ENVIRONMENT SENSITIVITY ANALYSIS FOR NEAR SHORE REGION USING GIS BASED ESI MAP

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***ABSTRACT*:** Recently, hazard maps relating to various types of natural disasters like flood, landslide, volcanic activity and earthquake have become common in Japan. Along with these, ESI (Environmental Sensitivity Index) maps for oil spill have also been prepared. However, practical use of ESI has not always fully examined. On the other hands, ESI mapping guidelines have been originally prepared by U.S. OR&R of NOAA (Office of Response and Restoration, National Oceanic and Atmospheric Administration) and they have already finished preparing GIS based ESI maps for environmental sensitivity covering whole extent of their shoreline. The natures of ESI guidelines are principally reflecting their own culture, social and economic condition. In this study, fishery damage and its economic loss is defined as one of the major component of "environmental sensitivity" because the Sea of Okhotsk is known as one the best fishing grounds in the world and fishery industries have been underpinning Hokkaido local economy. And damage risk will be increased by Sakhalin oil and gas developing projects in the Sea of Okhotsk. This study proposes an example of ESI guideline containing fishery data around Abashiri city facing the Sea of Okhotsk. ESI maps containing information on fish catch and precise fishing grounds are thought to be able to solve conflictions between stakeholders for managing spill incident and compensation.

***KEYWORDS*:** *Oil Spill Accident, ESI (Environment Sensitivity Index) Map, Socio-economic information*

1. FEATURES OF SPILL RESPONSE OF JAPAN

1.1 Lesson of Nakhodka Spill

On January 2nd, 1997, the Russian tanker named NAKHODKA was navigating towards Petropavlovsk-Kamchatski in the Sea of Japan carrying 19,221 kiloliters of heavy C oil with her. This tanker had been broken into two sections in the heavy sea with 7.5 m effective wave height approximately 100 km of Oki Island, and spilled approximately 8,660 kiloliters of oil (Sao, 1998). The remaining bow section of the ship turned upside down and drifted five days in the current, until waves and wind finally grounded it on the coast of Mikuni Town, Fukui Prefecture on January 7th .

By this tanker accident, oil affected more than 1,300 km of shoreline including over 9 prefectures and 88 cities and towns. At that time, Japanese National Contingency Plans and laws had not assumed the accident happened outside of Japan waters, then every countermeasure was taken to fit the needs of the moment with little formal planning nor unified incident command (Sawano, 1998).

By reflecting Nakhodka Spill, Marine Pollution and Disaster Prevention Law had has been added some provisions and revised. Main revised points are as follows:

(1) The director of Japan Coast Guard (JCG)

can order spill response to the relating organizations in case of an accident happened outside of Japan waters. (Chapter 41 section 2, added in 1998, revised in 2002).

(2) Director of JCG or other response directors (local governors are assumed) can make advances for response, then ask polluters to reimburse. (Chapter 41 section 3, added in 1998).

1.2 ESI DEFINITIONS PREPARED BY NOAA

ESI maps are critical part of an oil spill response damage and assessment. Natural resources, physical parameters, and economic factors must be identified in a manner that planners can determine the risk and response necessary in an event of an oil spill.

ESI maps have been developed digitally using GIS software, and contain three categories of information— shoreline classification, biological resources and human-use resources. Each category is significant to determine the sensitivity of an area and describing the species, habitats and economic factors that will be affected in the case of an oil spill.

The first category is shoreline classification, which is ranked according to its physical and biological character, including its relative exposure to wave and tidal energy; shoreline slope; substrate type and biological productivity and sensitivity. A shoreline's natural persistence to the oil and potential ease of cleanup also will be considered. NOAA's shoreline classification descriptions are found in **Table 1** (S. Masaki, et al. 2001)

The second category in ESI mapping is biological resources, encompassing animal species and habitats potentially at risk to an oil spill. This category is segmented into seven elements: marine mammals, terrestrial mammals, reptiles and amphibians, invertebrates, habitats and plants, birds, and fish. These elements are further divided into sub-categories. For example, the following are sub-categories for habitats and plants: algae, kelp, wetlands, coral reefs, etc. Attribute information about these biological resources are collected and input into a database associated with the ESI map. Such information includes the scientific and ordinary names, concentration and species number.

The final category is human-use resources, which is divided into four components: high-use recreational access locations, management areas, resource extraction locations, and archaeological/historical resource locations. Recreational access locations can include boat ramps, ports and marinas, and beaches. Wildlife protection areas, national parks, and marine sanctuaries are represented under management areas. Resource extraction locations include such things as water intakes and fishnets, while archaeological/historical resources include locations that are deemed a cultural significance.

