Changes in fishing grounds of four drag-bagnet fisheries in Korean waters (2008-2014)

Jung Hwa CHOI* · Steven S. Intelmann[1] · Robert A. McConnaughey[1]

** Jeju Fisheries Research Institute, National Institute of Fisheries Science, Jeju 63068, Korea*

[1] Alaska Fisheries Science Center, National Oceanic & Atmospheric Administration, Seattle, WA 98115, USA

Abstract

Changes in the fishing grounds for four drag-bagnet fisheries (large trawl, large pair trawl, large Danish seine and middle Danish seine) were investigated by year and sea-blocks in Korean waters. We used catch and effort data by sea-block (latitude × longitude: 30′ × 30′) of the National Institute of Fisheries Science (NIFS) and yearly fishing production statistics of the Korean Statistic Information Service from 2008 to 2014. The main benthic habitat of fishing ground was sand and sandy mud material. The average swept areas for the four fisheries were 181.7 km^2, 606.4 km^2, 2,720.9 km^2 and 252.8 km^2, respectively. The main fishing ground was around Jeju Island and the eastern South Sea. The main fishing ground moved to the northern part of the South Sea during the study period due to a closure of fishing grounds and changes in the target species.

Keywords: Four drag-bagnet fisheries, Main fishing ground, Swept area, Benthic habitat

*Corresponding author: choi2291@korea.kr, Tel: +82-64-750-4360, Fax: +82-64-750-5883

Introduction

In the late 1990s, Korea's offshore fishery experienced major changes due to the regulation of fishing activities in fishing grounds other than the exclusive economic zone (EEZ) due to the conclusion of the fishing agreements between Korea and Japan, Korea and China, and China and Japan related to the declaration of the EEZ in the late 1990s (Cho, 2012; Kim, 1999; Lee et al., 2013). In particular, in the case of the Large Pair Trawl, most of the fishing activities in the EEZ on the Chinese side until the early 1990s disappeared due to the Korea-China fishing agreement and the increase in Chinese ships. The decrease in fishing area due to the change in the fishing relationship between Korea, China and Japan led to a decrease in offshore fishing permits and adjustment of the number of fishermen (Kim and Kim, 2004).

Changes in the main fishing area of Korea's offshore trawlers

It is presumed that this was caused not only by the loss of fishing grounds in neighboring countries due to the enactment of the fishing agreements between Korea, China and Japan, but also by the improvement of fishing gear since the late 1980s, the large-scale reduction of fishing vessels in the late 1990s, and changes in the target fish species due to climate change (Lee et al. al., 2013). For example, the trawl fishery began in the East China Sea and southwest of Jeju Island in the 1990s and early 2000s for hairtail, yellow croaker, blue crabs and conger eels. In the late 2000s, due to the reduction of fishing grounds, cutlassfish and blackfish were caught in the southern seas of Heuksando and southwestern seas of Jejudo (Kim and Ahn, 2018; Lee et al., 2013). However, it is known that offshore trawl net fishing is affected by the quality of the fishing area, which depends on the fishing gear, fishing method (NIFS, 2008), and the sediment type (Lee, 1999; Jang et al., 2016; Pitcher et al., 2017). In order to examine the fishing location and sediment characteristics by industry, spatial analysis of the fishing location should be undertaken. However, due to the difficulty in securing data on the fishing location, analysis of the main fishing grounds and the central fishing grounds for offshore trawlers, an analysis on the fishing effort according to the sediment characteristics was not conducted. In this study, the change pattern of the main fishing grounds and the changes in the central fishing grounds of the four fisheries of Korea's offshore trawlers from 2008 to 2014 were investigated. It was intended to provide data for fishery management.

Materials and Methods

The analysis of this study included four offshore trawl fisheries, Large Trawl, Large Pair Trawl, Large Danish Seine, and Middle Danish Seine, based at the Busan Joint Fish Market. From the fishing information reported by all fishing boats based at the market, the fish catch and fishing effort data obtained by the National Fisheries Research Institute from 2008 to 2014 by sea block (latitude 30´× longitude 30´) were used. In order to understand the fishing characteristics and swept area of each fishery, the average tow duration, the average vessel speed, the number of tows per day, and the size of each net were specified by experts and fishermen of each fishery. As a result, the net width of Large Trawl and Middle Danish Seine was 30-50 m, and the width of Large Pair Trawl and Large Danish Seine was 110 m. In addition, the estimated sampling rates for each of the Busan fleets are as shown in Table 1. Through this, the average swept area for each fishery was estimated.

Analysis method

The catch and effort by each fishery were examined for each year by using the data for each sea block. Effort data for each fishery were analyzed separately to determine the center of the fishing grounds using ArcGIS Spatial Analyst (Spatial Statistics Tool). This was done using the Median Center script, to identify the location that minimizes overall effort-weighted (km^2) Euclidean distance to the tows in a year.

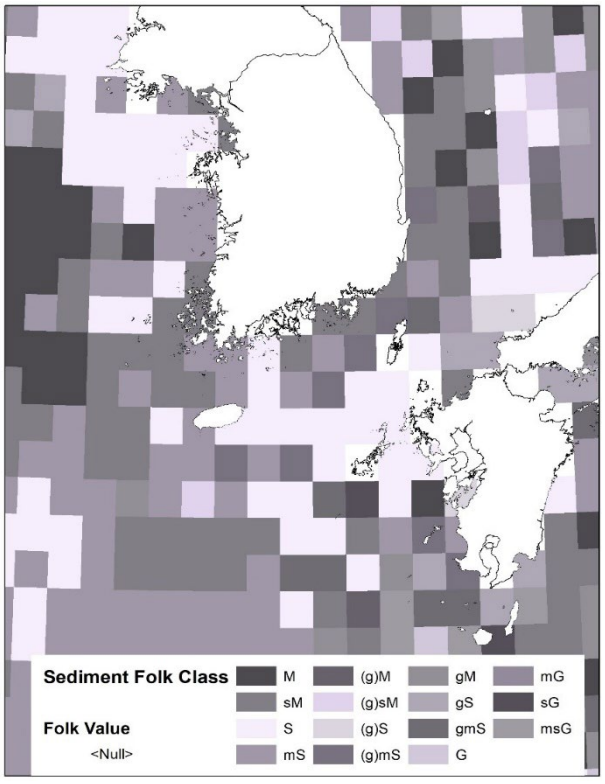

Fig. 1. Sediment classification in Korean waters from dbSEABED according to Folk's (1980) ternary scheme. M: mud, G: gravel, S: sand.

The sediment data used for the relationship between main fishing area and sediment classification was dbSEABED (https://instaar.colorado.edu/ ~jenkinsc/dbseabed/), and the sediment data for each sea block was classified according to the Folk Sediment Class scheme and compared with the fishing results of each offshore trawling fishery (Fig. 1).

