. fisheries research institute	Survey of fishing ground environment	Survey of fixed nets	To understand the water quality near fixed nets	F.Y. 1971-	COD, salinity, turbidity	1/month	36
			Survey of water quality	To understand the water quality at fishing grounds	F.Y.1995-	COD, DO, salinity, turbidity	1/month	18
			Survey of red tide	To understand the status of red tides	F.Y.1966-	Area of red tide, phytoplankton	During red tide event	Toyama Bay
Fishing ground monitoring by fisheries department		Survey of marine organisms		To monitor fishing ground environment	F.Y.1996-	Zoobenthos, pollution indicator spp., sediment quality	April, October	8
		\Observation of coastal waters of Toyama bay		To investigate the coastal oceanography of Toyama Bay	F.Y.1953-	Water temp., salinity	1/month	26
Remote sensing data	Ministry of Environment/ NPEC	Marine environmental monitoring of Northwest Pacific region		To disseminate remote sensing info. for the Northwest Pacific region	2002-	Chlorophyll-a, SST	1-2/day (chlorophyll-a) 8-10/day (SST)	Toyama Bay
	NASA	Ocean Color WEB		Provision of remote sensing data	1978-	Chlorophyll-a, SST, turbidity	1-2/day	Global
Others	Toyama Pref. (Dept. of Health)	Reporting of food poisoning		To prevent food poisoning	1994-	Date, location, food type	Durig food poisoning	

1-3 Division of assessment area into sub-areas

In order to understand the status and causes of eutrophication at localized scales, the assessment area was divided into 5 sub-areas as shown in Figure II-1-3-1. As water quality and oceanographic characteristics within each sub-area are to be similar, factors such as riverine input, fishery activities, underwater topography, salinity distribution, ocean/tidal currents and red-tide events were considered in the division process.

Also to best utilize and to enable comparison with the survey results of existing monitoring programs, the boundaries set by the red-tide monitoring program of Toyama Prefectural Fisheries Research Institute were utilized as a basis for the sub-area division.

Figure II-1-3-1. The sub-areas of the Toyama Bay case study.

1-4 Selection of assessment parameters

All eutrophication related parameters surveyed in the assessment area were categorized into one of the following 4 assessment categories.

i) Category I Parameters that indicate degree of nutrient enrichment
ii) Category II Parameters that indicate direct effects of nutrient enrichment
iii) Category III Parameters that indicate indirect effects of nutrient enrichment
iv) Category IV Parameters that indicate other possible effects of nutrient enrichment

Among the available surveyed parameters, only the parameters that were applicable to the assessment procedure were selected based on their data reliability and continuity (i.e. data collected at fixed locations and at regular frequencies). Table II-1-4-1 shows the assessment parameters selected for the Toyama Bay case study.

Table II-1-4-1. Assessment parameters selected for the Toyama Bay case study

Category		Assessment parameter		Survey title
I	Degree of nutrient enrichment (nutrient load, nutrient concentration, etc.)	Nutrient load	Riverine input (T-N)	Data collection for simulation model [Department of environmental conservation, Toyama Prefecture]
			Riverine input (T-P)	
		Nutrient concentration (annual)	Total nitrogen (T-N)	Seawater quality survey [Department of environmental conservation, Toyama Prefecture], Toyama Bay project [NPEC]
			Total phosphorus (T-P)	
		Nutrient concentration (winterl)	Winter dissolved inorganic nitrogen (DIN)	Seawater quality survey [Department of environmental conservation, Toyama Prefecture]
			Winter dissolved inorganic phosphorus (DIP)	
			Winter DIN/DIP ratio	(Calculated value)
II	Direct effects of nutrient enrichment (increase of phytoplankton, turbidity, etc.)	Chlorophyll-a	Chlorophyll-a concentration (field data)	Seawater quality survey [Department of environmental conservation, Toyama Prefecture], Toyama Bay project [NPEC]
			Chlorophyll-a concentration (remote sensing data)	Environmental watch-system of the North west Pacific [Ministry of Environment/NPEC], Ocean Color WEB[NASA]
			Sea area ratio with high chlorophyll-a concentration (remote sensing data)	
		Phytoplankton	Red-tide events (diatom species)	Red-tide survey [Toyama Prefectural Fisheries Research Institute]
III	Indirect effects of nutrient enrichment (increase of organic matter, decrease in dissolved oxygen, etc.)	Oxygen deficiency	Dissolved oxygen (DO)	Seawater quality survey [Department of environmental conservation, Toyama Prefecture], Toyama Bay project [NPEC]
		Fish kill	Abnormal fish kill incidents	Report of maritime accidents [Department of environmental conservation, Toyama Prefecture]
		Organic carbon/oragnic matter	Chemical oxygen demand (COD)	Seawater quality survey [Department of environmental conservation, Toyama Prefecture], Toyama Bay project [NPEC]
IV	Other possible effects of nutrient enrichment (shellfish poisoning, etc.)	Plankton blooms	Red-tide events (Noctiluca sp.)	Red-tide survey [Toyama Prefectural Fisheries Research Institute]
		Algal toxins	Shellfish poisoning incidents	Report on food poisoning [Department of Health]

2 Data processing

2-1 Organization of collected data

To prepare for data processing stage, the collected raw data were first organized into tabular formats. Table II-2-1-1 and II-2-1-2 show the formats used for regular monitoring data and satellite image data, respectively. The collected data were also organized by survey year to enable interannual comparisons.