1.3 DEVELOPMENT OF ESI MAPS IN JAPAN AND THE OTHER COUNTRIES

The effort to develop ESI maps for Commander Naval Forces Japan (CNFJ) resulted in a unique gathering of data as well as provided several important findings for the ESI team. First, several Japanese agencies have overlapping and conflicting management responsibilities regarding open water areas and the shoreline. The Japan Coast Guard is the leading authority for open water/ open ocean issues in Japan but does not have coverage for the shoreline. While looking for shoreline management authorities in Japan, it was found that three agencies manage coastal conservation areas for different purposes: Fisheries Agency, Ministry of Land, Infrastructure and transport, and Ministry of Agriculture, Forestry, and Fisheries. **Table 2** summarizes open water/open ocean and shoreline management responsibilities.

The other point, in Japan, several agencies already have developed ESI maps for possible oil spill incidents. The Environment Agency, the Ministry of Land, Infrastructure and transport, the Japan Coast Guard, and the Fisheries Agency prepared them. These maps were not developed using standardized guidelines or were applicable to oil spill cleanup. For example, these maps have fewer classifications of coastal sensitivity rankings, and the maps are drawn on such a large scale that very few details can be included. **Table 3** shows the comparison of ESI maps developed by NOAA and by the Japanese agencies.

2. IMPROVEMENT OF ESI MAP BY APPLYING FISHERY INFORMATION

In the fisheries cooperative association of Abashiri, Hokkaido, the total quantity of catches of marine fisheries is 47,291 tons a year (Abashiri City, 2002). The total value of production of marine fisheries is about 7,098 million yen. The total quantity and value of scallop, Alaska pollack, and salmon in 2002 are 33,088 tons and 4,044 million yen which represent 70% and 56% of the total quantity and value of annual fish production. Here, the importance of coastal area for scallop cultivation in Abashiri area should be noted.

An interview to fishermen was done to make clear the seasonal use of fishing area and species. In this interview, 1/50,000 scaled bathymetric chart prepared by Japan Coast Guard was used to identify the position of fishing area.

From the interview, fishing grounds associating with species, fishing methods with regard to water depth have become clear and every result has plotted on the chart maps.

Figure 1 shows that the methods of fishing operation in Abashiri from April to December. There are lots of fishing methods like set net, dredge net, gill net, longline fishery, basket net fishery and so on.

Overall finishing activities are not active from January to March because coastal area is covered with drift ice, but offshore trawl, gill net targeting the species of pacific herring and Alaska Pollack, longline fishery, octopus baitless angling are octopus bagnet are common even in these months.

Figure 2 shows shoreline ranking of Abashiri coastal area. **Figure 3, 4, 5, and 6** show the seasonal distribution of commercial fishery associating with species.

Table 4 shows the period of drift ice cover. The drift ice is called “Ryu-Hyo” in Japanese and they are coming from the river of Amur and the ice cover is affecting fishing activities of Abashiri area. Ice cover is usually observed from December to March, average about 85 days in this area.

3. DISCUSSION

As ESI maps have been prepared principally for spill response since 1980’s showing the shoreline ranking of 1 to 10; these numbers do not contain any biological or socio-economic information.

Considering the importance of fishing activities and associated industries of Abashiri area, information and data for fishing have to be added onto the ESI maps, and these maps will play a unique role. One typical example will be a shoreline ranked 1 but has quite high sensitivity: **figure 4**, **5** and **6** show vicinity areas of shoreline ranked 1 produce sea urchin and shrimp which are very high economic value. These areas should be protected with high priority in a case of spill event.

4. CONCLUSION

ESI maps should be an essential tool for managing oil spill incident. For Japan and fishery-active countries, fishery data will be another key to define “sensitivity” against oil spill.

The goal of ESI map is to minimize both natural and socio-economic damages. Various kinds of conflictions which are to be raised in case of an actual spill event, ESI maps with fishery data will be helpful to manage issues.

For the key information for fishery should be summarized as follows and these data will be shown “spatially” in ESI maps:

1. Area of fishing grounds associating with species,
2. Fishing periods,
3. Fishing methods.

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Table 1. Environmental Sensitivity Index shore classification.

