Ecological traits and population dynamics of Japanese common squid *Todarodes pacificus* that concerned with the fishing grounds and fishing seasons of Japanese and Korean fisheries

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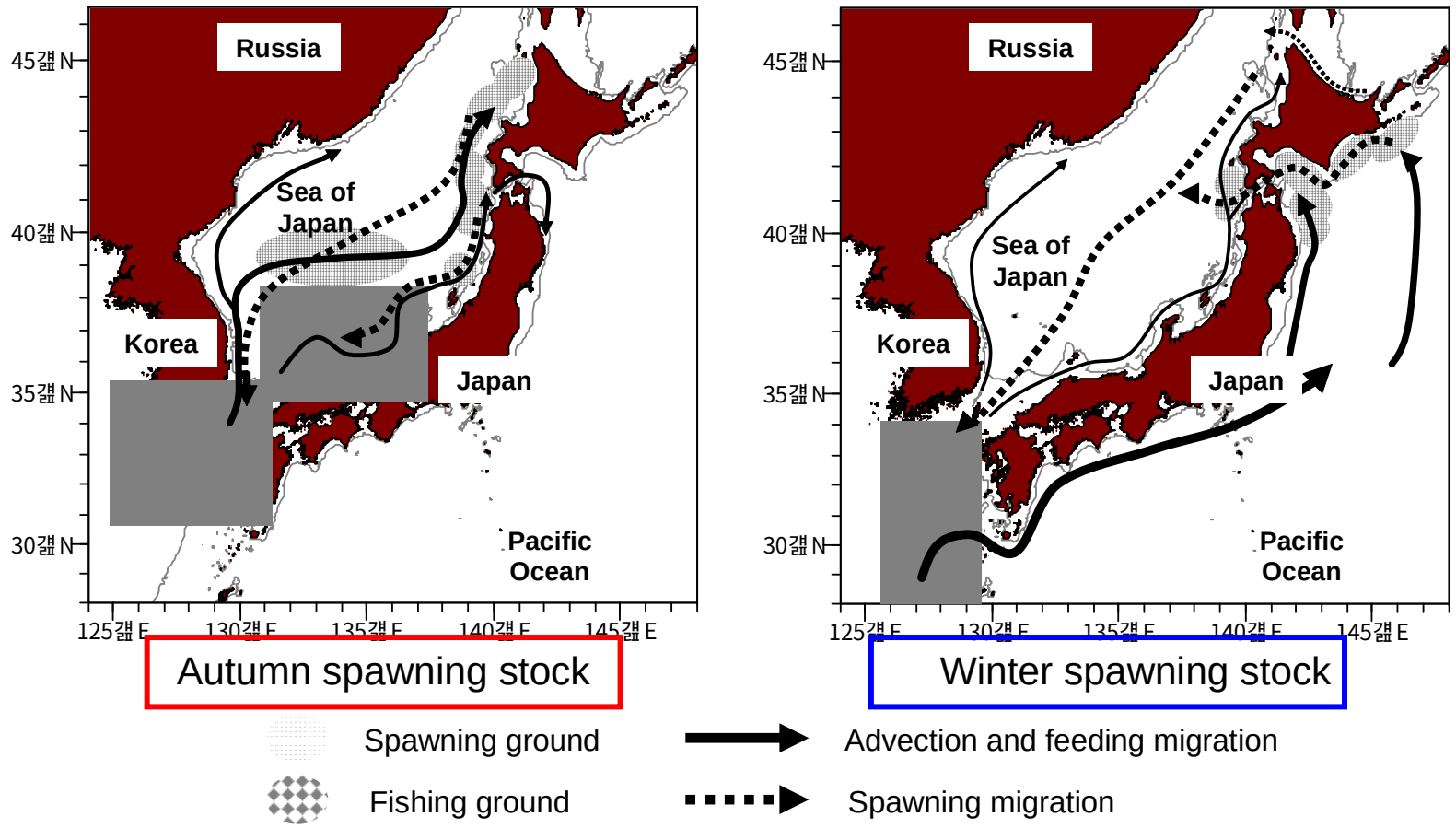
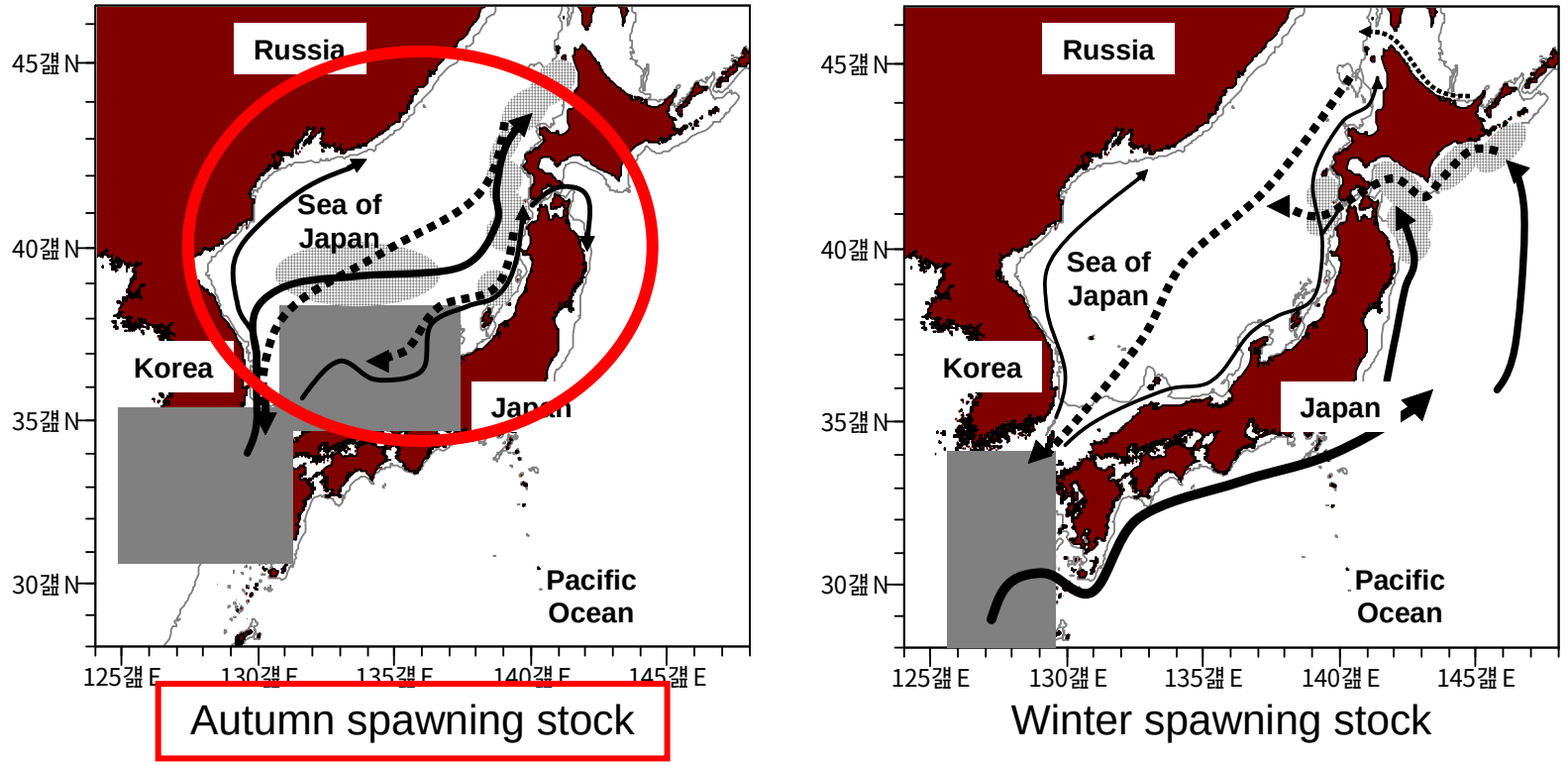
Japanese common squid (*Todarodes pacificus*) is distributed in the northwest Pacific including the Sea of Japan, and is the most important cephalopod species for Japanese and South Korean fisheries.

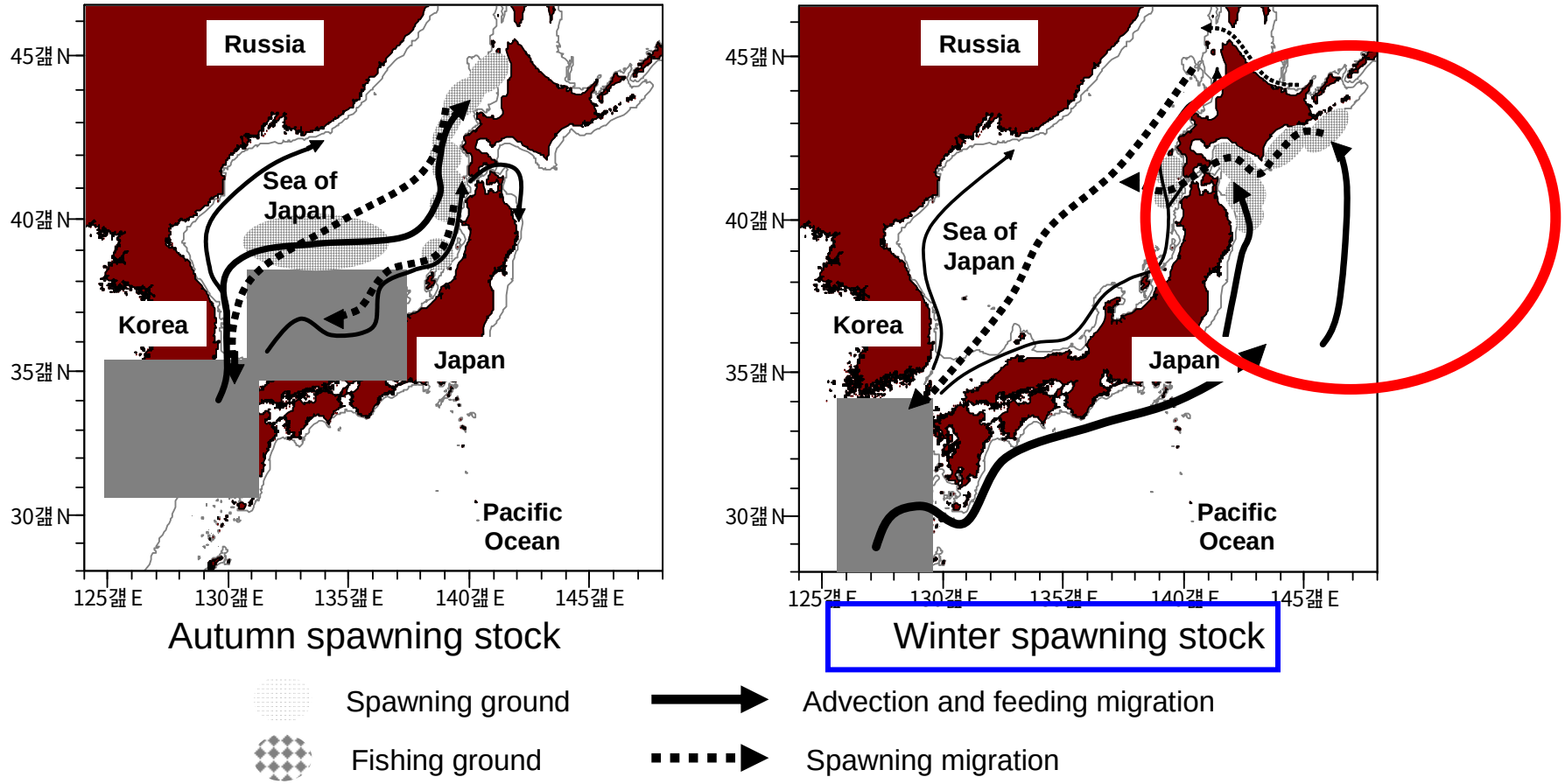


Basically, Japanese common squid can be divided into two main stocks. The autumn spawning stock is distributed and migrates mainly in the Sea of Japan. The winter spawning stock distributes along the Pacific side and migrates around the Japanese Islands counter clockwise.