Results

Catch amount and net area by fishery

During the study period, the average annual catch of the Large Trawl was 67,617 tons, and the catch increased every year. The average annual catch of Large Pair Trawl was 54,387 tons. The average annual catch of Large Danish Seine was

11,785 tons and that of Middle Danish Seine was 22,535 tons. The amount of fishing effort determined through the number of sets for each fishery was an increasing trend except for the Large Pair Trawl, and the swept area was also found to increase overall.

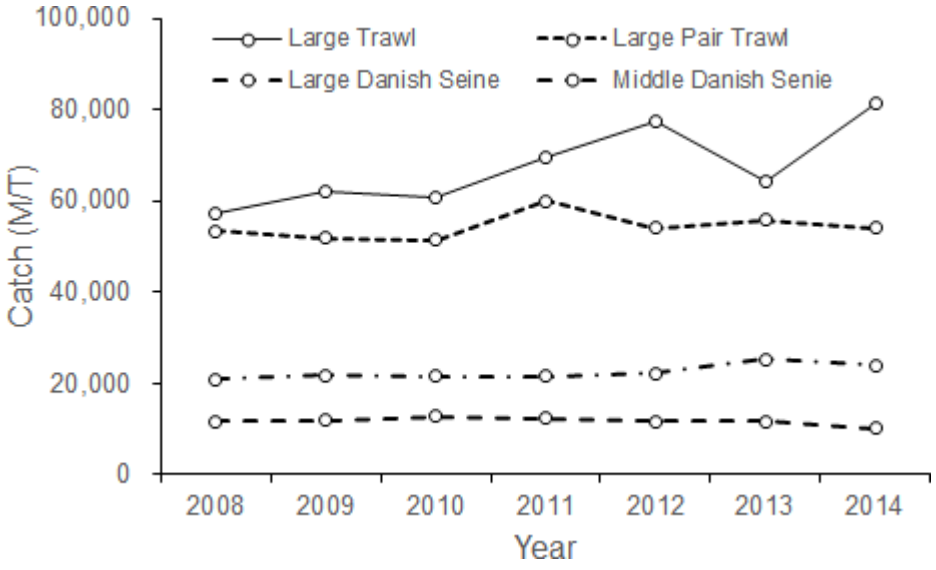

Fig 2. Annual catches (tonnes) for the four drag-bagnet fisheries in Korean waters from 2008 to 2014.

In the case of the Large Trawl, the highest fishing area was 241.5 km^2 in 2013, and the lowest was 112.9 km^2 in 2008. In the case of the Large Pair Trawl, the highest value was 678.7 km^2 in 2008, and the lowest value was 492.7 km^2 in 2011. The Middle Danish Seine was the highest value in 2013. It was 329.2 km^2, and the lowest in 2008 was 131.3 km^2. Among the four fisheries, the Large Danish Seine showed the highest area swept with an annual average of about 2,720.9 km^2, while the Large Trawl appeared to be lowest area swept with an average of 181.7 km^2 (Table 1).

Table 1. Four drag-bagnet fisheries trawling information in Korean waters

Fishing Type	Net Width (km)	Speed (kts)	Duration (hrs)	Sampling Rate	Average Swept Area (km^2)
Large Trawl	0.045	3	2	1.0	181.7
Large Pair Trawl	0.126	3	3	1.0	606.4
Large Danish Seine	0.117	2	2	0.5	2,720.9
Middle Danish Seine	0.030	4	1	1.0	252.8

Sediment distribution

The distribution of sediment in all sea areas in Korea including the offshore trawl net fishing area was found to be mostly sandy. As for the characteristics of each sea area, most of the seas around Jeju and the South Sea were sandy, but the Gyeongnam coast had less mud than the near seas. It appeared as a sandy mud with a lot of it. In the case of the West Sea (Yellow Sea), the coast has a lot of sand and mud, whereas towards the center it is more muddy. In the case of the East Sea, the coast was sandy mud, whereas the deep waters were mostly muddy. From this, it can be seen that the bottom type in the central sea area of the east, west, and south seas where trawling takes place and the seas around Jeju were sand and sandy mud.

Main fishing ground by fishery

The main fishing ground of the Large Trawl showed a high amount of fishing effort centered on the eastern part of the South Sea in 2008, but after 2011, a rather high amount of fishing effort was observed around Heuksan Island in the West

Sea, indicating that the fishing area was extended to the West Sea. It was found that fishing mainly took place around Ulleungdo in the East Sea (Fig. 3)