Rank		Physical Factors	Example
1	Exposed, Impermeable Vertical Substrates	A shoreline that has regular exposure to wave and tidal energy, no potential for subsurface oil penetration, and a slope of 30°or greater is included into this ranking. Because of the impermeable substrate and its exposure to waves, oil remains on the surface, thus allowing natural forces to remove the oil. Little or no cleanup is usually required. This is the least sensitive classification.	1A = Exposed rocky shores (E)(L)(R) 1B = Exposed, solid, man-made structures (E)(L)(R) 1C = Exposed rocky cliffs with boulder talus base 1C = Exposed, rocky cliffs/Boulder talus base
2	Exposed, Impermeable Substrates, Non-Vertical	This shoreline is similar to that in Rank 1, except the slope is less than 30°. Cleanup is made easy because of the exposure to high wave energy and the impermeable substrate.	2A = Exposed wave-cut platforms in bedrock, mud, or clay (E) 2A = Shelving bedrock shores (L) 2A = Rocky shoals; bedrock ledges along rivers (R) 2B = Exposed scarps and steep slopes in clay (E)
3	Semi-Permeable Substrate	This shoreline is composed of low-sloping, well-compacted sediment, which limits oil penetration to less than 10 cm. Cleanup is simplified by a hard substrate, permitting both foot and vehicle traffic.	3A = Fine- to medium-grained sand beaches (E) 3B = Scarps and steep slopes in sand (E) 3B = Eroding scarps in unconsolidated sediments (L) 3B = Exposed, eroding river banks in unconsolidated sediments (R) 3C = Tundra cliffs (E)
4	Medium Permeability	The grain of this shoreline is much coarser than that in Rank 3. Oil is able to penetrate up to 25 cm below the surface, and its slope is between 5 and 15°. Cleanup efforts are hindered because erosional and deposition cycles are rapid, and vehicles tend to push oil further into the loosely packed sediment.	4 = Coarse-grained sand beaches (E) 4 = Sand beaches (L) 4 = Sandy bars and gently sloping banks (R)
5	Medium-to-High Permeability	Penetration of oil can go as deep as 50 cm into the substrate, and the slop is between 8 and 15°. Contaminated sediment is difficult to remove without causing significant erosion and disposal problems.	5 = Mixed sand and gravel beaches (E)(L) 5 = Mixed sand and gravel bars and gently sloping banks (R)
6	High Permeability	Because of the large grained sediments, oil can penetrate up to 100 cm below the surface. An intermediate slope, between 10 and 20°, restricts vehicles from assisting in the cleanup effots. Riprap, a man-made break wall to limit wave and tidal energy, has added problems. Riprap usually is constructed at the high-tide line, which is where oil concentrations are strongest. Because of the large size of riprap boulders, oil penetrates deeply, and flushing is not always effective. Only by removing and replacing it can one ensure it is completely clean.	6A = Gravel beaches (E)(L) 6A = Gravel bars and gently sloping banks (R) 6A = Gravel beaches (cobbles and boulders) (E) - Southeast Alaska only 6A = Gravel beaches (granules and pebbles) (E) – Southeast Alaska only 6B = Riprap (E)(L)(R) 6B = Gravel beaches (cobbles and boulders) (E) – Southeast Alaska only 6C = Riprap (E) - Southeast Alaska only
7	Exposed, Flat, Permeable Substrate	The sediments on this shoreline are water saturated, which limits the oil from penetrating. Low trafficability, high infaunal densities, and a slope of less than 10°are also characteristics of this rank. Cleanup can be difficult because of a potential to grind the oil deeper into the substrate because of increased foot traffic.	7 = Exposed tidal flats (E)(L)
8	Sheltered Impermeable Substrate	This shore line is similar to that in Rank 2 except that it is shelterd from the wave and tidal forces. The substrate is compacted and hard, composed of bedrock, man-made materials, or stiff clay, and the slope is greater than 15°. High algae and organism coverage is usually present. Shoreline cleanup can be difficlt and intrusive, usually done for aesthetic reasons.	8A = Sheltered rocky shores and sheltered scarps in bedrock, mud, or clay(E) 8A = Sheltered rocky shores (impermeable) and sheltered scarps in bedrock, mud, or clay (E) – Southeast Alaska only 8A = Sheltered scarps in bedrock, mud, or clay (L) 8B = Sheltered, solid man-made structures, such as bulkheads (E)(L)(R) 8B = Sheltered rocky shores (permeable) (E) – Southeast Alaska only 8C = Sheltered riprap (E)(L)(R) 8D = Sheltered rocky rubble shores (E) 8E = Peat shorelines (E) 8F = Vegetated, steeply-sloping bluffs (R)
9	Sheltered, Flat, Semi-Permeable Substrate	Again, this shoreline classification is sheltered from wave and tidal energy, with a slope less than 10°. The sediment is water saturated, limiting oil penetration. Cleanup efforts face the same difficulties as in Rank 7.	9A = Sheltered tidal flats (E) 9A = Sheltered sand/mud flats (L) 9B = Vegetated low banks (E)(R) 9B = Sheltered, vegetated low banks (L) 9C = Hypersaline tidal flats (E)
10	Vegetated Emergent Wetlands	The substrate is generally flat, with a high concentration of organic, muddy soil. Grassy or woody vegetation frequently covers this classification. Cleanup tends to cause significant damage and long-term impacts to this delicate ecosystem. This is the most sensitive classification.	10A = Salt- and brackish-water marshes (E) 10B = Freshwater marshes (E)(L)(R)(P) 10C = Swamps (E)(L)(R)(P) 10D = Scrub-shrub wetlands (E)(L)(R)(P) 10D = Mangroves (in tropical climates) (E) 10E = Inundated, low-lying tundra (E)