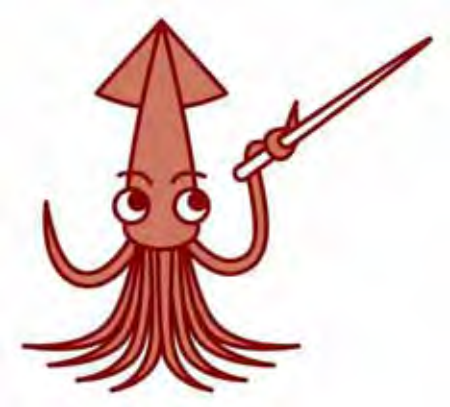
Fishing grounds of the Japanese common squid shift seasonally with the migration routes.

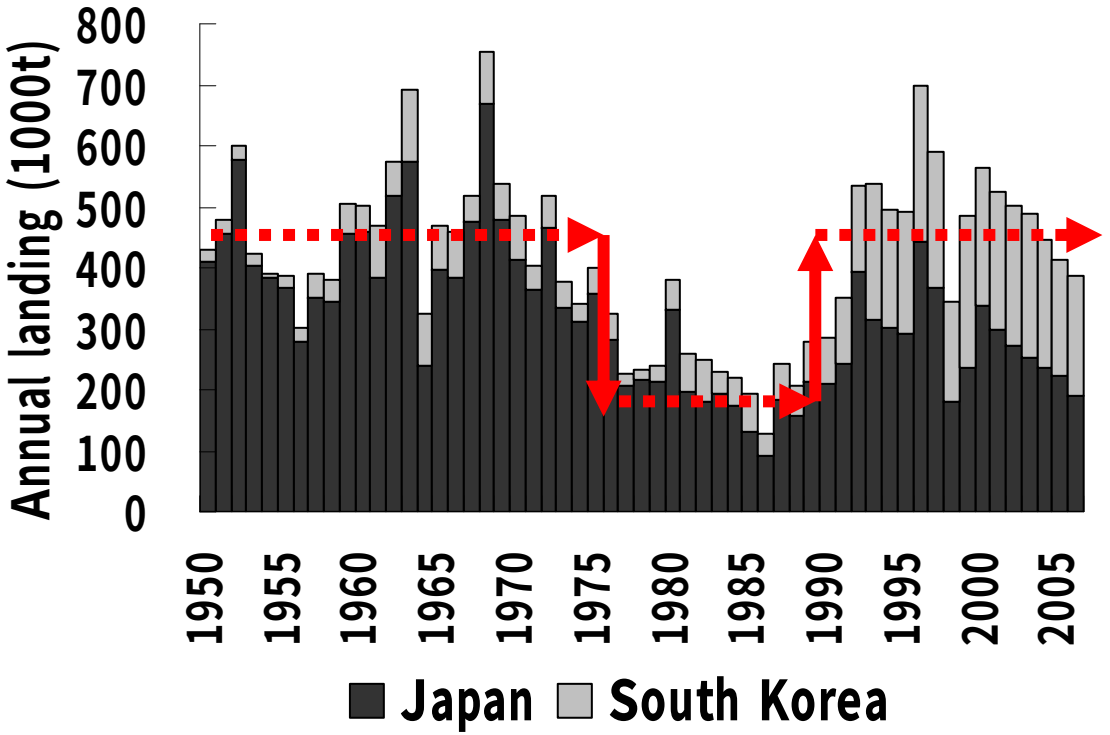
The autumn spawning stock is caught in the Sea of Japan by the Japanese fleet in summer and around the Tsushima Strait by the Korean fleet in autumn.



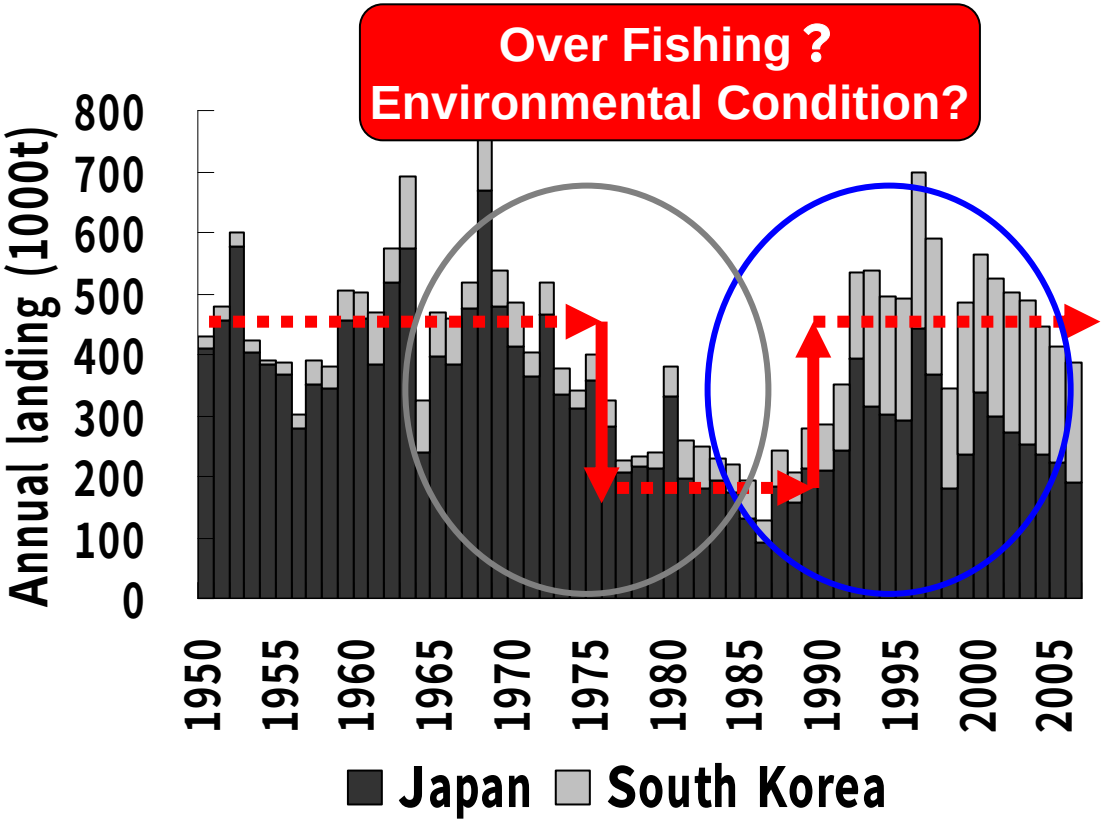
Fishing grounds of the Japanese common squid shift seasonally with the migration routes.

The winter spawning stock is caught along the Pacific side (around Hokkaido) by the Japanese fleet in autumn and in the Sea of Japan by Japanese and Korean fleets in winter.





Total annual catches by Japanese and South Korean fisheries were about 500,000 t during the 1950s and 1960s, but they decreased to 200,000 t during the 1980s. Catches have rebounded to about 500,000 t in recent years.



It was reported that the decrease in catch of Japanese common squid during the 1970s and 1980s was caused by excessive fishing effort at that time.

However, it has become clear that not only fishing effort but also changing environmental conditions have affected the stock size of Japanese common squid.

Generally, it is suggested that a regime shift occurred in 1989, and sea surface temperatures (SST) in the northwest Pacific have shown positive anomalies since 1989.

1977

Cool

1980s

1989

Warm

1990s

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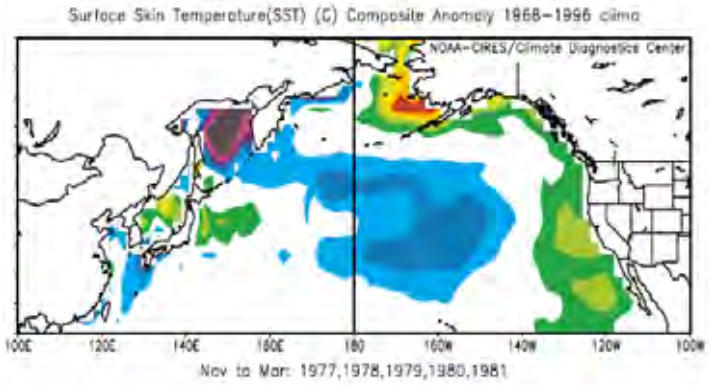
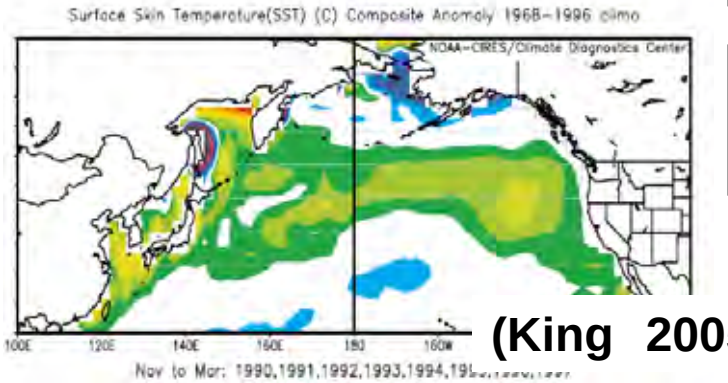




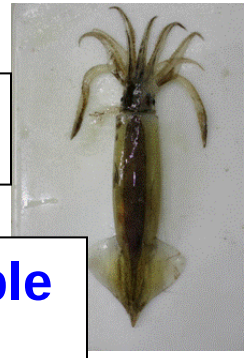
(King 2005)

1977

Unfavorable condition

1989

Favorable condition



This shift from cool to warm SST coincided with an increase in the stock size of Japanese common squid, suggesting the regime shift influenced the stock size of Japanese common squid.

The aim of this study

In this study, our aim is to make proposals for a plan for the sustainable and effective management of the Japanese common squid, based on the impact of variability in oceanographic conditions on the dynamics of the species.

Outline

1)We summarized the changes in fishing grounds and fishing season of Japanese common squid with the changes in oceanographic conditions, in particular changes on a decadal scale.

2)We reviewed the population dynamics and changes in ecological traits (migration pattern, spawning season and spawning ground) of Japanese common squid with changes in oceanographic conditions, and discuss the influence of the changes on ecological traits in relation to the fishing grounds and fishing seasons.