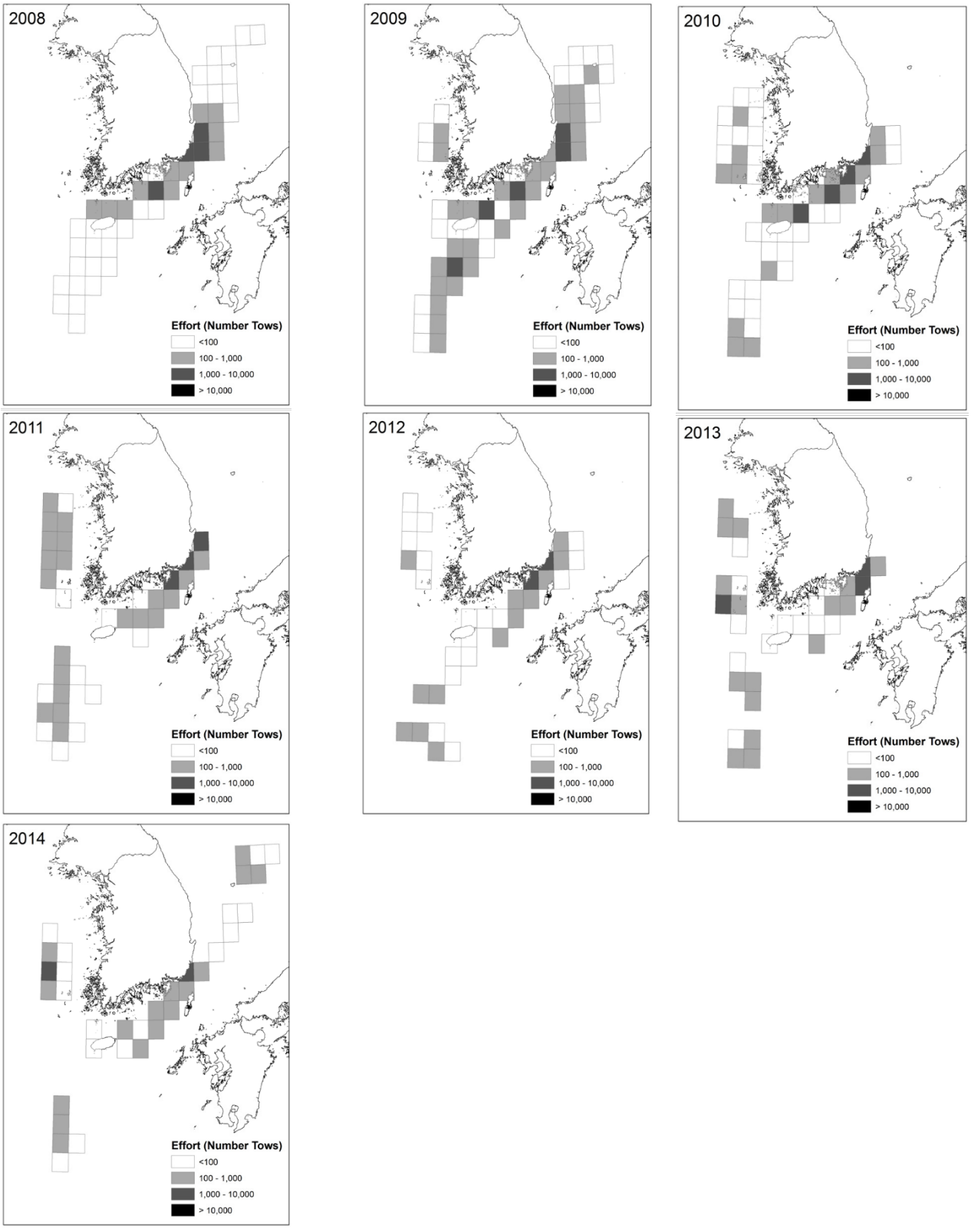

Fig. 3. Geographic distribution of annual effort of Large Trawl fishery from 2008 to 2014.

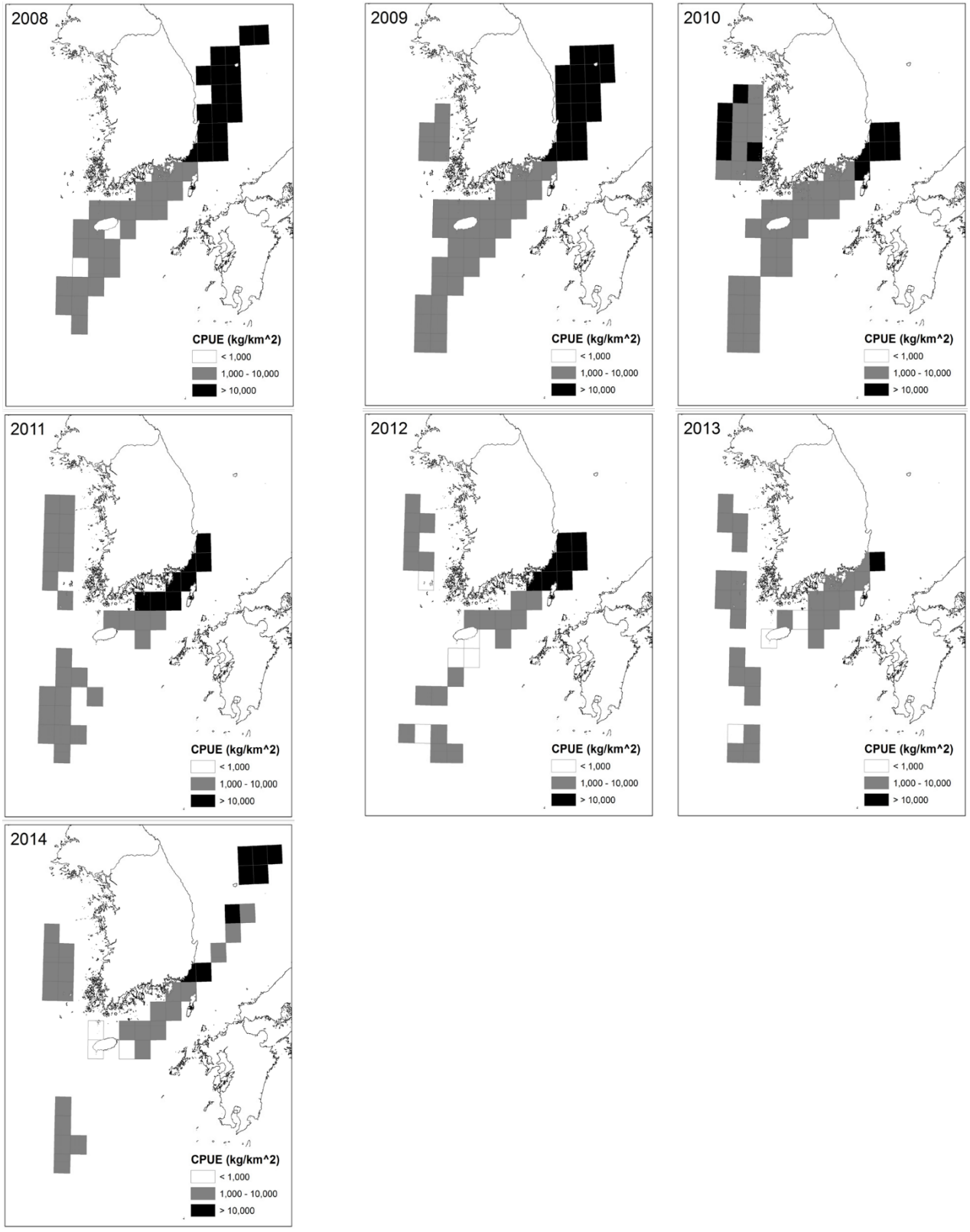

Fig. 4. Geographic distribution of annual CPUE of Large Trawl fishery from 2008 to 2014.