Remote sensing data were processed into monthly merged data by calculating the monthly averaged concentration of each pixel (size: 1 km x 1 km).

Table II-2-1-1. Format for regular monitoring data.

Survey year	Site info.		Sampled date	Results			Remarks
	Site no.	Site name		DIN	DIP	Chlorophyll-a	
				mg/L	mg/L	µg/L	
1998	J-5	Jintzu River 5	1999/4/8	1.2	0.03	1.6	
1998	J-8	Jintzu River 8	1999/5/8	1.1	0.05	1.7	

Table II-2-1-2. Format for remote sensing data.

P	L	Longitude	Latitude	2002	2002	2002	2002	2002	2002
				1	2	3	4	5	6
1	1	137.5000	37.5000	0.8400	1.1000	0.8064	1.2100	0.7741	1.1616
1	2	137.6363	37.4337	0.8400	1.1000	0.8064	1.2100	0.7741	1.1616
1	3	137.7726	37.3674	0.6000	0.7857	0.5760	0.8643	0.5530	0.8297
1	4	137.9089	37.3011	0.1680	0.2200	0.1613	0.2420	0.1548	0.2323

2-2 Screening and sorting of data into sub-areas

After the data organization process, the collected data were categorized either into regular monitoring data, remote sensing data or other types of data, and then were sorted into the relevant sub-areas after excluding any unsuitable data for the assessment.

2-2-1 Regular monitoring data

For water quality parameters/data that were collected under regular monitoring programs, data obtained from the mixed waters at surface (0.5m) and middle layer (2m) were generally used for the assessment. However, surface layer data were used for monitoring site located in the central area of Toyama Bay, as only sea surface layer is being monitored.

Data that were not obtained through standardized analytical methods and data obtained from near the rivermouth areas (i.e. areas affected by freshwater input) were excluded from the assessment. After this screening process, the collected regular monitoring data were sorted into the sub-areas by the location (latitude/longitude) of their monitoring sites. Table II-2-2-1 provides information on the regular monitoring sites in Toyama Bay.

Table II-2-2-1. List of regular monitoring sites in Toyama Bay.