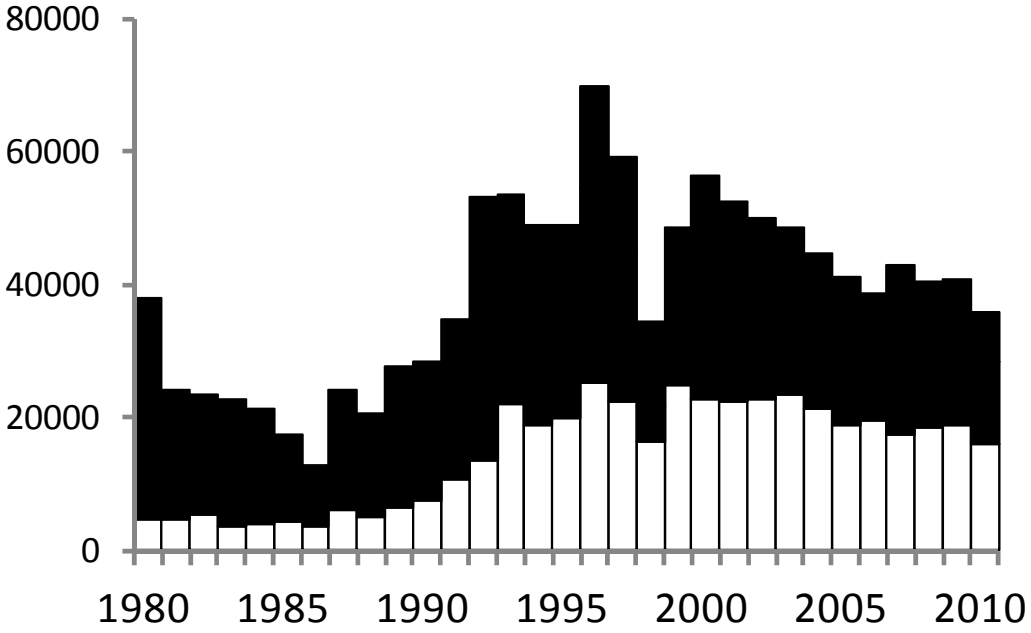
Summary of the changes in fishing grounds and fishing season

Materials and Methods

In order to summarize the changes in fishing grounds and fishing season, we used monthly catch records of Japanese and South Korean fisheries during 1980-2010.

1) Japanese catch records are the data used for the stock assessment report by the Fisheries Agency.

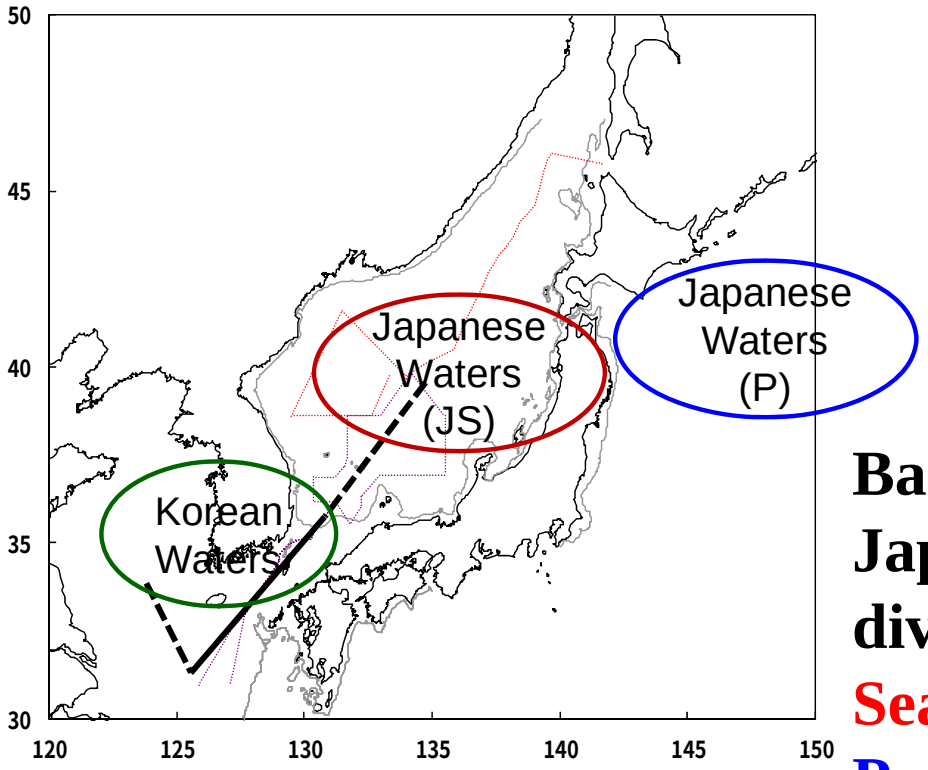
2) South Korean catch records are monthly catch statistics by NFRDI, which is obtained through internet.



Changes in annual catch statistics of Japanese common squid by Japanese (■) and South Korean (□) fisheries

Summary of the changes in fishing grounds and fishing season

Materials and Methods

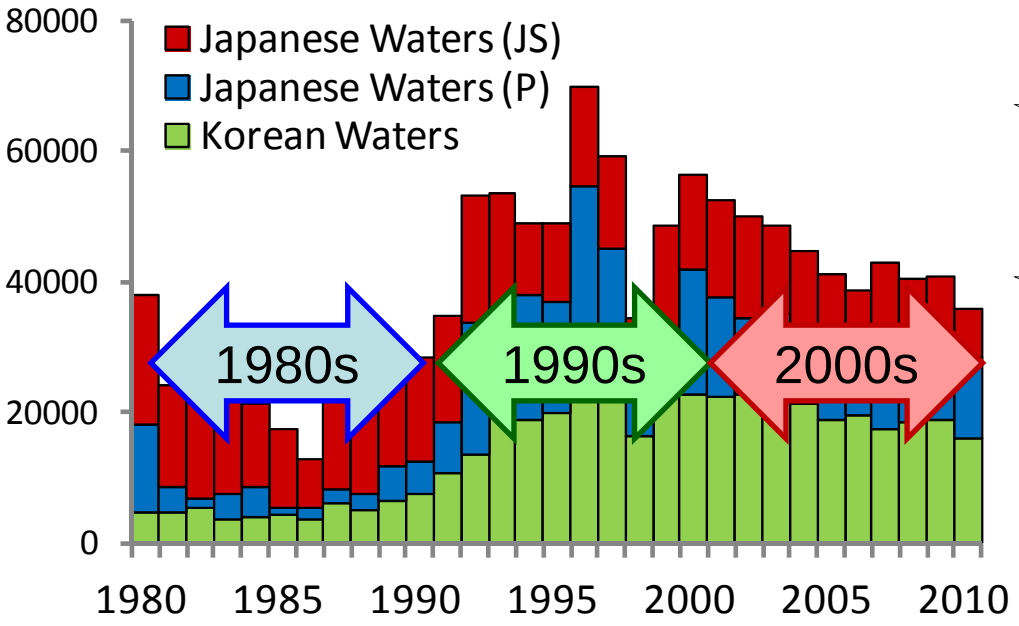


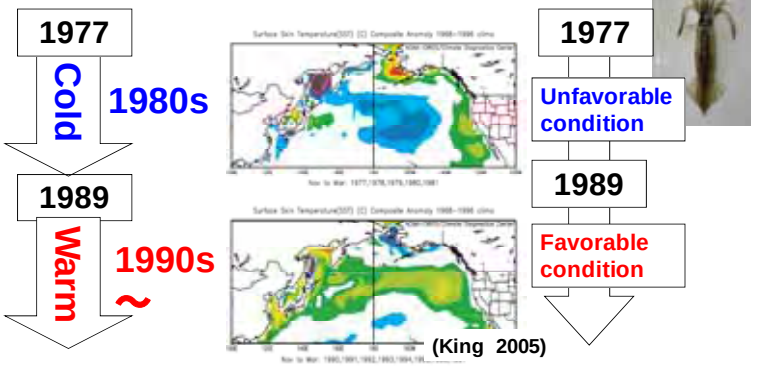
Based on these catch records, Japanese catch records were divided into two regions, the Japan Sea side of Japanese waters and the Pacific side of Japanese waters. Catch records by the South Korean fleet were treated as the catch in Korean waters.

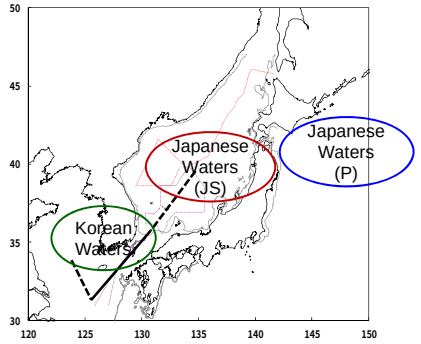
Materials and Methods

Decadal changes

Catch records were averaged for each decade (1980s, 1990s, 2000s). Basically, it is considered that the 1980s was a cool period, 1990s was a period of warm winters and 2000s was a warm period all year around. And the changes in fishing grounds of Japanese common squid on a decadal scale were examined.