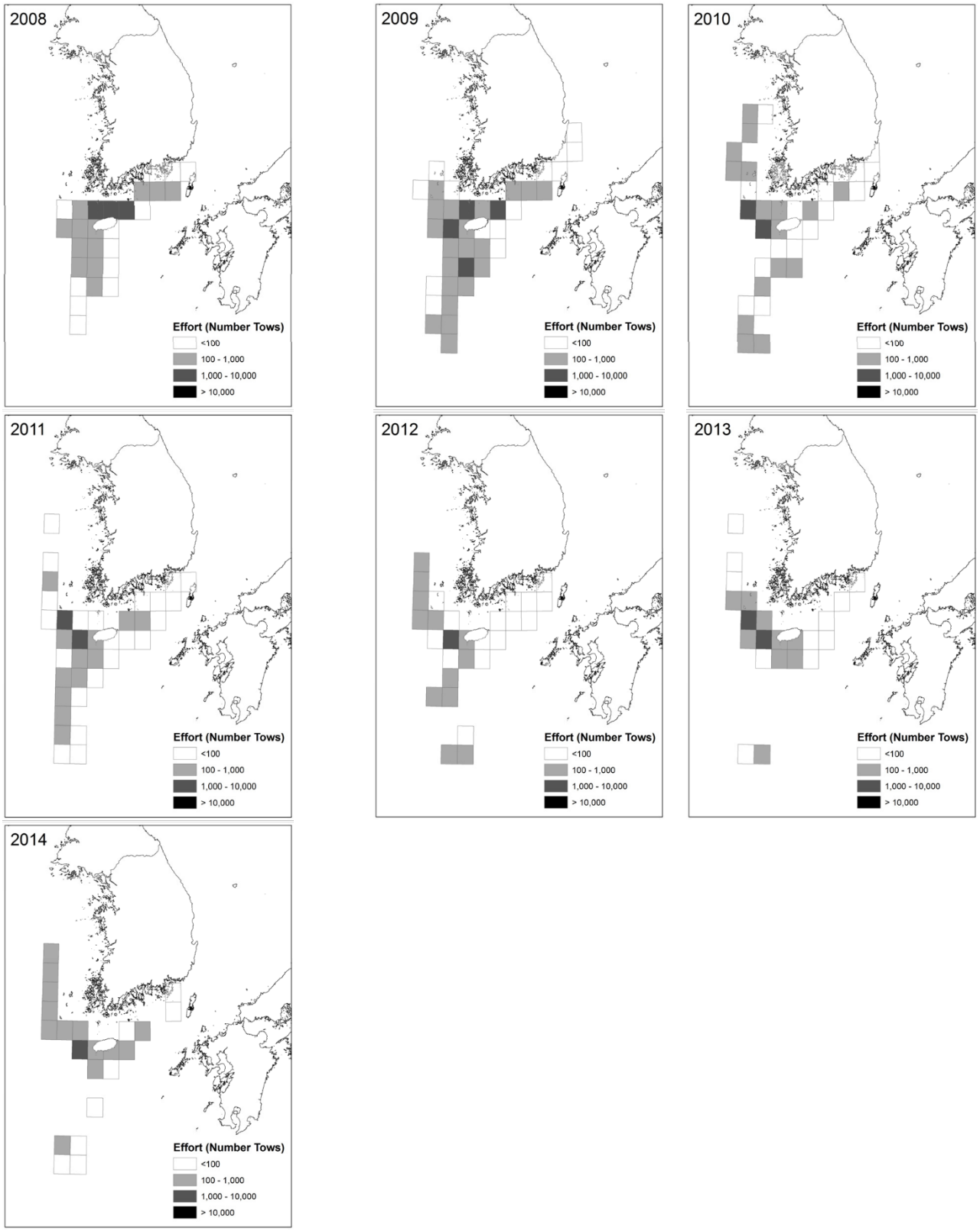

Fig. 5. Geographic distribution of annual effort of Large Pair Trawl fishery from 2008 to 2014.

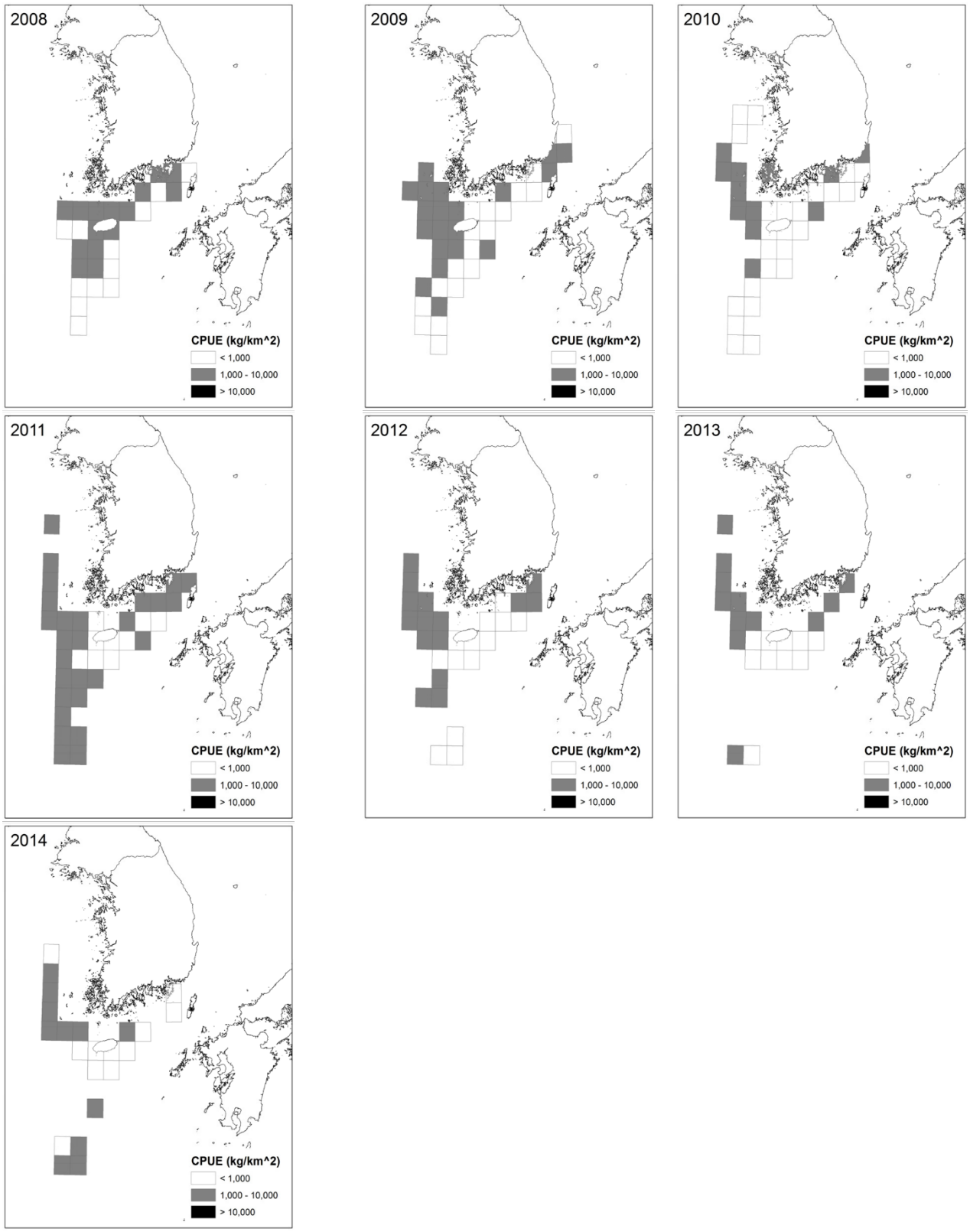

Fig. 6. Geographic distribution of annual CPUE of Large Pair Trawl fishery from 2008 to 2014.