	Area name	Sea area	Name of survey site			Location				Status of regular monitoring			Type	Excluded sites			
			Site name	Abbreviation	Site no.	Latitude (N°)	Longitude (E°)	Implemented year	Pixel no.	Regular survey	Supplementary	Toyama Bay PJ		Rivermouth	Site location	Analysis method	Other
Toyama Bay	Sub-area A	Other sea area	Other 8	S-8	1660710	36.9131	137.3953	2005	P080L122	✔	1997-2005		A				
			Other 9	S-9	1660711	36.9700	137.4803	2005	P087L115	✔							
			Other 10	S-10	1660712	36.9925	137.5886	2005	P097L113	✔	1997-2005						
	Sub-area B	Jintzu rivermouth	Jintzu 1	J-1	1660501	36.7728	137.2086	2005	P063L137	✔			B	✔			
			Jintzu 2	J-2	1660502	36.7772	137.2222	2005	P064L137	✔				✔			
			Jintzu 3	J-3	1660503	36.7728	137.2358	2005	P066L137	✔				✔			
		Jintzu rivermouth	Jintzu 4	J-4	1660601	36.7767	137.2039	2005	P063L137	✔			A				
			Jintzu 5	J-5	1660602	36.7828	137.2222	2005	P064L136	✔	1997-2005						
			Jintzu 6	J-6	1660603	36.7764	137.2406	2005	P066L137	✔							
		Other sea area	Jintzu 7	J-7	1660702	36.7981	137.2222	2005	P064L134	✔			A				
			Other 5	S-5	1660707	36.7789	137.2786	2005	P069L136	✔							
			Other 6	S-6	1660708	36.7931	137.3311	2005	P074L135	✔	1997-2005						
			Other 7	S-7	1660709	36.8256	137.3703	2005	P078L131	✔							
			St.1 (Namekawa)	St.1		36.7933	137.3317		P074L135			✔			✔ (except COD)	✔ (except COD)	✔ (No data of ammonia
			St.2 (Namekawa)	St.2		36.8317	137.3317		P074L131			✔			✔	✔	✔ (No data of ammonia
			St.3 (Jintzu coast)	St.3		36.7933	137.2533		P067L135			✔			✔	✔	✔ (No data of ammonia
			St.4 (Jintzu offshore)	St.4		36.8317	137.2533		P067L131			✔			✔	✔	✔ (No data of ammonia
	Sub-area C	Oyabe rivermouth	Oyabe 1	O-1	1660301	36.8036	137.0681	1993	P051L134	O(1976~1993)			B	✔			✔ (Survey finished)
			Oyabe 2	O-2	1660302	36.8008	137.0764	2005	P052L134	✔				✔			
			Oyabe 3	O-3	1660303	36.7939	137.0803	2005	P052L135	✔				✔			
		Oyabe rivermouth	Oyabe 4	O-4	1660401	36.8131	137.0681	1996	P051L133	O(1976~1996)			A				✔ (Survey finished)
			Oyabe 5	O-5	1660402	36.8072	137.0847	2005	P052L133	✔	1997-2005						
			Oyabe 6	O-6	1660403	36.7939	137.0914	2005	P053L135	✔							
		Other sea area	Oyabe 7	O-7	1660701	36.8197	137.0997	2005	P054L132	✔			A				
			Other 4	S-4	1660706	36.7894	137.1356	2005	P057L135	✔	1997-2005						
			St.6 (Shinminato coast)	St.6		36.7933	137.1550		P058L135			✔			✔	✔	✔ (No data of ammonia
			St.7 (Shinminato offshore)	St.7		36.8317	137.1550		P058L131			✔			✔	✔	✔ (No data of ammonia
			St.8 (Koyabe coast)	St.8		36.8317	137.0900		P053L131			✔			✔	✔	✔ (No data of ammonia
	Sub-area D	Other sea area	Other 1	S-1	1660703	36.9081	137.0461	2005	P049L122	✔			A				
			Other 2	S-2	1660704	36.8714	137.0119	2005	P046L126	✔	1997-2005						
			Other 3	S-3	1660705	36.8353	137.0444	2005	P049L130	✔							
			St.9 (Hyomi coast)	St.9		36.8717	137.0117		P046L126			✔			✔ (except COD)	✔ (except COD)	✔ (No data of ammonia
Supplementary sites	Sub-area E	Central area	Toyama Bay central area	Central area		37.0033	137.2300		P065L111		1999-2005	✔	-				Data overlap (Chl-a)
			St.5 (Jintzu offshore)	St.5		36.8717	137.2533		P067L126			✔			✔	✔	✔ (No data of ammonia
	Background area	Open ocean	Open ocean	Open ocean		37.6950	137.8133		P117L034		1999-2005	✔	-				Data overlap (Chl-a)

Note: The shaded cells indicate the excluded monitoring sites

2-2-2 Remote sensing data

Some pixels in the assessment area could not acquire sufficient quantity of monthly merged data for assessment, due to factors such as cloud cover and land effects. Therefore, for the Toyama Bay case study, pixels that had less than 80% monthly merged data were considered as invalid and were excluded, since they may affect the reliability of the assessment. Pixels near the river mouth areas were also excluded. After these screening procedures, the monthly merged data were sorted into the relevant sub-areas.

Table II-2-2-2 and Figure II-2-2-1 show the pixels that were used in the Toyama Bay case study.

Table II-2-2-2. Pixels used in the Toyama Bay case study.

	1	2	3 =1-2	4	5 = 3-4	6
Sub-area	Total no. of pixels	No. of pixels in rivermouth area	Total no. of pixels (excluding rivermouth)	No. of invalid pixels	No. of pixels used for assessment	Percentages of valid pixels
A	183		183	43	140	76.5
B	189	7	182	58	124	68.1
C	81	3	78	38	40	51.3
D	122		122	74	48	39.3
E	1311		1311	9	1302	99.3
Total	1886	10	1876	222	1654	88.2

Table II-2-2-1. Pixels used in the Toyama Bay case study. (Pixels colored with blue were used for the assessment. Pixels colored with brown were excluded from the assessment)

2-2-3 Other types of data

Data that were not collected through regular monitoring or remote sensing such as amount of riverine input, area of red tide events and location of pollution/food poisoning incidents were sorted into the relevant sub-areas as shown in Table II-2-2-3.

Table II-2-2-3. Sorting other types of data into sub-areas.

Sub-area	Amount of riverine input	Area of red tide event	Locations of pollution/food poisoning incidents
A	Kurobe River	Between boundary of Niigata Pref. and Kurobe City	Sort in accordance to latitude/longitude
B	Joganji River Jintsu River	Between Kurobe City and mouth of Jintsu River	
C	Sho River Oyabe River	Between mouth of Jintsu River and Oyabe River	
D	-	Between mouth of Oyabe River and boundary of Ishikawa Pref.	
E	-	Central area of Toyama Bay	

2-3 Data processing of assessment parameters

2-3-1 Preparation of data sets

Following the sorting process, assessment values were calculated and data sets were prepared for each assessment parameter. Table II-2-3-1 shows the format of the data sets.