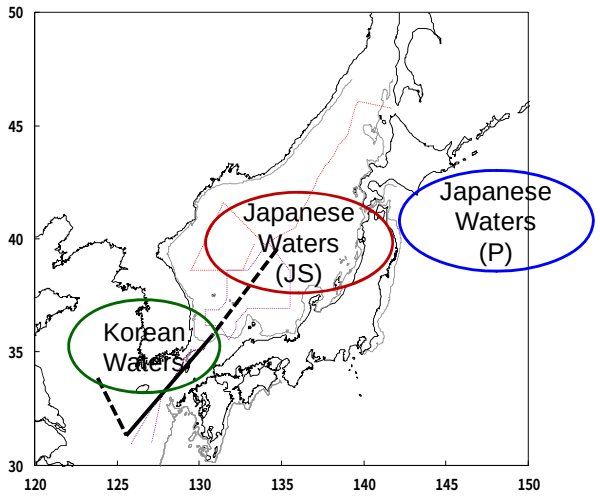


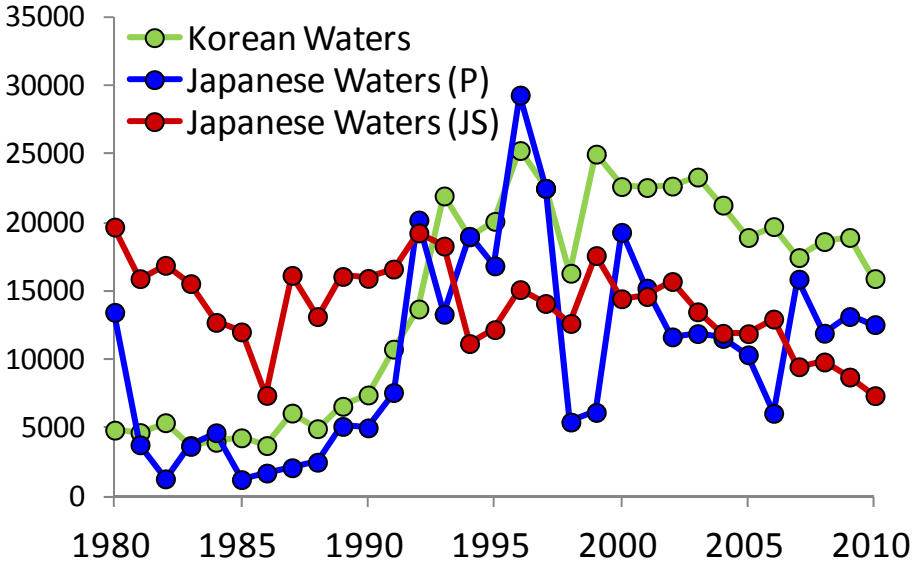




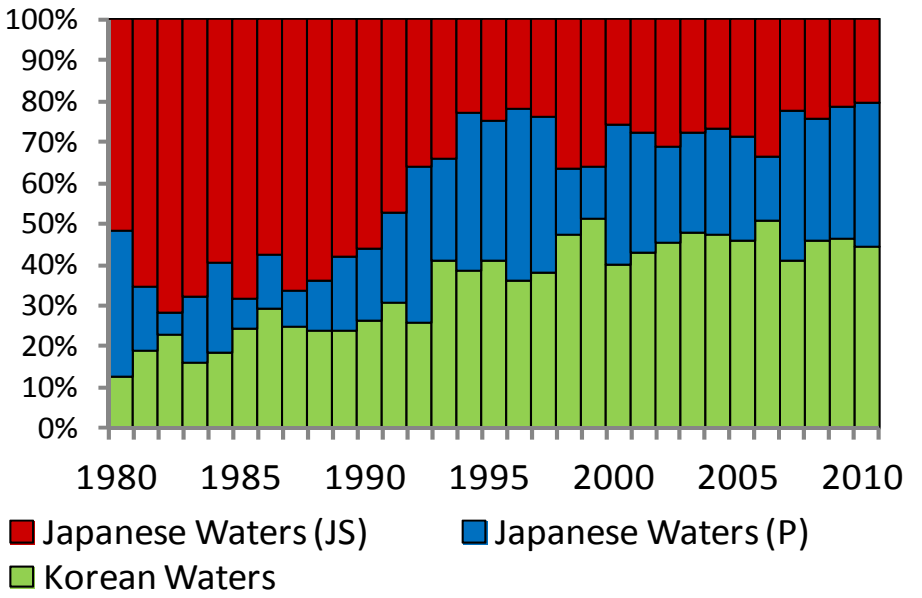
Summary of the changes in fishing grounds and fishing season

Results (Annual changes)



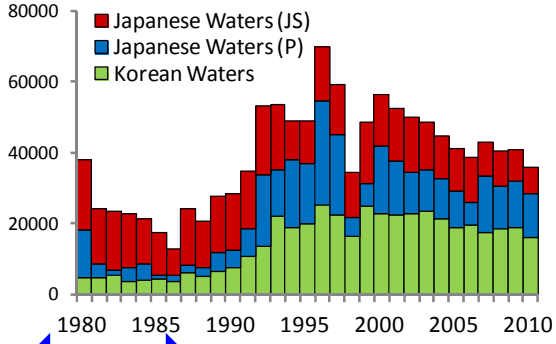


Catches on the Japan Sea side of Japanese waters were dominant during the 1980s. But catches along the Pacific side of Japanese waters and in Korean waters increased in the beginning 1990s. Catches in Korean waters have been dominant since 1998.

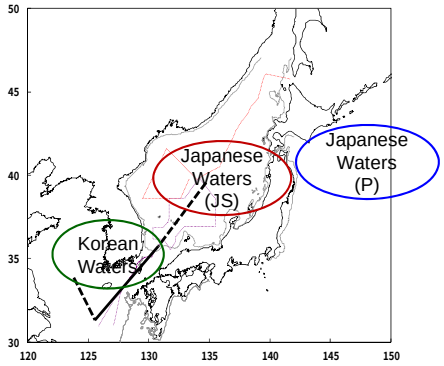


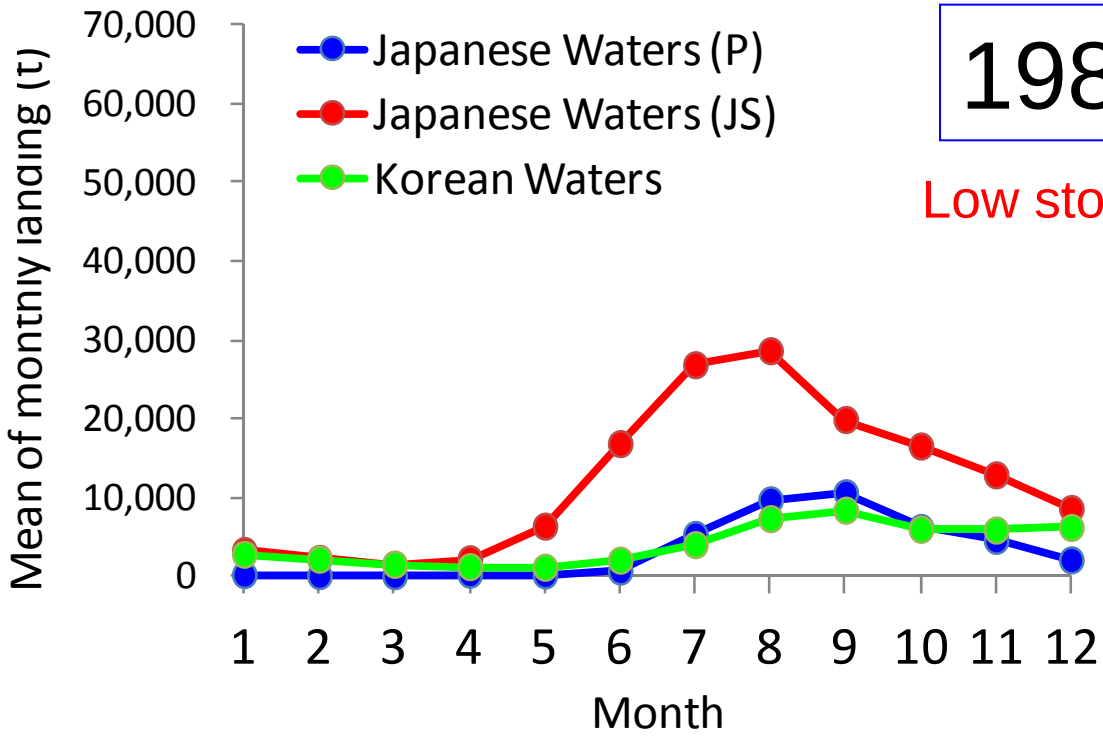
Summary of the changes in fishing grounds and fishing season

Results (Decadal changes in fishing ground and season)



1980s





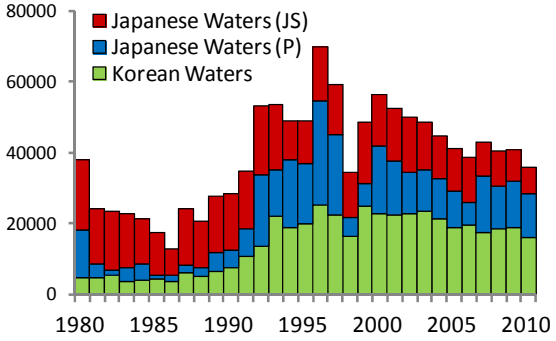
1980s

Low stock size

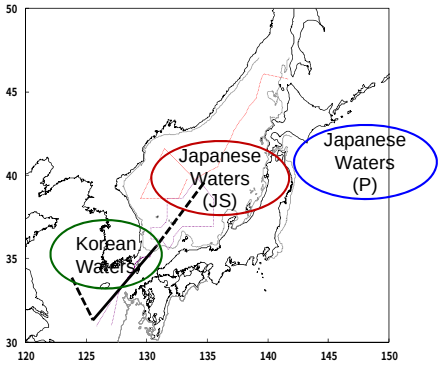
In the 1980s the main fishing ground of Japanese common squid was located along the Japan Sea side of Japanese waters and the peak of fishing season was in summer (July-August).

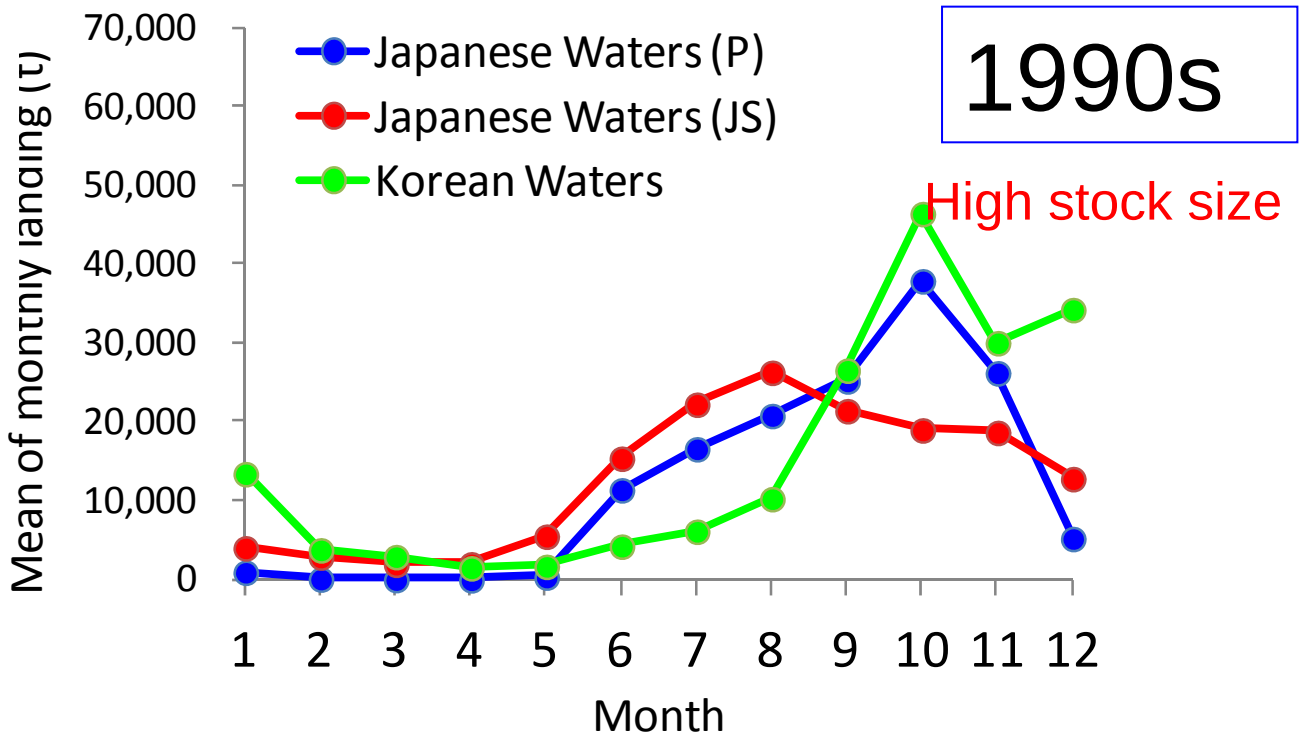
Summary of the changes in fishing grounds and fishing season

Results (Decadal changes in fishing ground and season)



1990s

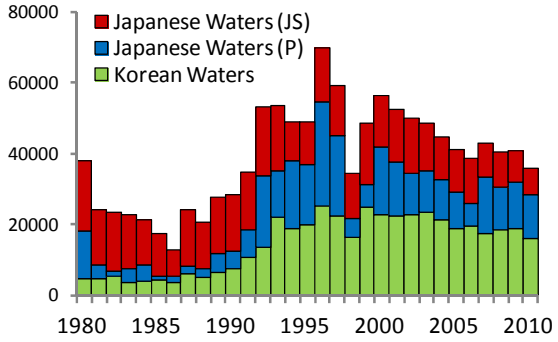




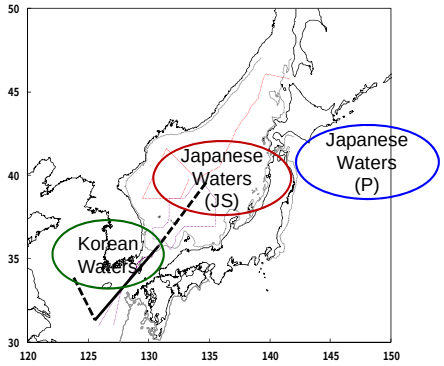
In the 1990s, catches of Japanese common squid increased along the Pacific side of Japanese waters and in the Korean waters, and the peak of fishing season shifted to October during this period.