F

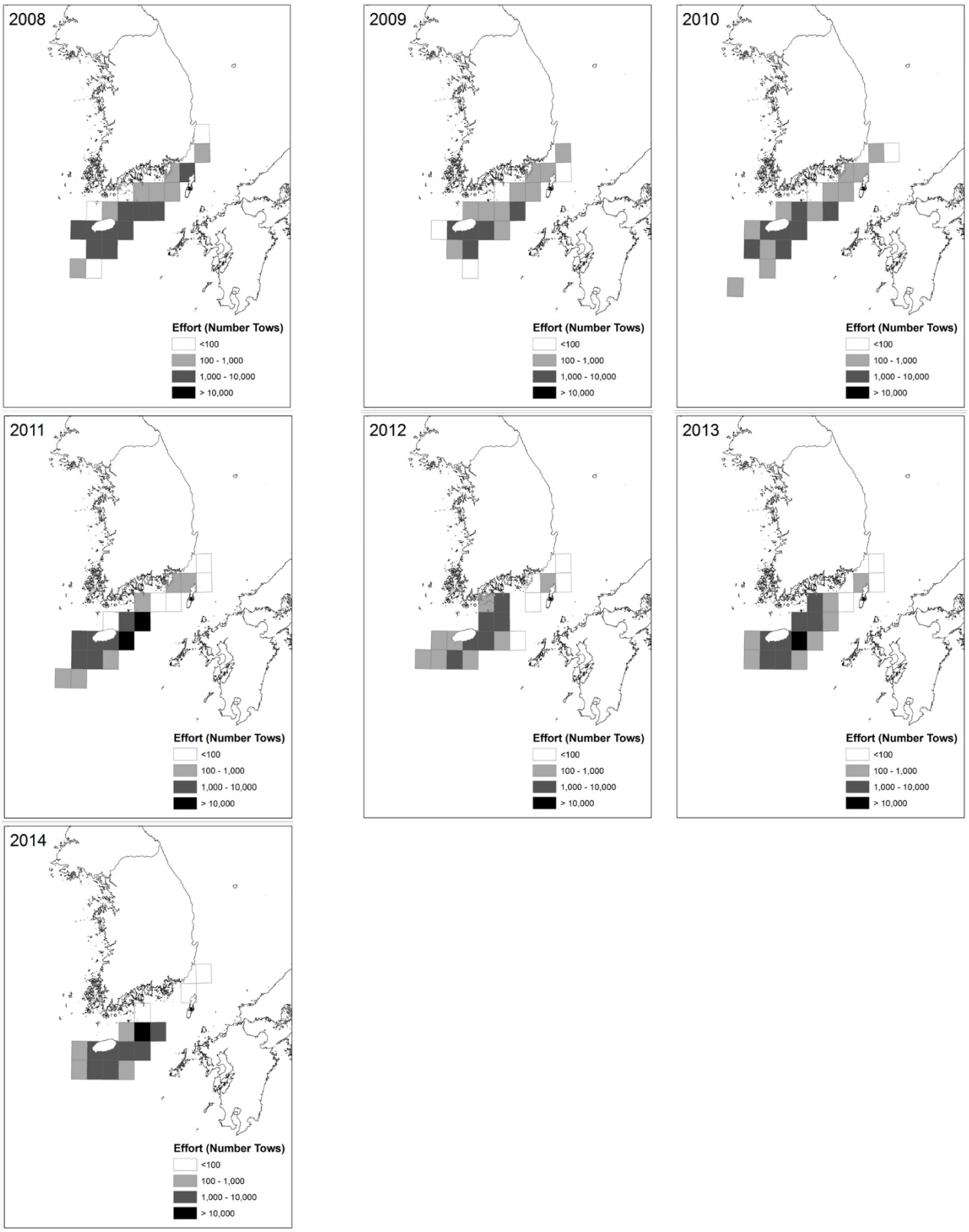

Fig. 7. Geographic distribution of annual effort of Large Danish Seine fishery from 2008 to 2014.

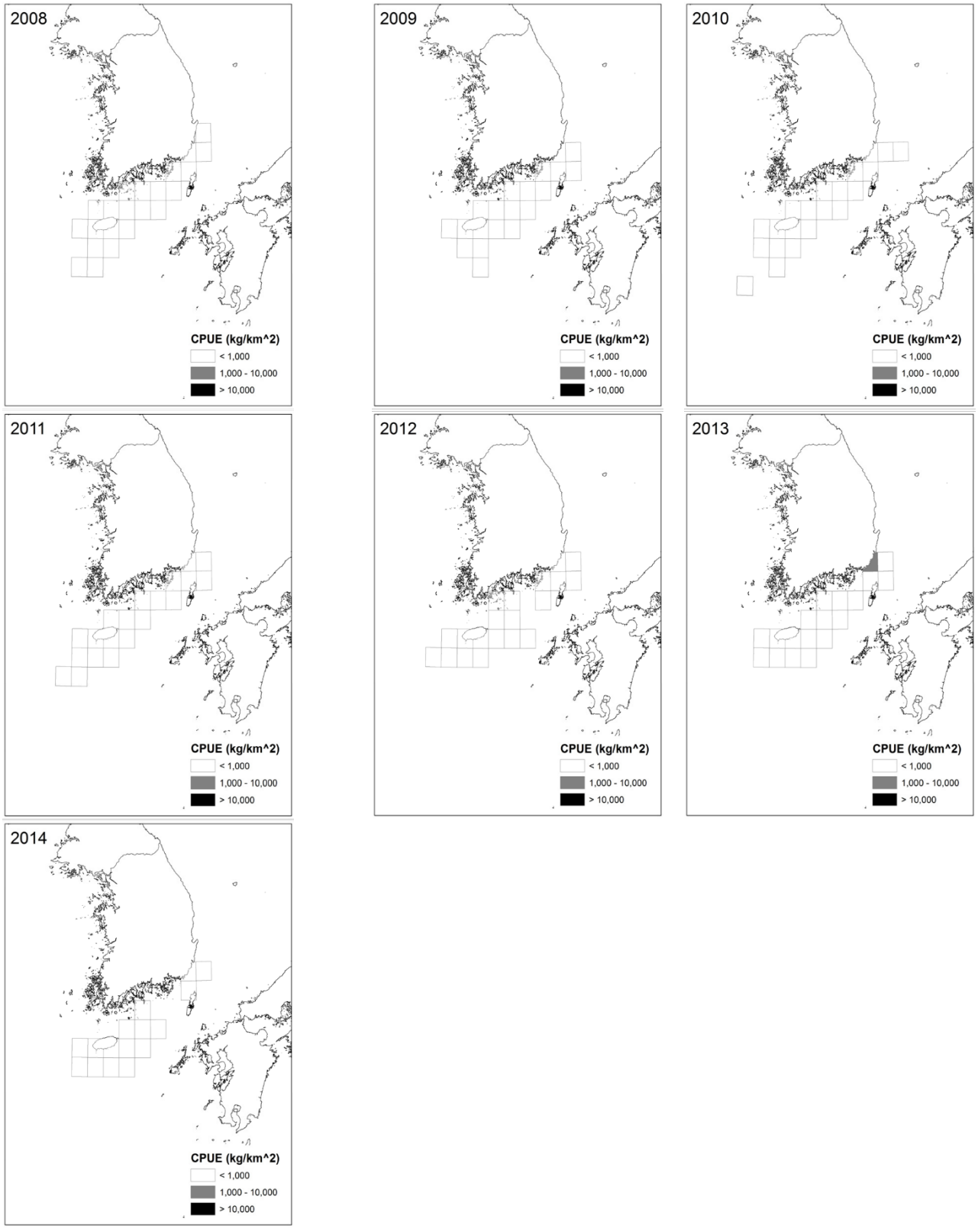

Fig. 8. Geographic distribution of annual CPUE of Large Danish Seine fishery from 2008 to 2014.