Estuarine: (E), Lacustrine: (L), and Riverine: (R), Palustrine: (P)

S. Masaki, et al. (2001).

Table 2. The difference of ESI map on the shoreline management in each agency of America and Japan

Agency	Area of Responsibility
Japan Coast Guard	Open water/open ocean
Fishing Ports Division, Fisheries Agency	Fishing ports
Ports and Harbor Bureau, Ministry of Transportation	Ports and harbors
River Bureau, Ministry of Construction	Rest of the shorelines(a.k.a., construction shorelines)
Agricultural Structure Improvement Division, Ministry of Agriculture, Forestry and Fisheries	Agricultural and forestry shorelines

S. Masaki, et al. (2001).

Table 3. Comparison of Environmental Sensitivity maps in the United States and Japan

Agencies	Map	Coastal Sensitivity Index	Coastal Sensitivity Rank Assignment	Coastal Sensitivitiy Types	Scale
NOAA (United State)	Environmental Sensitivity Index Map	Yes	Rank based on physical and biological characteristic and ease of clean up.	10+	1/24,500
Environment Agency (Japan)	Coastal Sensitivitiy Maps for Oil Spills	Yes	Shoreline sensitivity classification composed of topography and geology as well as the natural environment, fisheries, industries, and recreational	5	1/100,000
Maritime Disaster Prevention Association, Ministry of Land, Infrastructure and transport	Risk Infromation Map for Coastal Environmental Conservation	Yes	No explanation is provided.	8	1/50,000
Fisheries Agency (Japan)	Oil Spill Fishery Impact Information Map	Yes	Classified shoreline topography, ecosystem, fisheries, and others assess the extent of damage in the event of an oil spill.	5	N/A

S. Masaki, et al. (2001).

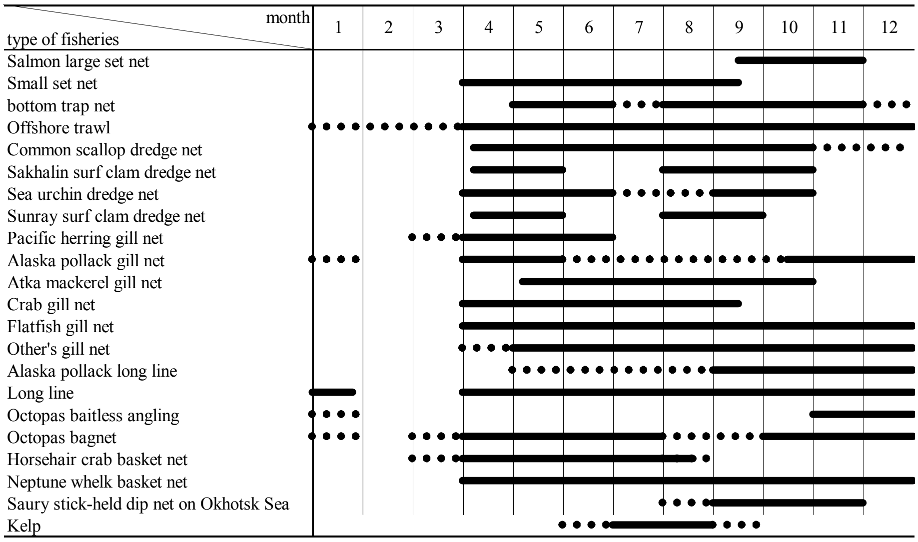

Figure 1 Operation periods of fishing methods in Abashiri, Hokkaido

Table 4 The ice covered period with drift ice in Abashiri city

year	first day	final day	total days
1989	2 Feb.	3 Apr.	62
1990	21 Jan.	7 Apr.	77
1991	17 Jan.	18 Apr.	92
1992	31 Jan.	8 Apr.	69
1993	10 Feb.	9 May	89
1994	26 Jan.	30 Apr.	95
1995	20 Jan.	28 Apr.	99
1996	29 Jan.	22 Apr.	85
1997	24 Jan.	29 Mar.	65
1998	16 Jan.	26 Mar.	70
1999	13 Jan.	19 Apr.	96
2000	18 Jan.	4 Apri.	78
2001	6 Jan.	8 Apr.	93
2002	27 Jan.	25 Apr.	89
2003	11 Jan.	28 Apr.	108

Note 1: First day: the first day of drift ice is observed.

Note 2: Final day: the last day of drift ice is beyond visual field.