Table II-2-3-1. Format of the data sets.

Category	Assessment parameter	Assessment value	Sub-area	Name of survey site	Unit	Data range (initial year)	Data range (final year)	Calculated assessment values

2-3-2 Calculation of assessment data

Data that were used for the assessment (assessment data) were calculated from the assessment values. Table II-2-3-2 shows the calculation methods of assessment data.

Table II-2-3-2. Calculation methods of assessment data.

Assessment data		Calculation methods
Comparison	Latest data (b)	Calculate the mean of the last 3-years assessment values
	Ratio (b/a)	Calculate b/a a: background value
Occurrence	No. of occurrences in the last 3 years	Calculate the total no. of occurrences in the last 3 years
Trend	Results of *t*-test (all data)	Calculate if there are any statistically significant increase or decrease trend with t-test of all data (significance level=5%)
	Results of *t*-test (data after 1997)	Calculate if there are any statistically significant increase or decrease trend with t-test of data after 1997 (significance level=5%)

3 Setting of assessment criteria

3-1 Basic assessment policy

In order to assess the eutrophication status of the assessment area, identification criteria for the assessment data, classification criteria for the assessment parameters and categories, and assessment criteria for the assessment area/sub-areas were set.

3-2 Setting of identification criteria of the assessment data

The eutrophication status of the assessment data was identified by comparison, occurrence and trend identification tools, and on the basis of identification criteria set for each identification tool. The 'comparison/occurrence' identification tools identify the current status of eutrophication, and the 'trend' identification tool identifies the future trend of eutrophication.

3-2-1 Identification by comparison (current status)

With the comparison method, eutrophication status of the assessment data was identified by the ratio of assessment data and background value. Based on the calculated ratio, the assessment data was identified as 'relatively high', 'moderate' or 'similar or lower than background' on the basis of the set identification criteria.

A) Setting of background value

The background values (a) were set either by using the values of an established environmental standard or by using values measured in an area that have had negligible influence from anthropogenic activities. In regards to winter DIN/DIP ratio, the ratio in the deep ocean layer of Toyama Bay was used as the background value. Table II-3-2-1 shows the background values used in the Toyama Bay case study for each assessment parameter.

Table II-3-2-1. Background values (a) used in the Toyama Bay case study.

Category	Assessment parameter	Assessment value	Reference site	Data used	Background value (a)
I	T-N	Annual mean	Open ocean	Average of annual mean values between 1999-2005	0.100 mg/L
	T-P	Annual mean	Open ocean	Average of annual mean values between 1998-2005	0.008 mg/L
	Winter DIN	Winter mean	Open ocean	Winter mean value of F.Y. 2003	0.080 mg/L
	Winter DIP	Winter mean	Open ocean	Winter mean value of F.Y. 2003	0.009 mg/L
	Winter DIN/DIP	Winter mean	Deep ocean water	Deep ocean water data of 2001	12.3
II	Chlorophyll-a (field data)	Annual max.	Open ocean	Average of annual max. between 1999-2005	1.000 μg/L
		Annual mean	Open ocean	Average of annual mean values between 1999-2005	0.362 μg/L
	Chlorophyll-a (satellite data)	Annual max.	Max. of background area	Average of annual max. between 1998-2005	1.180 μg/L
		Annual mean	Mean of background area	Average of annual mean values between 1998-2005	0.406 μg/L
III	DO	Annual min.	-	Fisheries water quality standard	6.000 mg/L
	COD	Annual average	Open ocean	Average of annual mean values between 1998-2005	1.004 mg/L

B) Identification criteria of comparison identification tool

Table II-3-3-2 shows the identification criteria set for the comparison identification tool.

Table II-3-2-2. Identification criteria of the comparison identification tool.

Score	Identification results	Identification criteria
+	Relatively high	b/a>1.1 (upper 33%)
-	Moderate	b/a>1.1 (under the upper 33%)
	Similar or lower than background	b/a≤1.1

Note: b= average of last 3-years
a= background value

3-2-2 Identification by occurrence (current status)

The eutrophication status was identified by occurrence or non-occurrence of events. The score was '+' if there was more than one occurrence in the last 3-years, and '-' if there was no occurrence. Table II-3-2-3 shows the identification criteria for the occurrence identification tool.

Table II-3-2-3. Identification criteria of the occurrence identification tool.

Score	Identification results	Identification criteria
+	Occurrence	More than one occurrence in the last 3-years
-	Non-occurrence	No occurrence in the last 3-years

3-2-3 Identification by trend (future trend)

The future trend of eutrophication was identified by whether there was any statistically significant increasing or decreasing eutrophication trend in the assessment parameters. Table II-3-2-4 shows the identification criteria for the trend identification tool.

Table II-3-2-4. Identification criteria of the trend identification tool.