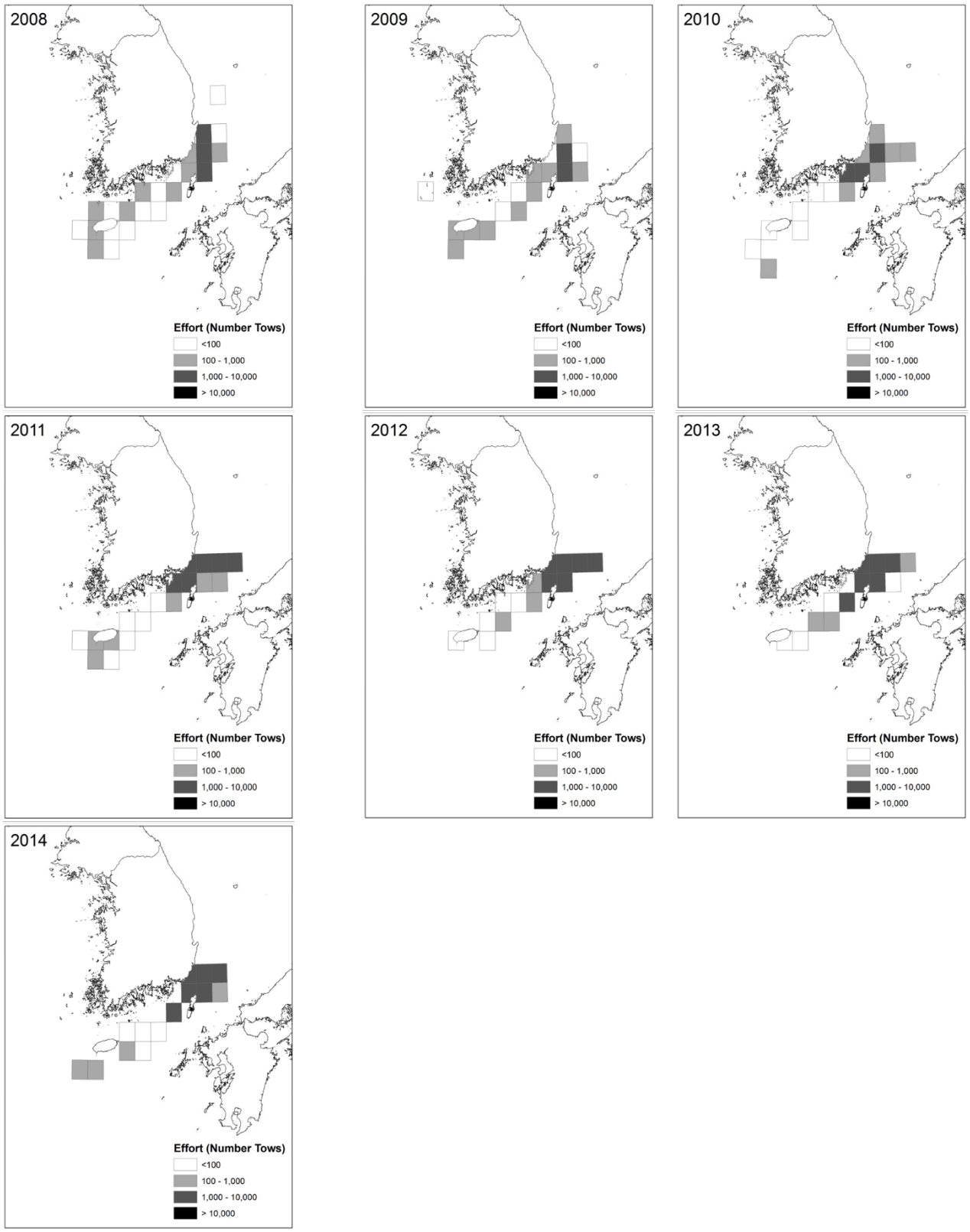

Fig. 9. Geographic distribution of annual effort of Middle Danish Seine fishery from 2008 to 2014.