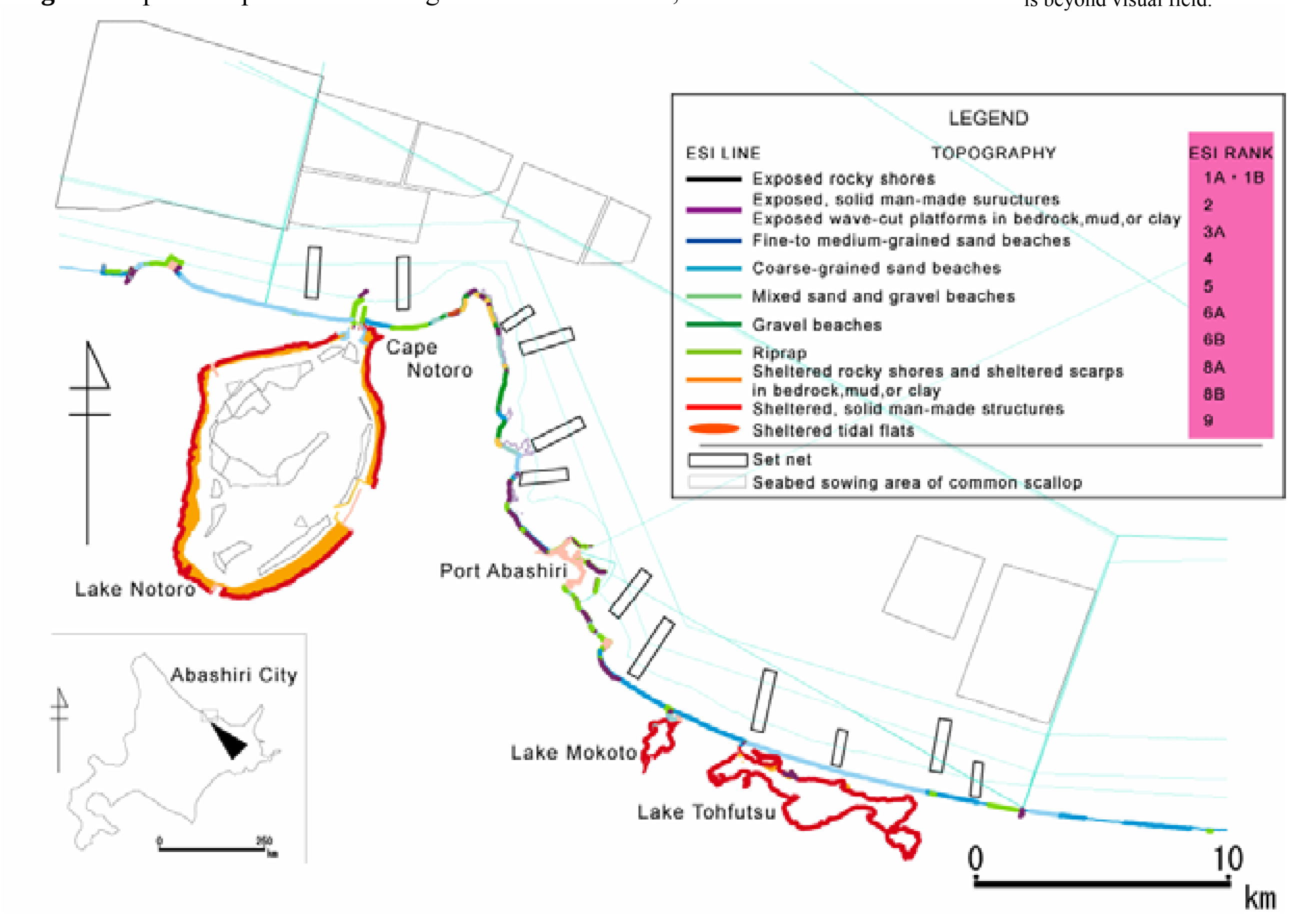

Figure 2 Shoreline Ranking of Abashiri coastal area

Sources: Boxes in this figure show the fishing area based on the results of interview to Cooperative Association of Abashiri, Hokkaido in Feb. 2004. Shoreline classification is based the research of Hokkaido Geological Survey Institute.