Score	Identification results	Identification criteria
+	Significant increase	Statistically significant increase identified by t-test (significance level = 5%)
±	No significant increase/decrease	No statistically significant increase or decrease identified by t-test (significance level = 5%)
-	Significant decrease	Statistically significant decrease identified by t-test (significance level = 5%)

3-3 Setting of classification criteria of the assessment parameters

3-3-1 Identification tools of the assessment parameters

The eutrophication status of each assessment parameter was classified by combining the identification results obtained by the 'comparison/occurrence' and 'trend' identification tools. Table II-3-3-1 shows the assessment values and identification tools applied for each assessment parameter.

Table II-3-3-1. Combination of identification tools applied for each assessment parameter in the Toyama Bay case study.

Category	Assessment parameter	Assessment value	Identification tools*)		
			Comparison	Occurrence	Trend
I	Riverine input (T-N, T-P)	Annual mean			✓
	T-N, T-P	Annual mean	✓		✓
	Winter DIN/DIP concentration	Winter mean	✓		✓
	Winter N/P ratio (DIN/DIP)	Winter mean	✓		✓
II	Chlorophyll-a concentration (field data)	Annual max. Annual mean	✓		✓
	Chlorophyll-a concentration (remote sensing data)	Annual max. Annual mean	✓		✓
	Sea area ratio with high chlorophyll-a concentration (remote sensing data)	Annual max. Annual mean			✓
	Red-tide events (diatom species)	Annual no. of events		✓	✓
III	DO	Annual min.	✓		✓
	Abnormal fish kill incidents	Annual no. of events		✓	✓
	COD	Annual mean	✓		✓
IV	Shellfish poisoning incidents	Annual no. of events		✓	✓
	Red-tide events (*Noctiluca* sp.)	Annual no. of events		✓	✓

* Comparison: comparison with environmental standard or background value
Occurrence: occurrence or non-occurrence of events
Trend: degree of increase/decrease

3-3-2 Classification by comparison/occurrence

For assessment parameters that the comparison or occurrence identification tools were applied to, the eutrophication status of the assessment parameters were classified as either 'high status' or 'low status' on the basis of the set classification criteria. Table II-3-3-2 shows the classification criteria for the identification results obtained by the comparison and occurrence identification tools.

Table II-3-3-2. Classification criteria for the results obtained by the comparison and occurrence identification tools.

Classification	Definition	Classification criteria
H (High status)	Relatively high eutrophication level	When there was more than one survey site within the sub-area that was identified as '+'
L (Low status)	Moderate eutrophication level or similar to background level	When all survey sites within the sub-are were identified as '-'

3-3-3 Classification by trend

For assessment parameters that the trend identification tools were applied to, the eutrophication status of the assessment parameters was classified as 'decrease trend', 'no trend' or 'increase trend' on the basis of the set classification criteria. Table II-3-3-3 shows the classification criteria for assessment parameters that the trend identification tools were applied to.

Table II-3-3-2. Classification criteria for assessment parameters that the trend identification tools were applied.

Classification	Definition	Classification criteria
I (Increase Trend)	Increasing eutrophication trend	When there was more than one survey site within the sub-area that was identified as '+'
N (No Trend)	No increasing or decreasing eutrophication trend	When all survey sites had no increasing or decreasing trend (Neither I nor D)
D (Decrease Trend)	Decreasing eutrophication trend	When all survey sites within the sub-area were identified as '-'

3-3-4 Classification of assessment parameter

After obtaining the classification results for 'current status' and 'future trend', the assessment parameters were then classified into 6 eutrophication groups in accordance to the classification criteria shown in Table II-3-3-4. If an assessment parameter could be assessed only by the trend method, the assessment parameter was classified as 'decrease trend', 'no trend' or 'increase trend'.

Table II-3-3-4. Classification criteria of assessment parameter.

Classification	Classification results
HI (High status and Increase Trend)	Current status high and increasing trend
HN (High status and No Trend)	Current status high but no increasing or decreasing trend
HD (High status and Decrease Trend)	Current status high but decreasing trend
LI (Low status and Increase Trend)	Current status low but increasing trend
LN (Low status and No Trend)	Current status low but no increasing or decreasing trend
LD (Low status and Decrease Trend)	Current status low and decreasing trend

Classification by trend only

Classification	Classification results
I (Increase Trend)	Increasing trend
N (No Trend)	No increasing or decreasing trend
D (Decrease Trend)	Decreasing trend

3-4 Classification criteria of the assessment categories

In the OSPAR procedure, the assessment categories are classified as '+', if there is more than one assessment parameter within the assessment category that is classified as '+'. The assessment categories are classified as '-', if all assessment parameters within the same assessment category are classified as '-'.

In the Toyama Bay case study, the assessment category was classified by selecting one classification result of the assessment parameters within the assessment category that most appropriately represented the eutrophication status of the area. However, if the classification results among the assessment parameters in the same assessment category were contradictory, and therefore it was unreasonable to select one representative classification result, the assessment category was not classified with its reasons stated.