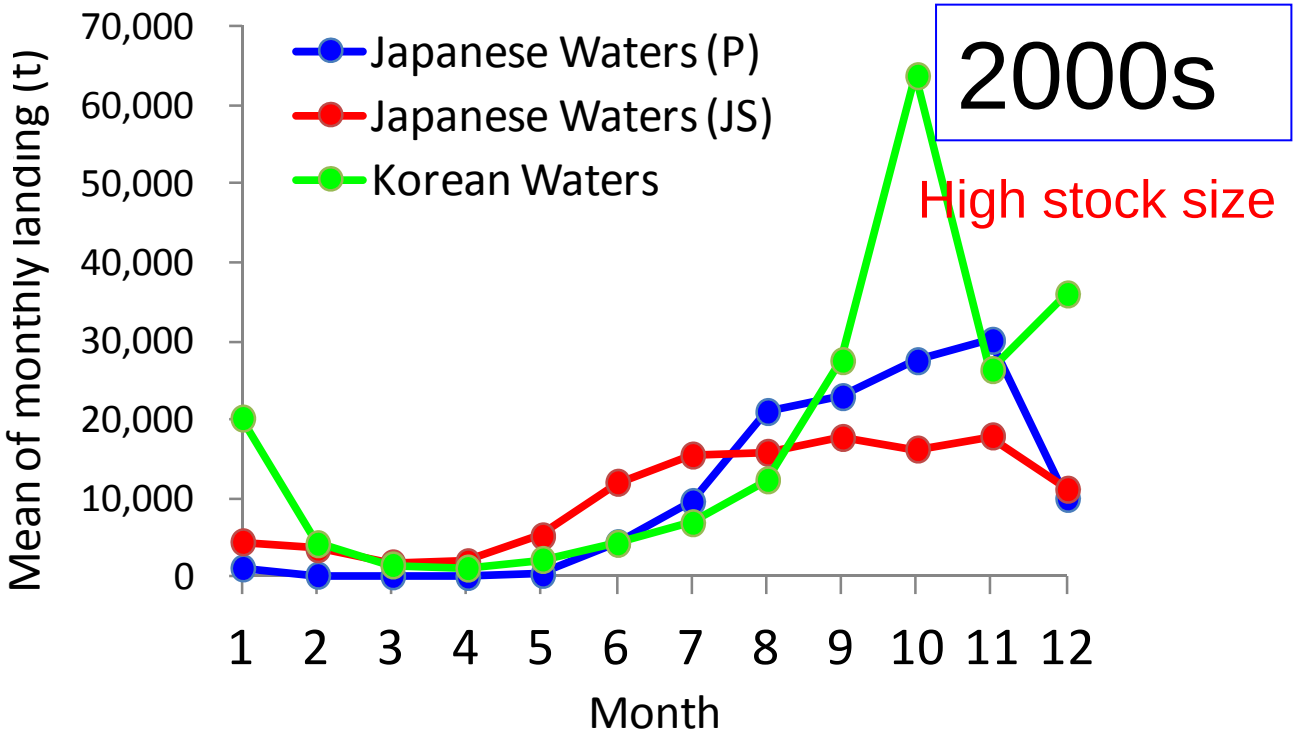
Summary of the changes in fishing grounds and fishing season

Results (Decadal changes in fishing ground and season)



2000s

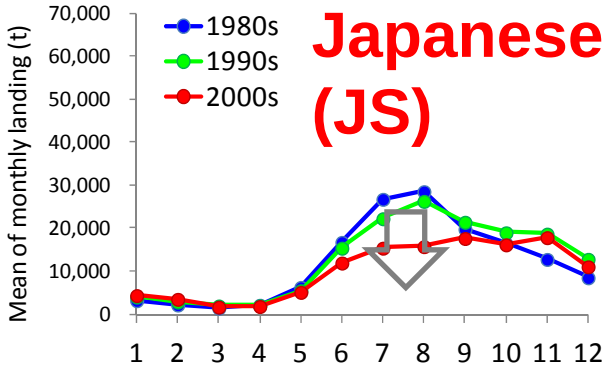




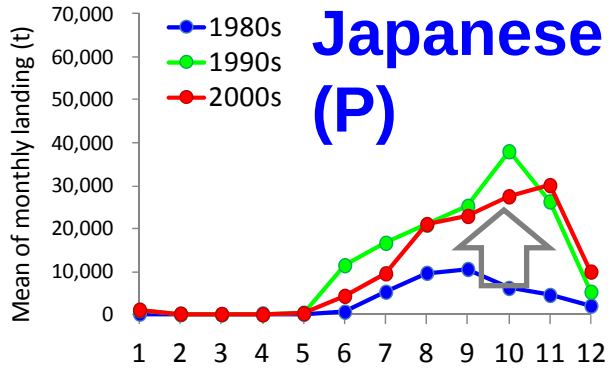
The catches of Japanese common squid decreased on the Japan Sea side of Japanese waters in the summer in the 2000s, and the peak of fishing season along the Pacific side of Japanese waters shifted to November.

Summary of the changes in fishing grounds and fishing season

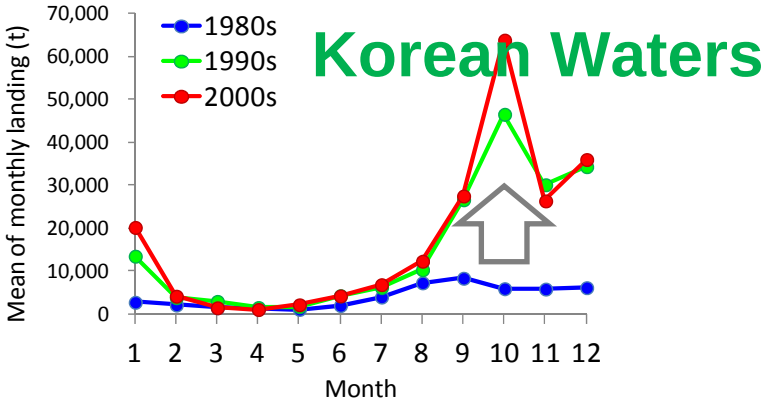
Results (Regional changes in fishing season)



In the Japan Sea side of Japanese waters, catches in summer (July and August) of the 2000s decreased slightly.



Along the Pacific side of Japanese waters, catches in summer and autumn (during June and November) have increased since the 1990s.

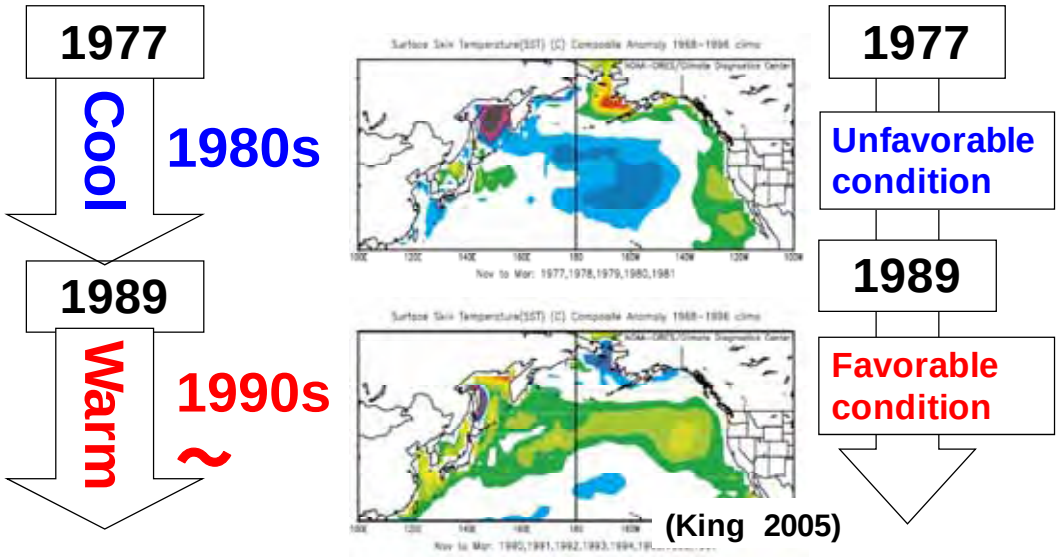


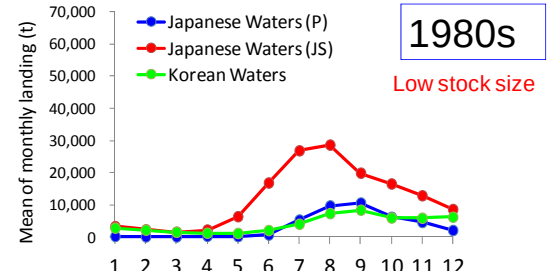
Catches in autumn and winter (during September and January) have increased drastically since the 1990s in Korean waters.

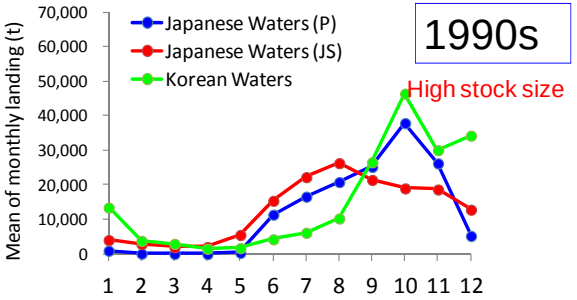
Summary of the changes in fishing grounds and fishing season

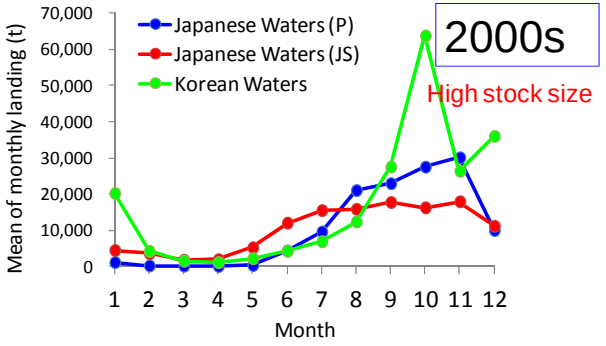
Results (Summary)

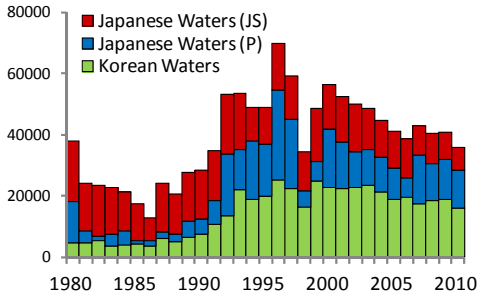
It appears that the main fishing grounds and fishing season of Japanese common squid have shifted with the changes in oceanographic conditions on a decadal scale.