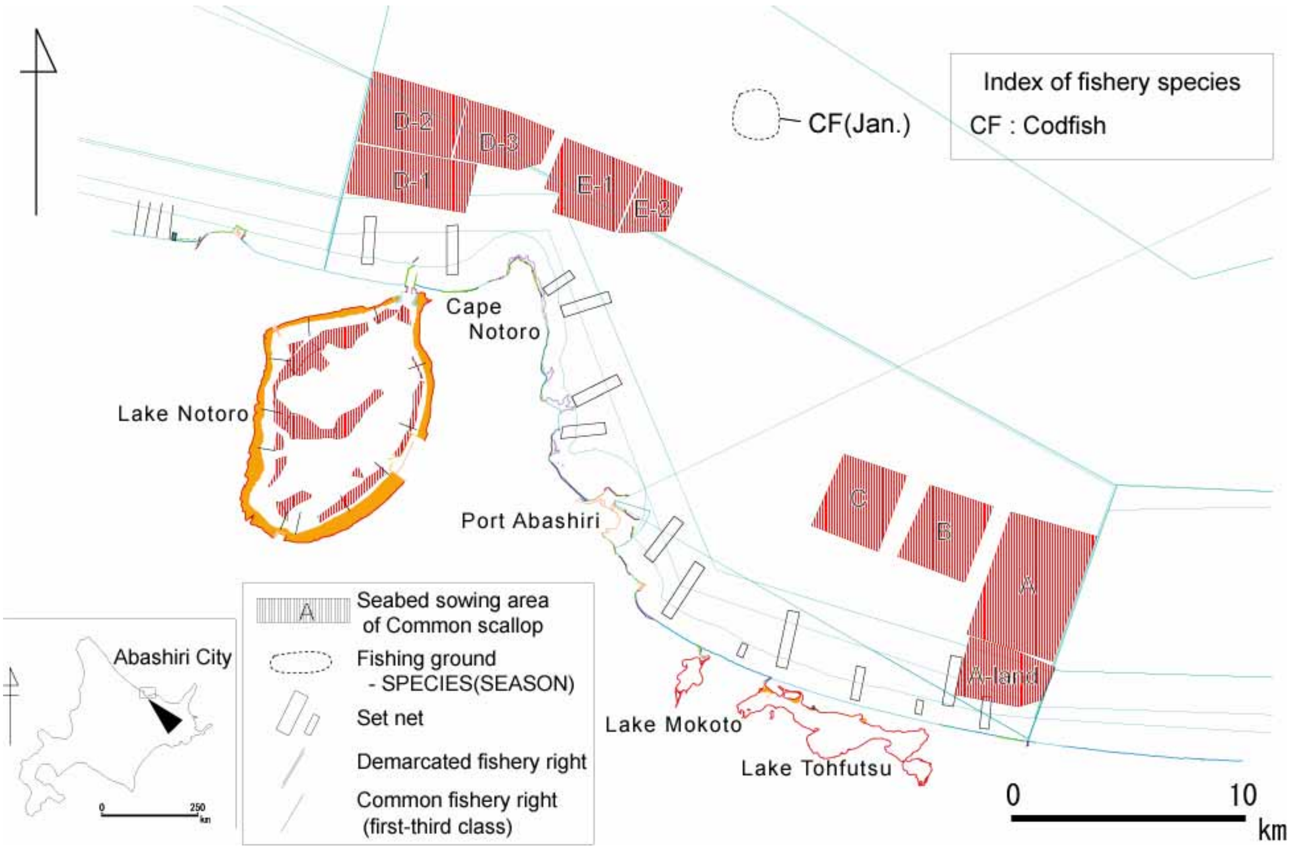

Figure 3 ESI Map with fishery information of Abashiri coastal area, Hokkaido (From Jan. to Mar.)

Source: Same as figure 2.