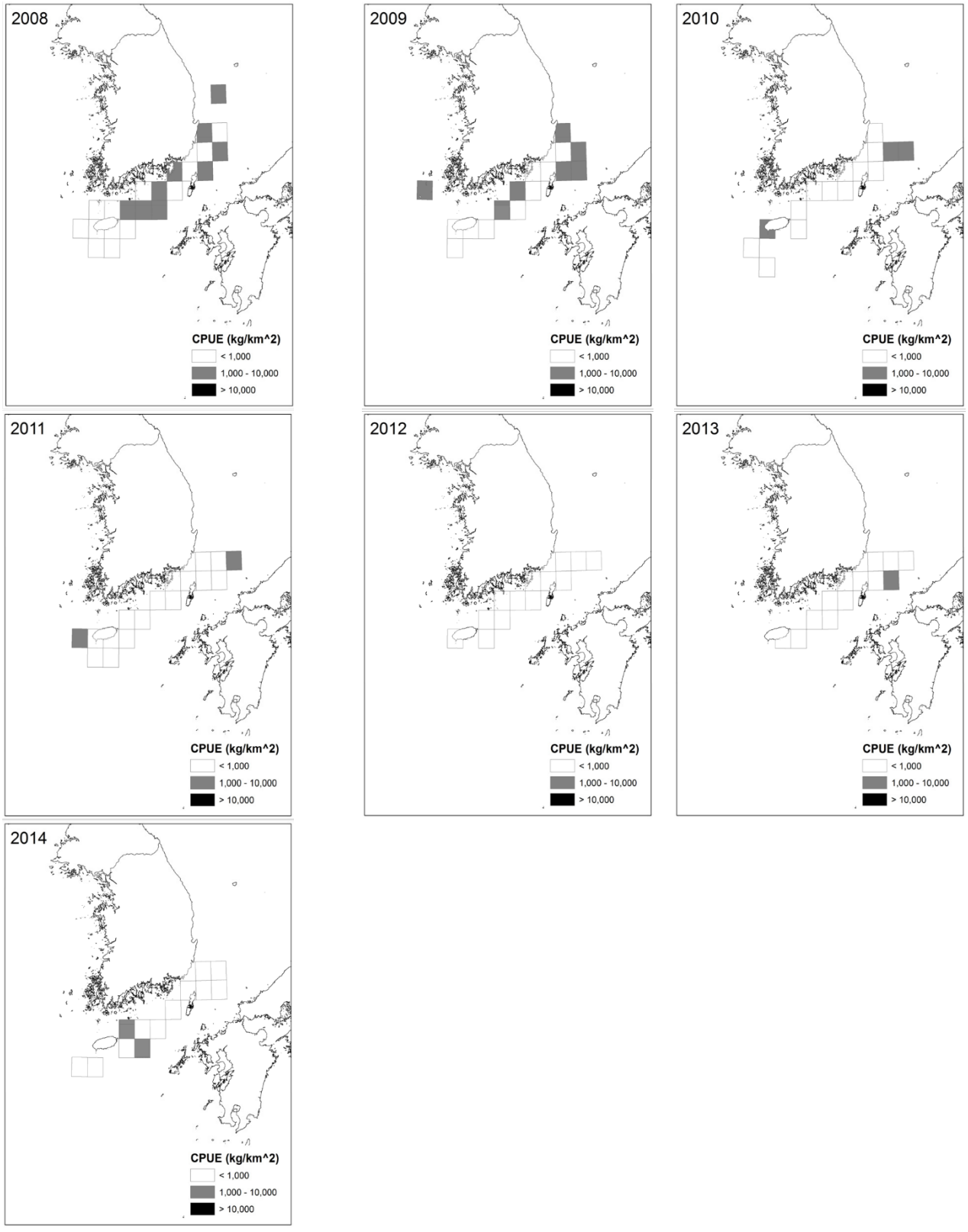

Fig. 10. Geographic distribution of annual CPUE of Middle Danish Seine fishery from 2008 to 2014.

The catch per unit effort was generally high at 10,000 kg/haul from the eastern part of the South Sea to the northern part of the eastern sea during the study period, and a high value of 10,000 kg/haul or more was found in the western sea in 2010 (Fig. 4). During the entire study period, the Large Pair Trawl showed a high amount of fishing effort centered on the southern sea and western part of Jeju (Fig. 5), and the catch per unit effort was mostly 1,000-10,000 kg/haul, which was lower than that of the Large Trawl, and the western part of Jeju. This value was higher than that of the eastern sea of Jeju (Fig. 6). During the entire study period, the Large Danish Seine showed a high amount of fishing effort in the southern sea including around Jeju, and showed a high value especially in the waters near Jeju. From 2008 to 2013, a high amount of fishing effort was observed in the waters near Jeju and Gyeongnam coast, but in 2014, it showed a high value only in the waters around Jeju.(Fig. 7). The catch per unit effort was low at 1,000 kg/haul in most of the sea areas where fishing was conducted (Fig. 8). In 2008 and 2009, the Middle Danish Seine showed high fishing effort in similar waters to the Large Danish Seine, but after 2010, they showed high fishing effort in the southern and eastern seas of the East Sea (Fig. 9). The catch per unit effort showed a rather high value in the southern and western seas in 2008 and 2009, but showed a limitedly low value in the southern and southern eastern seas after 2010, and showed a rather high value in eastern side of Jeju in 2014 (Fig. 10).

Changes in major fishing grounds by fishery

The Large Trawl was first introduced to fishing grounds in the southern part of the East Sea in 2008.

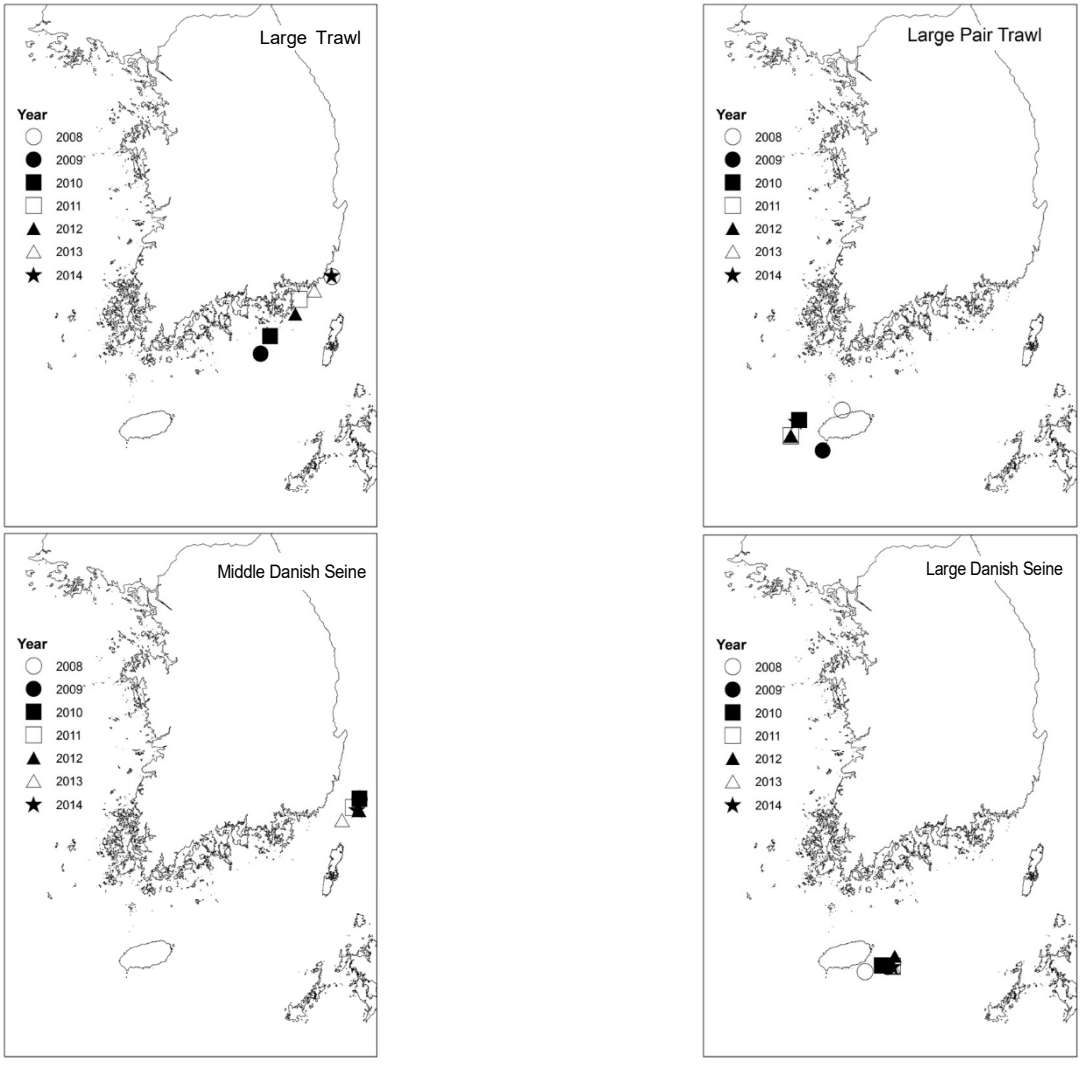

Fig. 11. Annual changes of the center of fishing ground for four drag-bagnet fisheries from 2008 to 2014.

In 2009, moved to the southern seas, Yokji Isalnd and then gradually moved northward toward the southern seas of the East Sea. During the entire study period, the geographic center of this fishery was observed in the seas surrounding Jeju. After moving from the northern seas of Jeju in 2008 to the southern seas in 2009, the western seas of Jeju appeared as the center of the fishing grounds. The Large Danish Seine appeared as the main fishing ground in the eastern seas of Jeju during the entire study period, and the Medium Danish Seine was formed centered on the southern part of the East Sea. Therefore, it was found that most of the four fishery of the offshore trawlers moved to the north during the study period (Fig. 11).