3-5 Classification criteria of the assessment area/sub-areas

In the OSPAR procedure, the assessment area is classified into 'problem area', 'potential problem area' or 'non-problem area' by integrating the classification results of the 4 assessment categories. An assessment area is classified as 'potential problem area' when the quantity/quality of data were insufficient to perform an assessment. The OSPAR procedure developed this classification system to identify areas that require further environmental monitoring and nutrient reduction measures in terms of eutrophication.

In this study, holistic assessment criteria were set for the assessment area/sub-area so as to diagnostically explain classification results of each assessment parameter and category.

4 Assessment process and results

The eutrophication status of each sub-area was assessed based on the set assessment criteria.

4-1 Assessment results of sub-area A

Table II-4-1-1 shows the classification results of the assessment categories of sub-area A. According to the classification results, there were no categories in sub-area A that showed progress in eutrophication.

Table II-4-1-1. Classification results of sub-area A.

Category	Basis of classification	Classification results	
I	Current status of all parameters were classified as low status and all parameters had no significant increasing trend	LN	In terms of degree of nutrient enrichment, current status was relatively low and there was no increasing or decreasing trend
II	Current status of all parameters were classified as low status and all parameters had no significant increasing trend	LN	In terms of direct effects of nutrient enrichment, current status was relatively low and there was no increasing or decreasing trend
III	Current status of all parameters were classified as low status and all parameters had no significant increasing trend	LN	In terms of indirect effects of nutrient enrichment, current status was relatively low and there was no increasing or decreasing trend
IV	Current status of all parameters were classified as low status and all parameters had no significant increasing trend	LN	In terms of other possible effects of nutrient enrichment, current status was relatively low and there was no increasing or decreasing trend

4-2 Assessment results of sub-area B

Table II-4-2-1 shows the classification results of the assessment categories of sub-area B. According to the classification results, the assessment categories I-III were at relatively high levels with no decreasing trend.

Table II-4-2-1. Classification results of sub-area B.

Category	Basis of classification	Classification results	
I	T-N, T-P and winter DIN were at high levels with no decreasing trend	HN	In terms of degree of nutrient enrichment, current status was relatively high and there was no increasing or decreasing trend
II	Chlorophyll-a of field and remote sensing were at high levels with no decreasing trend	HN	In terms of direct effects of nutrient enrichment, current status was relatively high and there was no increasing or decreasing trend
III	COD was at high levels with no decreasing trend	HN	In terms of indirect effects of nutrient enrichment, current status was relatively high and there was no increasing or decreasing trend
IV	Current status of all parameters were classified as low status and all parameters had no significant increasing trend	LN	In terms of other possible effects of nutrient enrichment, current status was relatively low and there was no increasing or decreasing trend

From the above results, sub-area B has been identified as ‘having relatively high levels of eutrophication and direct/indirect eutrophication impacts’. Therefore, it is necessary to strengthen monitoring activities and consider countermeasures on the basis of the monitoring results.

4-3 Assessment results of sub-area C

Table II-4-3-1 shows the classification results of the assessment categories of sub-area C. According to the classification results, the assessment categories I-III were at relatively high levels with no decreasing trend.

Table II-4-3-1. Classification results of sub-area C.

Category	Basis of classification	Classification results	
I	T-N, T-P, winter DIN and winter DIP were at high levels with no decreasing trend	HN	In terms of degree of nutrient enrichment, current status was relatively high and there was no increasing or decreasing trend
II	Chlorophyll-a of field and remote sensing were at high levels with no decreasing trend	HN	In terms of direct effects of nutrient enrichment, current status was relatively high and there was no increasing or decreasing trend
III	COD was at high levels with no decreasing trend	HN	In terms of indirect effects of nutrient enrichment, current status was relatively high and there was no increasing or decreasing trend
IV	Current status of all parameters were classified as low status and all parameters had no significant increasing trend	LN	In terms of other possible effects of nutrient enrichment, current status was relatively low and there was no increasing or decreasing trend

From the above results, sub-area C has been identified as ‘having relatively high levels of eutrophication and direct/indirect eutrophication impacts’. Therefore, it is necessary to strengthen monitoring activities and consider countermeasures on the basis of the monitoring results.

4-4 Assessment results of sub-area D

Table II-4-4-1 shows the classification results of the assessment categories of sub-area D. According to the classification results, all the assessment categories were at relatively low levels, but categories I and II showed increasing trend.

Table II-4-4-1. Classification results of sub-area D.