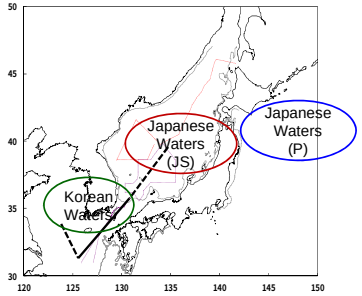




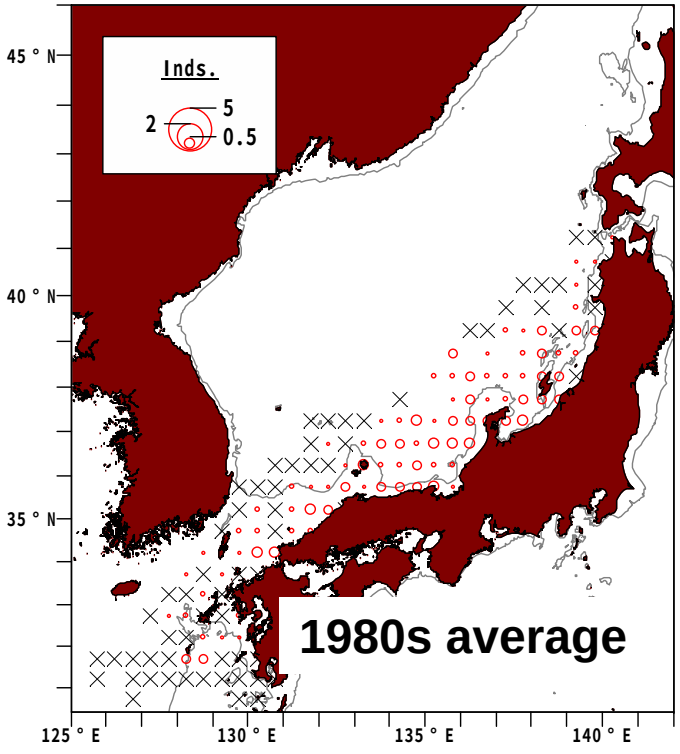


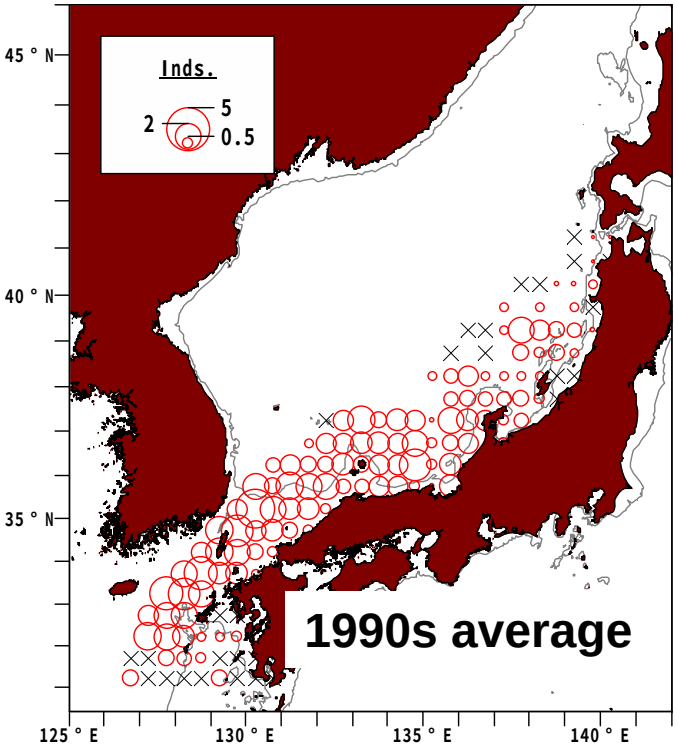


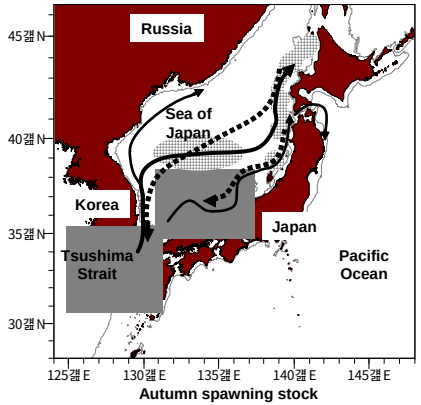




Brief review (Discussion) of the population dynamics and changes in ecological traits. Spawning ground (in the Sea of Japan)

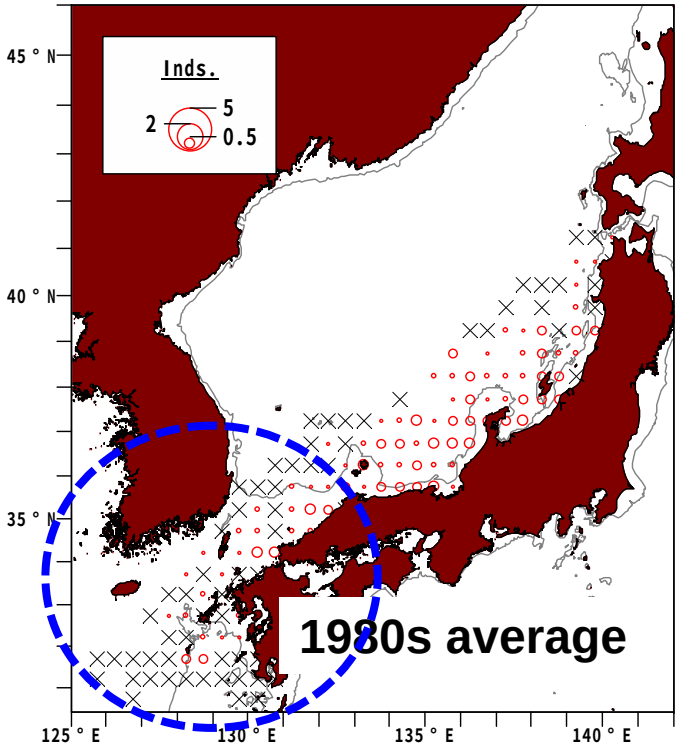


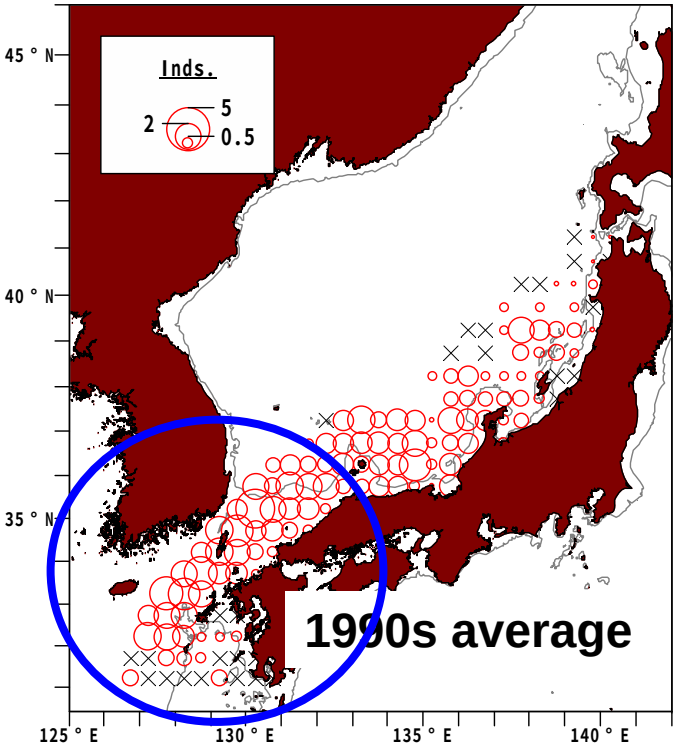


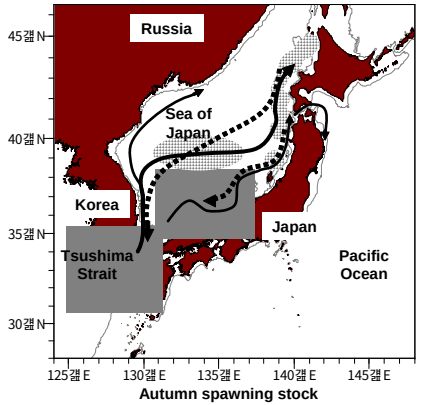


In the Sea of Japan (Autumn spawning stock), it was shown that the main spawning ground of the autumn spawning stock has expanded coinciding with the 1989 regime shift based on a paralarval survey.

Brief review (Discussion) of the population dynamics and changes in ecological traits. Spawning ground (in the Sea of Japan)

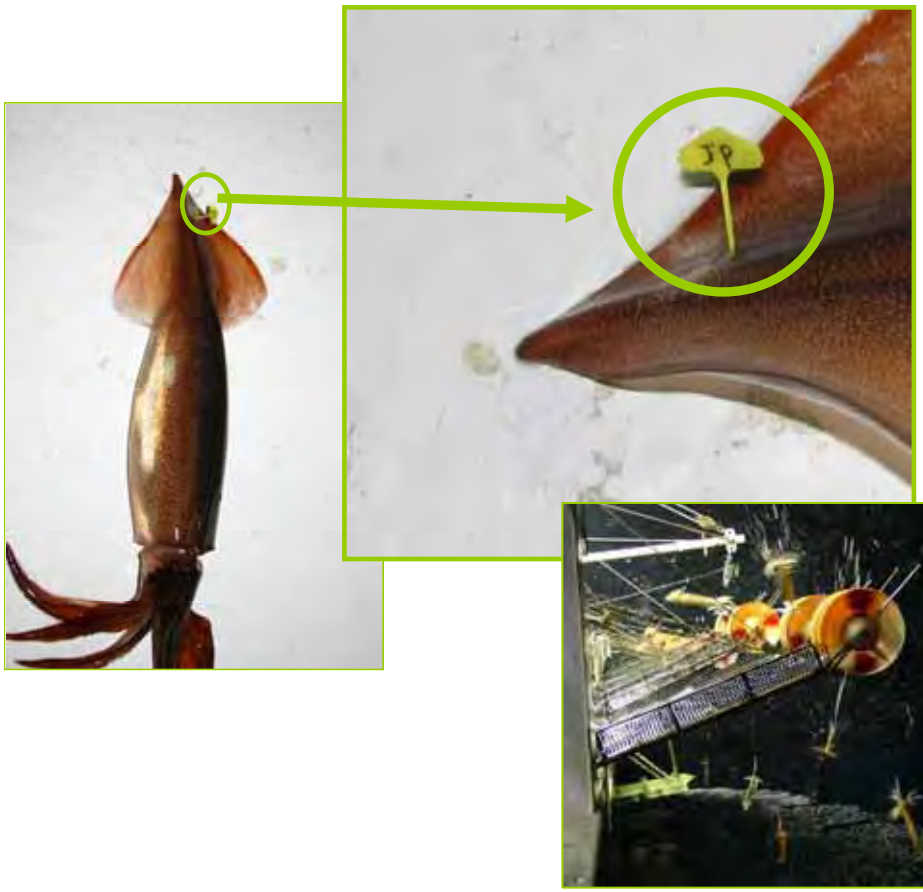


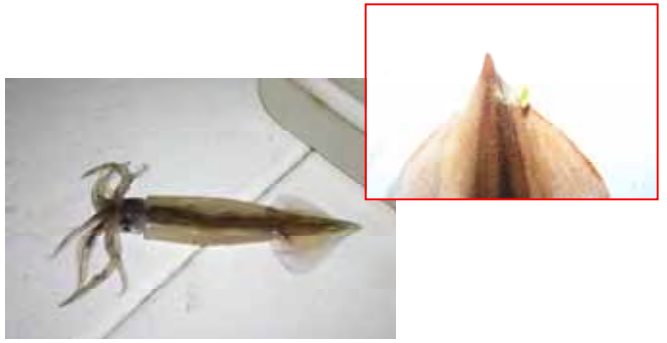




Paralarvae were not collected in the Tsushima Strait in the 1980s, but they were collected in this area after 1989 regime shift, suggesting the spawning ground of the autumn spawning stock expanded with the 1989 regime shift in the Sea of Japan.