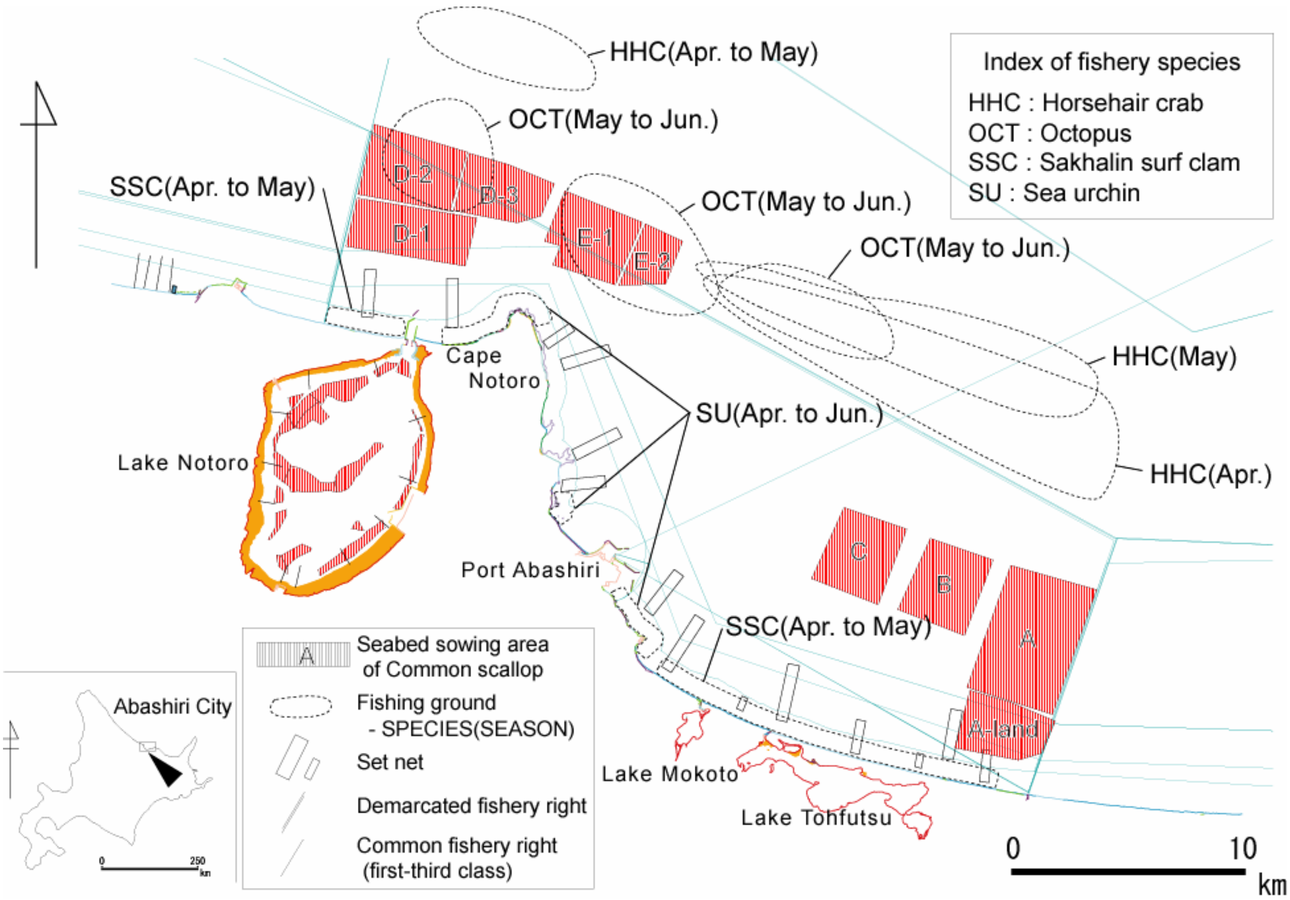

Figure 4 ESI Map with fishery information of Abashiri coastal area, Hokkaido (From Apr. to Jun.)

Source: Same as figure 2.