Category	Basis of classification	Classification results	
I	Current status of all parameters were classified as low status, but T-N and T-P showed significant increasing trend	LI	In terms of degree of nutrient enrichment, current status was relatively low but there was an increasing trend
II	Current status of all parameters were classified as low status, but chlorophyll-a (remote sensing) showed significant increasing trend	LI	In terms of direct effects of nutrient enrichment, current status was relatively low but there was an increasing trend
III	Current status of all parameters were classified as low status and all parameters had no significant increasing trend	LN	In terms of indirect effects of nutrient enrichment, current status was relatively low and there was no increasing or decreasing trend
IV	Current status of all parameters were classified as low status and all parameters had no significant increasing trend	LN	In terms of other possible effects of nutrient enrichment, current status was relatively low and there was no increasing or decreasing trend

Since some categories were under increasing trend, it is necessary to strengthen the monitoring activities so that the causes can be identified.

4-5 Assessment results of sub-area E

Table II-4-5-1 shows the classification results of the assessment categories of sub-area E. According to the classification results, there were no categories in sub-area E that showed progress in eutrophication.

Table II-4-5-1. Classification results of sub-area E.

Category	Basis of classification	Classification results	
I	Current status of all parameters were classified as low status and all parameters had no significant increasing trend	LN	In terms of degree of nutrient enrichment, current status was relatively low and there was no increasing or decreasing trend
II	Current status of all parameters were classified as low status and all parameters had no significant increasing trend	LN	In terms of direct effects of nutrient enrichment, current status was relatively low and there was no increasing or decreasing trend
III	Current status of all parameters were classified as low status and all parameters had no significant increasing trend	LN	In terms of indirect effects of nutrient enrichment, current status was relatively low and there was no increasing or decreasing trend
IV	Although there were some red tide events (*Noctiliuca* sp.), it was probably wind transported from another sub-area	LN	In terms of other possible effects of nutrient enrichment, current status was relatively low and there was no increasing or decreasing trend

5 Verification of results

5-1 Verification of water characteristics of field monitoring sites by remote sensing

Water characteristics in two regular monitoring sites in sub-area B were verified by comparing the remote sensing chlorophyll-a (satellite chlorophyll-a) data.

5-1-1 Verification by satellite chlorophyll-a mean concentration for the entire assessment period

Mean chlorophyll-a concentration for the entire assessment period in the regular monitoring site pixels (monitoring sites J-5 and S-5) and the spatially averaged sub-area B were compared.

The mean chlorophyll-a concentration in J-5 and S-5, located near the mouth of Jintsu River and in between Jintsu River and Joganji River, respectively, were higher than that of the spatially averaged sub-area B.

5-1-2 Verification by satellite chlorophyll-a monthly mean concentration

The monthly mean chlorophyll-a concentration in J-5 and spatially averaged sub-area B was compared. The results are shown in Table II-5-1-1. Large differences between J-5 and sub-area B values were observed especially during summer, which explains why chlorophyll-a concentration in J-5 was higher than that of the sub-area B.

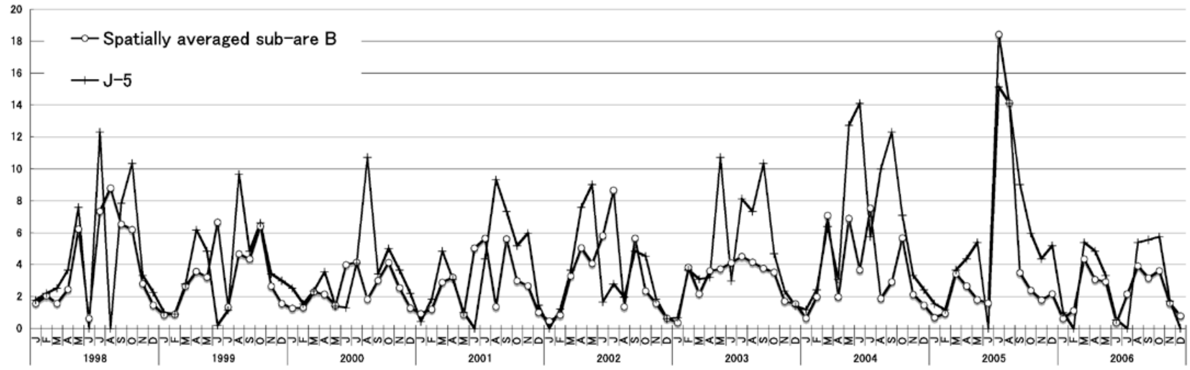

Figure II-5-1-1. Comparison of monthly mean chlorophyll-a concentration in J-5 and the spatially averaged sub-area B from 1998 to 2006.

5-2 Identification of new regular monitoring points

In order to identify new regular monitoring points, values such as maximum concentration and fluctuation range of satellite chlorophyll-a concentration were calculated for each pixel in sub-area B. Based on the calculated values, areas that require more intensive monitoring were identified by taking into account the locations of existing regular monitoring sites.

According to the above examination, there were no regular monitoring sites in areas that had large fluctuation range of satellite chlorophyll-a concentration (Figure II-5-2-1). This showed that remote sensing data could be applied when considering locations of new regular monitoring sites.