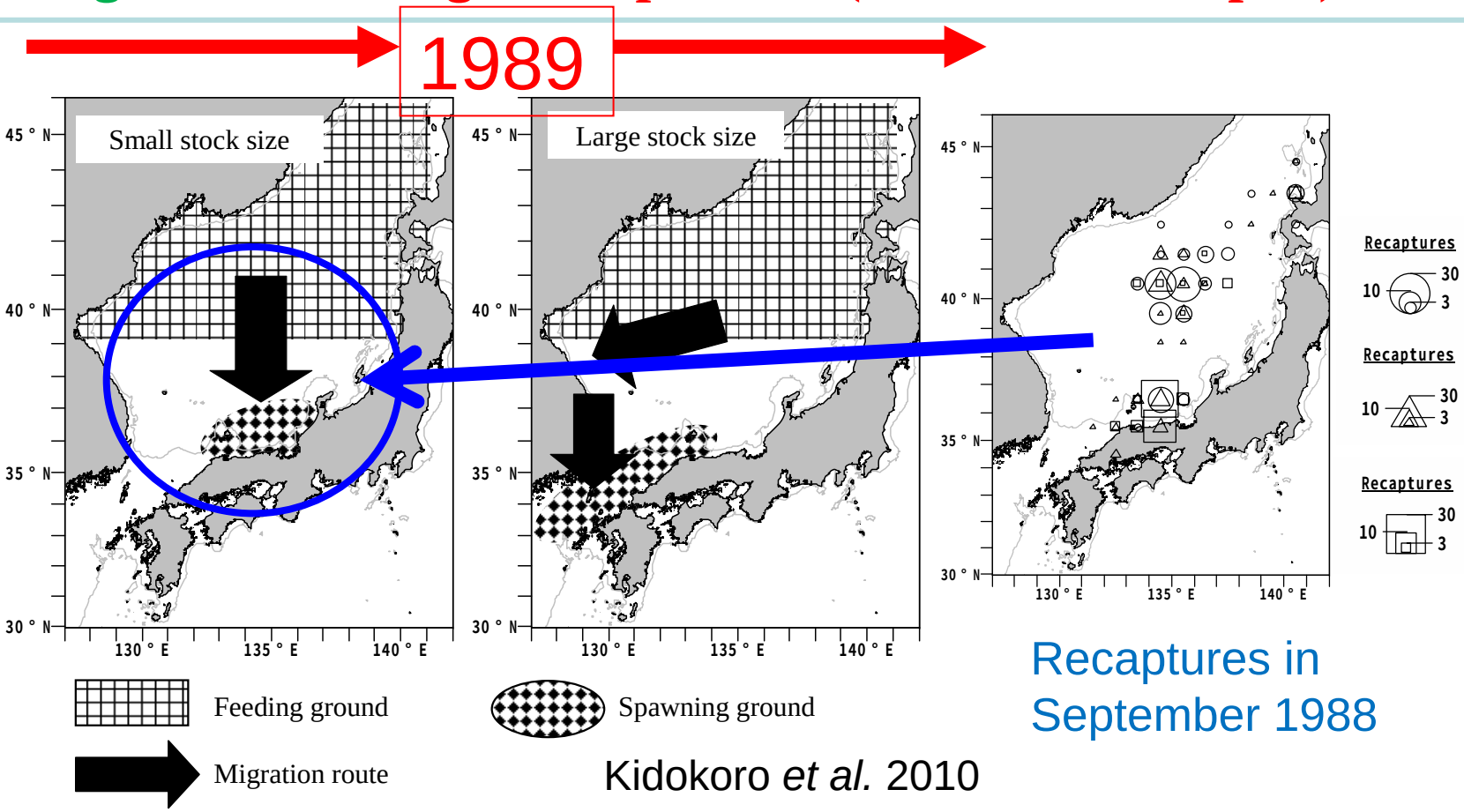
Brief review (Discussion) of the population dynamics and changes in ecological traits. Migration pattern (in the Sea of Japan)





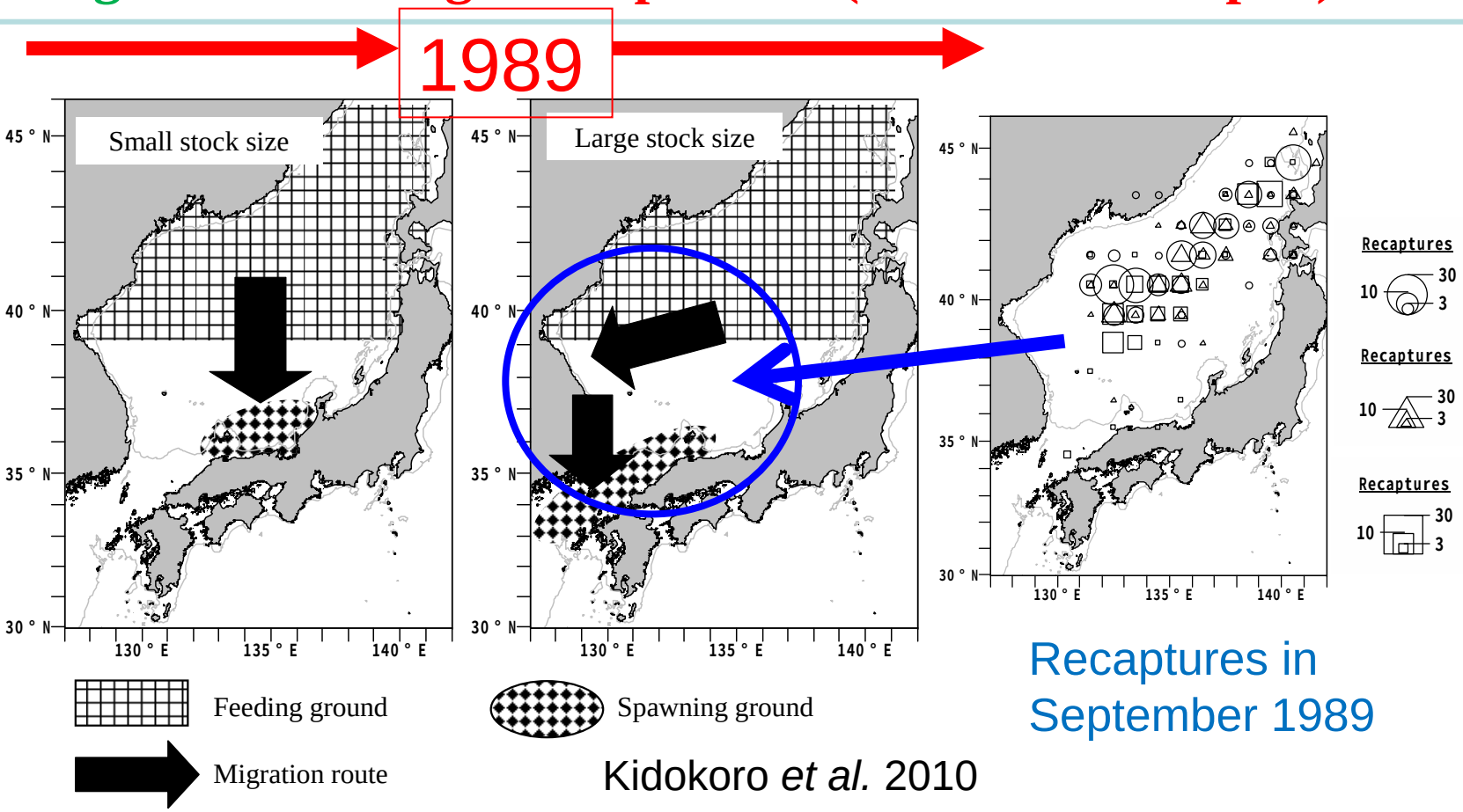
In the Sea of Japan, based on the recapture records of tagging experiments, it appeared that not only the spawning grounds but also spawning migration patterns have changed coinciding with the 1989 regime shift.

Brief review (Discussion) of the population dynamics and changes in ecological traits. Migration pattern (in the Sea of Japan)



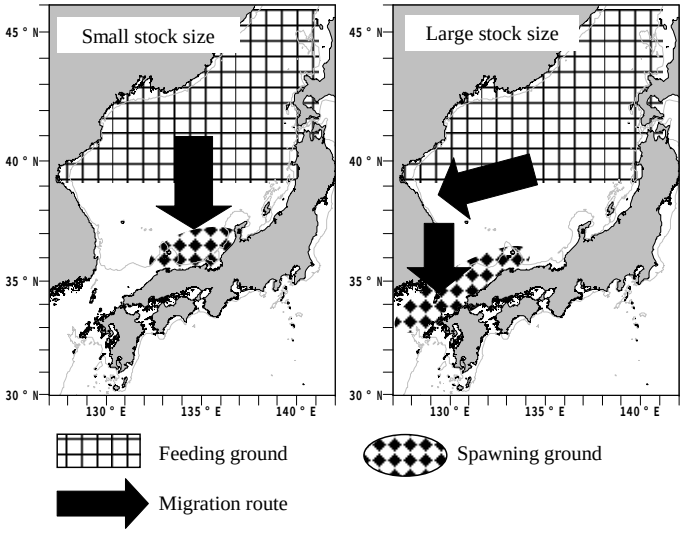
Japanese common squid (autumn spawning stock) moved towards waters off the central part of Honshu Island in the 1980s (before the 1989 regime shift).