Discussion

In the 1980s and 1990s, Korea's fishing boat fishing industry was greatly affected and came to change. In particular, Large Pair Trawl fishing among offshore fisheries was greatly affected by the reduction of fishing grounds and changes in target fish species as the fishing grounds that previously extended to the coast of China were reduced to within the Korean EEZ (Lee et al., 2013). Since then, the number of trawlers has been steadily decreasing until recently due to the decrease in the abundance of the target fish species and the fishing vessel reduction project in accordance with the fishing agreement. Lee et al. (2011) shows the results of aggregation analysis of catches by fish species by year of the Large Pair Trawl fishery from 1990 to 2007. According to the Korea-Japan and Korea-China Fishery Agreement, target fish species changed with the type of fishery and the used nets. It was reported that there was a clear difference in catches per unit effort between 1990s and the 2000s. In the 1990s, primarily demersal fish were caught, whereas in the 2000s, the proportion of pelagic fish was high. It was reported to be due to a high net mouth height (Lee et al., 2013).

Trawl net fishing is targeted using trawl type nets and seine type nets. It is a fishing industry that catches aquatic organisms that inhabit the fishery, and not only must be abundant in aquatic life in the target fishery, but also that the water is not too deep and there are no obstacles on the seabed (Lee and Lim, 1993; NIFS, 2008). Therefore, it is judged that the main fishing grounds of the trawl net will be determined by the seabed topography, the sediment type and the abundance of the target fishery resources. In other words, the sediment characteristics of the fishing grounds will be the basis for judging the potential area where trawlers can fish, and the amount of fishing effort will be the basis for judging the abundance of aquatic resources. The results of the fishing effort according to the characteristics of the bottom quality of each fishery in this study showed that the fishing effort was higher in sand and sandy mud than in mud in all the fisheries studied. Therefore, judging from the design characteristics of the trawl gear, it can be judged that the four trawling fisheries under study prefer sand and sandy mud. In addition, the catch per unit effort for each fishery is related to the distribution characteristics of major target organisms and the sediment and marine characteristics of the fishing area. Judging from the results of the catch, it is presumed that the catch per unit effort of trawl fishery is greatly affected by the distribution characteristics of the target organisms. Especially, Lee et al. (2013) reported that in the case of Large Pair Trawl fishing, the main fishing grounds were stretched from east to west in accordance with the signing of the Korea-China Fishery Agreement. In addition, according to the decrease of demersal fish, fishing grounds were mainly in the vicinity of Jeju Island and the southern coast targeting the pelagic fish. In addition, Ginger and Kang (2003) reported that the increase in the Tsushima warm current caused by climate change caused physical changes in the oceans around Korea, which not only affected the movement and spread of food organisms but also aquatic resources. By causing a change in distribution density, squid, mackerel, anchovies and horse mackerel were reported to be the main fish species instead of pollock and horsetail. However, since this study analyzed only the information and simple catches obtained from the fishing of 4 types of trawlers operating from the Busan Joint Fish Market, additional research will be conducted on data of all the fishing vessels and catches of the 4 trawlers in the future. It is considered necessary to carry out additional work.

Conclusion

We examined 4 types of Korea's offshore trawlers (Large Trawl, Large Pair Trawl, Large Danish Seine, Middle Danish Seine), with their home port at the Busan Joint Fish Market. As a result of examining the changes in major fishing grounds from 2008 to 2014 using information obtained from these fishing boats, we found the Large Trawl fleet fished mainly in the southern part of the East Sea, and the main fishing grounds for the Large Danish Seine was in the seas around Jeju. The Middle Danish Seine's fishing ground was centered on the southern seas of the East Sea.

Acknowledgements

This study was carried out with the support of the National Institute of Fisheries Science (R2021035).

References

Cho DO. 2012. Eliminating illegal bottom trawl fishing in thecoastal waters of Korea. Mar Pol 36, 321-326. https://doi.org/10.1016/j.marpol.2011.07.001.

Folk RL. 1980. Petrology of sedimentary rocks. Hemphill Publishing Company, Texas, U.S.A., 1-184.

Ginger AR and Kang YS. 2003. A comparison of three marineecosystems surrounding the Korean peninsula: Response to climate change. Progr Ocean 59, 357-379. https://doi.org/10.1016/j.pocean.2003.10.002.

Jang CS, Song WS, Kang M, Choi YH, Kim BY and An YS.2016. Fishing gear and method and improvement of regulation of the middle sized trawl fishery in the EastSea of Korea. J Korean Soc Fish Technol 52, 162-168. https://doi.org/10.3796/KSFT.2016.52.2.162.

Kim DY. 1999. Reorganization of international fisheries in the East China Sea and the Yellow of international fisheriesin the East China Sea and the Yellow Sea. J Fish Bus Admin 30, 97-118.

Kim DY and Kim BH. 2004. Restructuring of the off-shore otter trawl fishery in Korea. J Fish Mar Sci Edu 16, 124-141.

Kim KI and Ahn JY. 2018. A study on appearance frequenciesand fishing ground exploration of low-run fishing obtained by analyzing AIS data of vessels in the sea around Jeju Island.J Korean Soc Fish Ocean Technol 54,157-163. https://doi.org/10.3796/KSFOT.2018.54.2.157.

Lee BG and Lim HS. 1993. The development and future prospect of pair trawling in Korean waters since 1980's.J Fish Mar Sci Edu 5, 90-97.

Lee DW, Choi KH and Kang S. 2013. Changes of fishing ground of the large pair trawl fishery off Korean waters.Kor J Fish Aquat Sci 46, 917-922. https://doi.org/ 10.5657/KFAS.2013.0917.

Lee DW, Lee JB, Kim YH, and Kang S. 2011. Analysis of species assemblages caught by large-pair-trawler in Korean water. Kor J Fish Aquat Sci 44, 499-505. https://doi.org/10.5657/kfas.2011.0499.

Lee JH. 1993. Advanced fishing technology for cutting down production cost. Bull Korean Fish Technol 29, 64-69.

National Institute of Fisheries Science. 2008. Fishing gear ofKorea (revised edition). Hangul Graphics, Busan, 1-580.

Pitcher CR, Ellis N, Jennings S, Hiddink JG, Mazor T, Kaiser MJ, Kangas MI, McConnaughey RA, Parma AM, Rijnsdorp AD, Suuronen P. Collie JS, Amoroso R, Hughes KM and Hiborn R. 2017. Estimating the sustainability of towed fishing-gear impacts on seabed habitats: a simple quantitative risk assessment method applicable to data-limited fisheries. Meth Eco Evol 8, 472-480. https://doi.org/10.1111/2041-210X.12705.

.

2021. 04. 01 Received

2021. 04. 27 Revised

2021. 05. 17 Accepted