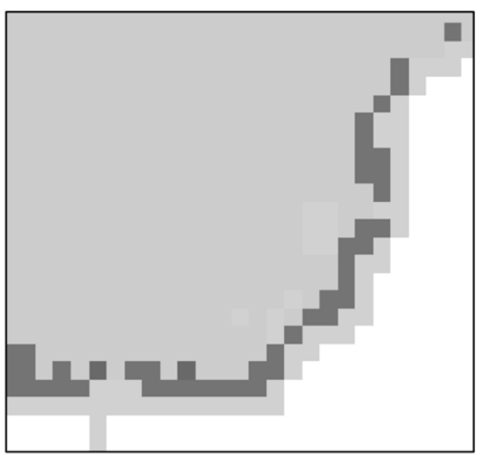

Figure II-5-2-1. Locations of the top 10 pixels with the large fluctuation range of satellite chlorophyll-a concentration (yellow pixels) and existing chlorophyll-a regular monitoring sites (purple pixels).

5-3 Verification of chlorophyll-a concentrations of regular monitoring

The monthly averaged chlorophyll-a concentration from F.Y. 1998 to 2005 obtained by remote sensing and regular monitoring were calculated and their seasonal variations were compared.

Chlorophyll-a concentration obtained by both remote sensing and regular monitoring gradually increased towards summer. However, while satellite chlorophyll-a peaked in July and decreased afterward, chlorophyll-a concentration obtained by regular monitoring remained at high levels until

October. Causes of these differences should be further examined.

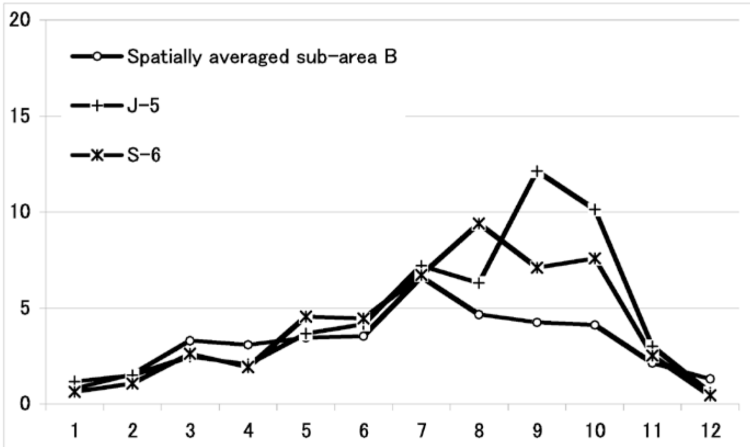

Table II-5-3-1. Comparison of monthly averaged chlorophyll-a concentration of remote sensing data and field data from F.Y. 1998 to 2005.

5-4 Verification of sub-area boundaries

Sub-area boundaries were verified by monthly averaged satellite chlorophyll-a data from1998 to 2006. For seasonal comparison of chlorophyll-a, the data from February to April were merged to represent spring season chlorophyll-a, and April to July to represent summer season chlorophyll-a.

The result showed that chlorophyll-a concentration was higher in summer season than in spring season in the inner bay area and along the eastern coast, and it corresponded to the boarder between sub-areas A-C and D-E.

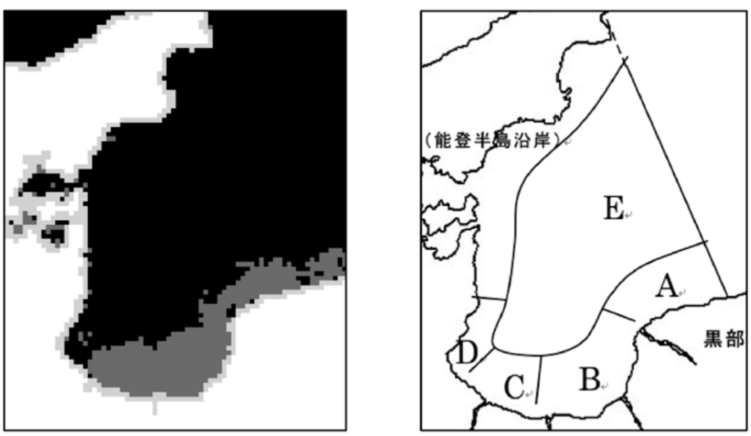

Figure II-5-4-2. Left image shows areas where chlorophyll-a concentration was higher in summer season than in spring season (purple pixels). Right image shows the sub-areas of the case study.

6 Conclusion and recommendation

- Re-examination of the Draft Procedures

  The identification criteria of assessment data should be re-examined to improve its reliability with more appropriate scientific approaches.
- Further utilization of remote sensing techniques

Assessment and analysis techniques of remote sensing must also be improved in accordance with its technological development.

- Improvement of the Draft Procedures

The validity and effectiveness of the Draft Procedures must be examined by collecting opinions from experts of various fields.