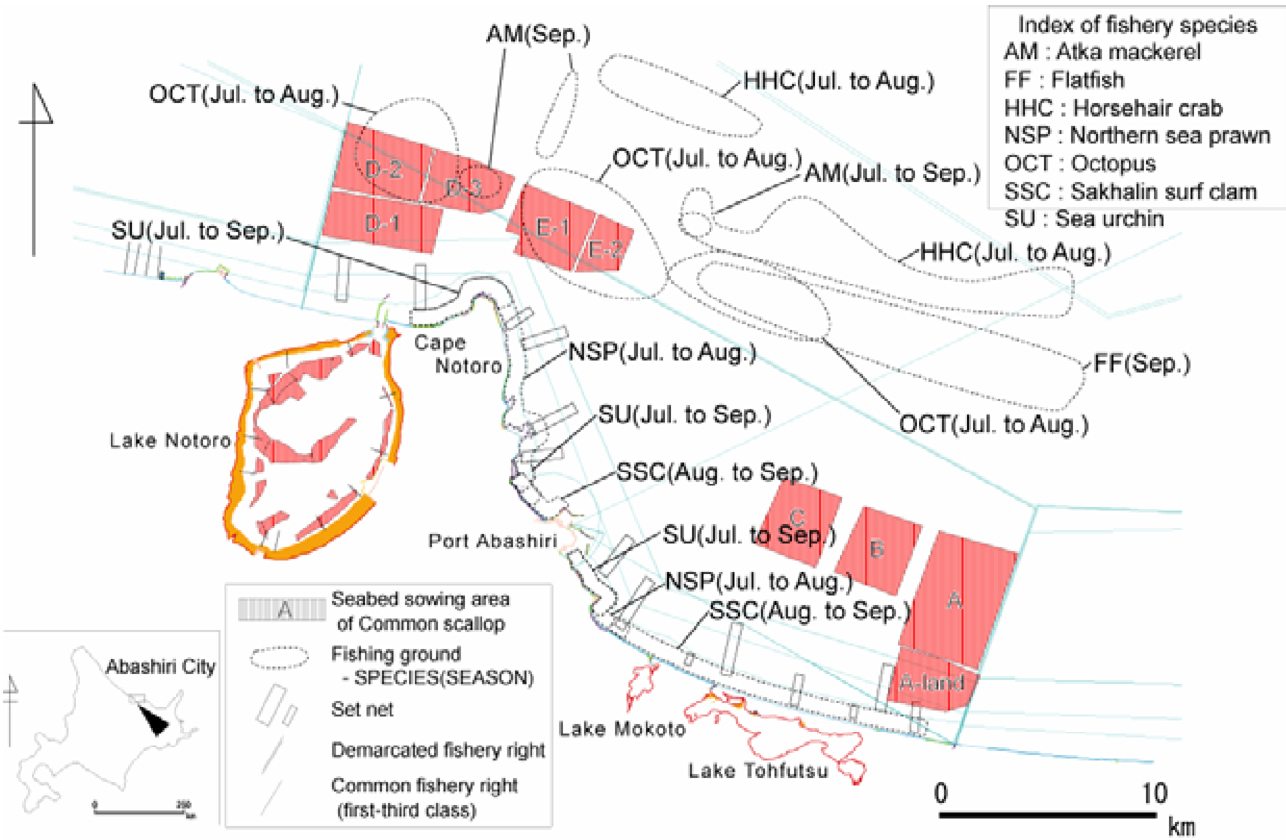

Figure 5 ESI Map with socio-economic information of Abashiri coastal area, Hokkaido (From Jul. to Sep.)

Source: Same as figure 2.

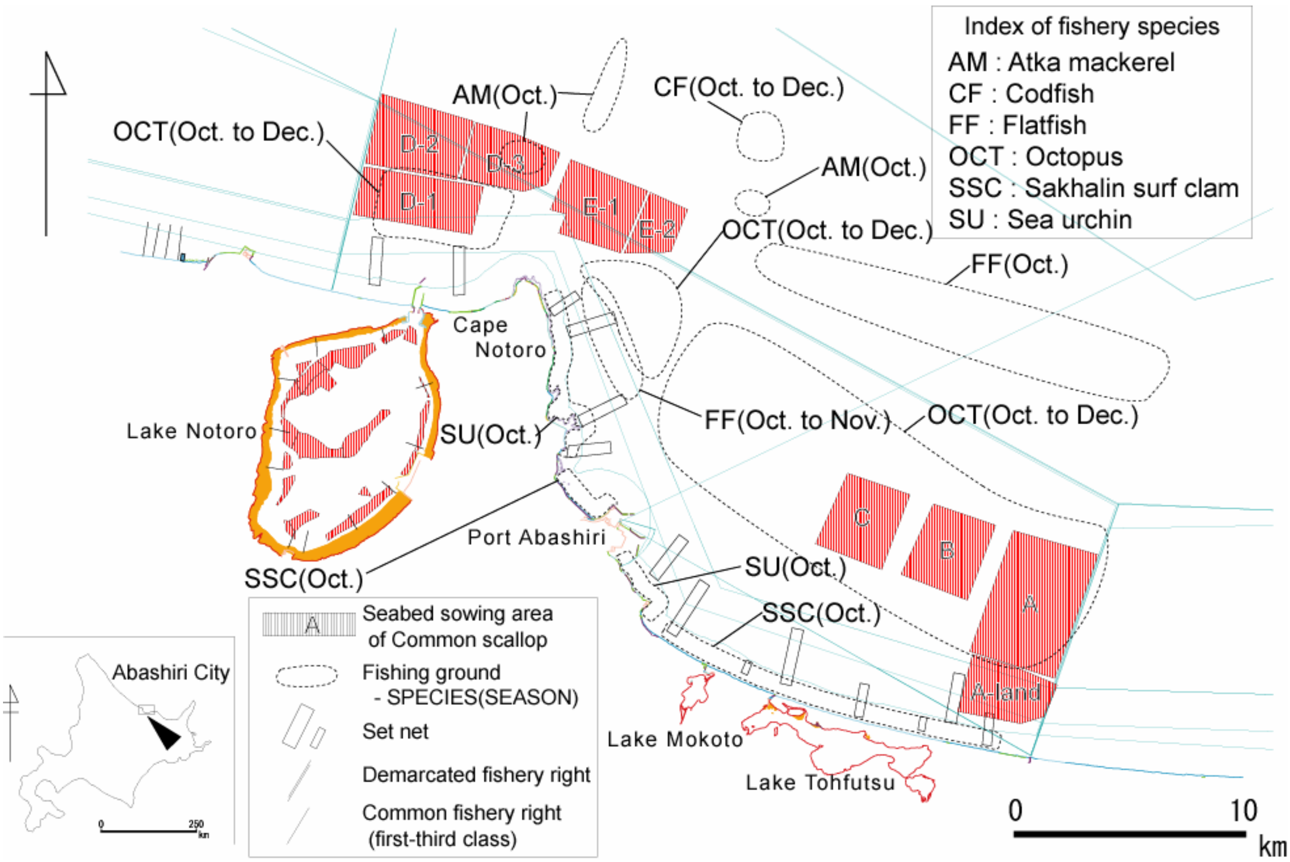

Figure 6 ESI Map with socio-economic information of Abashiri coastal area, Hokkaido (From Oct. to Dec.)

Source: Same as figure 2.