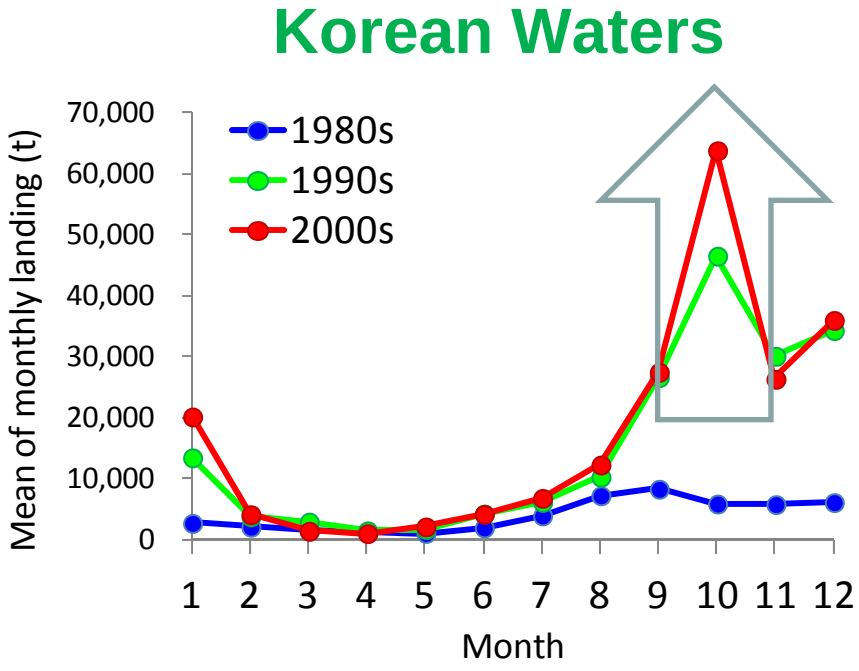
Brief review (Discussion) of the population dynamics and changes in ecological traits. Migration pattern (in the Sea of Japan)

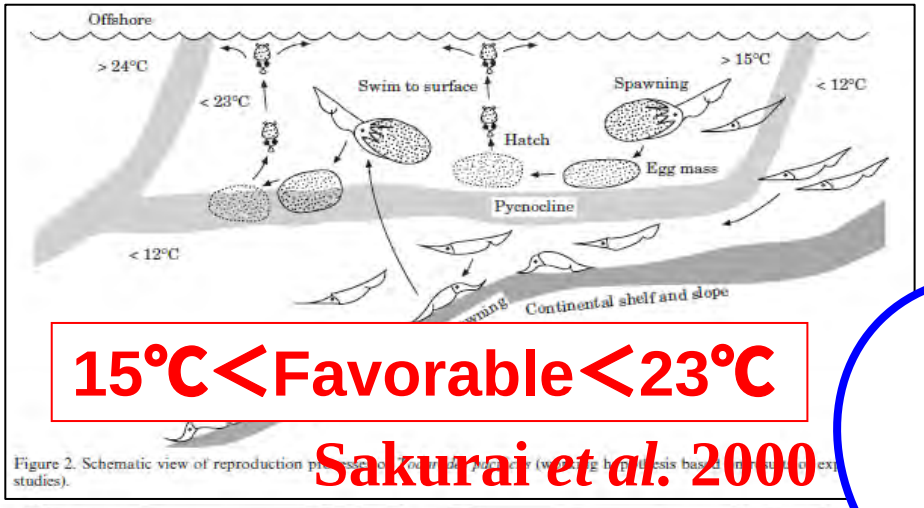


But, they moved towards the Korean Peninsula and the Tsushima Strait in the 1990s (after the 1989 regime shift).

These changes in migration patterns may have affected the changes in the main fishing grounds. **In the 1980s, Japanese common squid did not migrate toward Korean waters, therefore the fishing grounds were not formed sufficiently in this region. But, the migration pattern of Japanese common squid changed with the 1989 regime shift, and fishing grounds were formed in the Korean waters in the 1990s.**

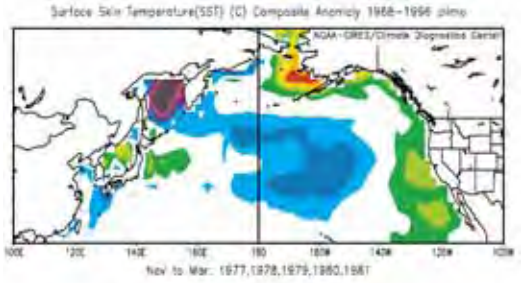




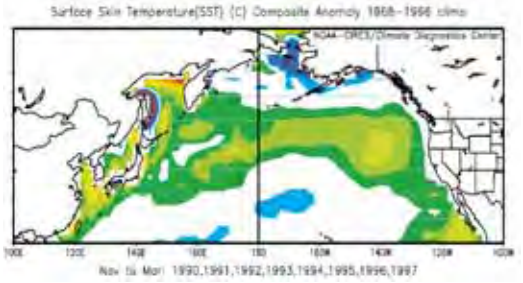


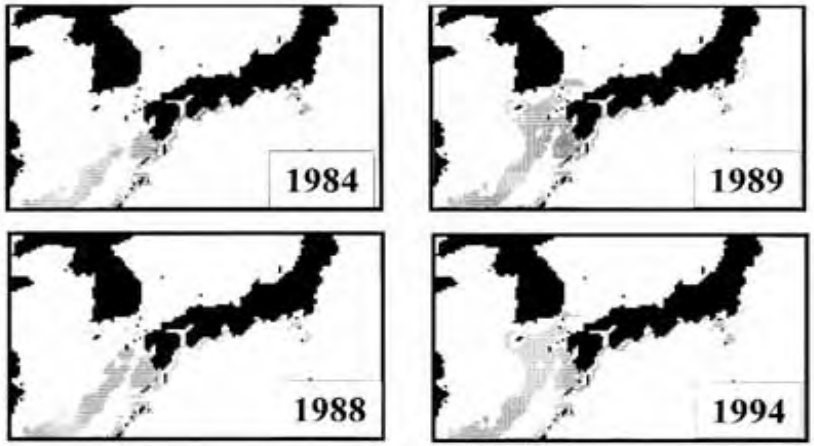
15℃＜Favorable＜23℃

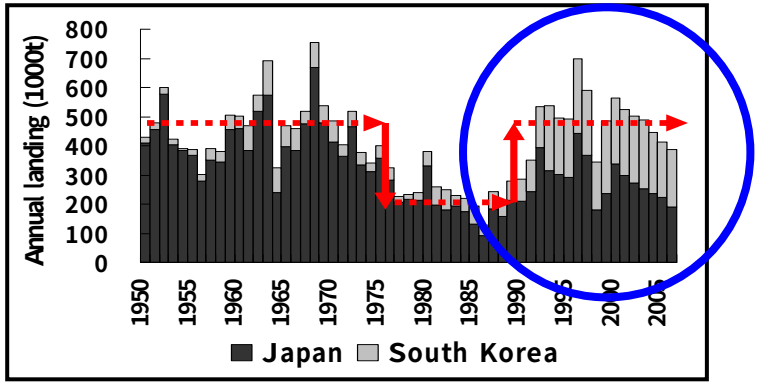
Sakurai *et al.* 2000



1989



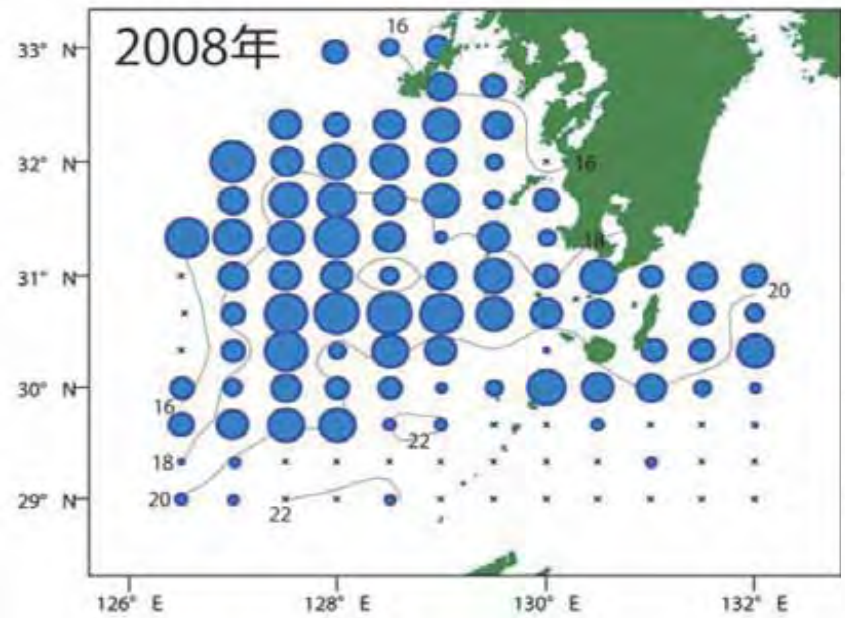


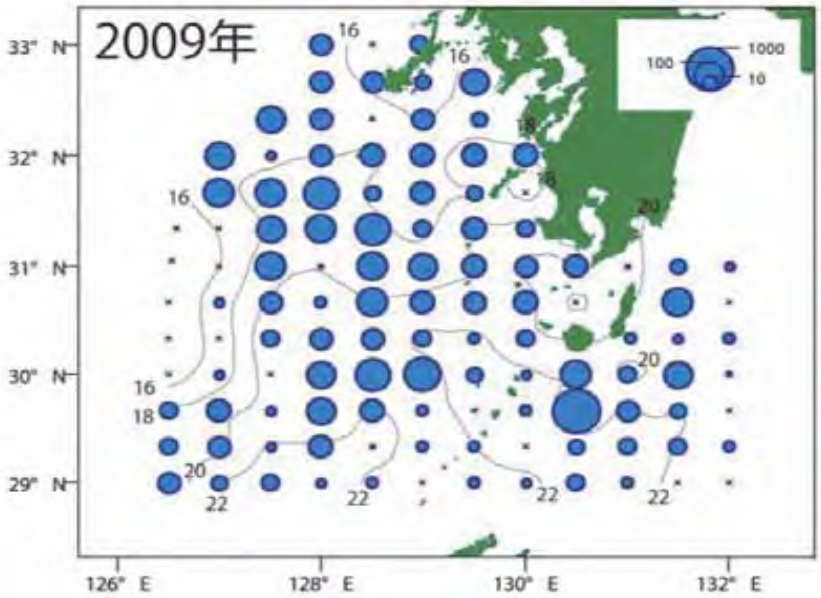


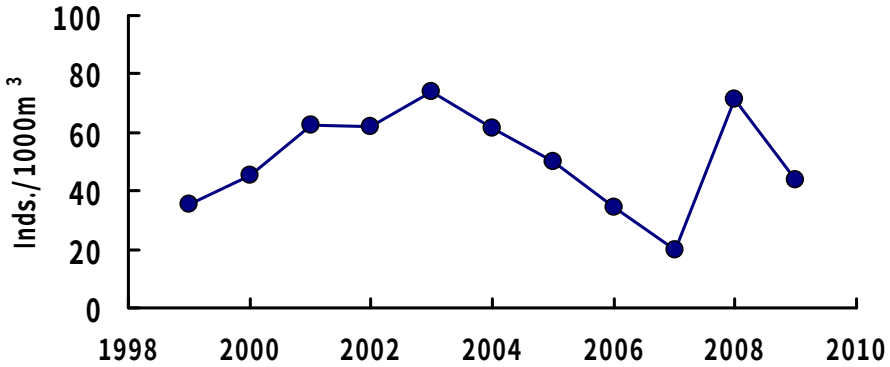
Sakurai *et al.* 2000

On the other hand, Sakurai et al. (2000) inferred that the spawning grounds of the Japanese common squid were not formed in the northern East China Sea in the 1980s, but spawning occurred after the 1989 regime shift.

They considered that the shifts in the spawning grounds caused the changes in the stock size of the Japanese common squid.







Actually, paralarvae of the winter spawning stock have been collected in the northern East China Sea in recent years, which support Sakurai's inference.

These changes with the 1989 regime shift have allowed the formation of spawning grounds in the East China Sea, and the flux of paralavae carried to the Pacific side by the Kuroshio, which is inferred to cause an increase in the stock size of the winter spawning stock and the catch along the Pacific side of Japanese waters.

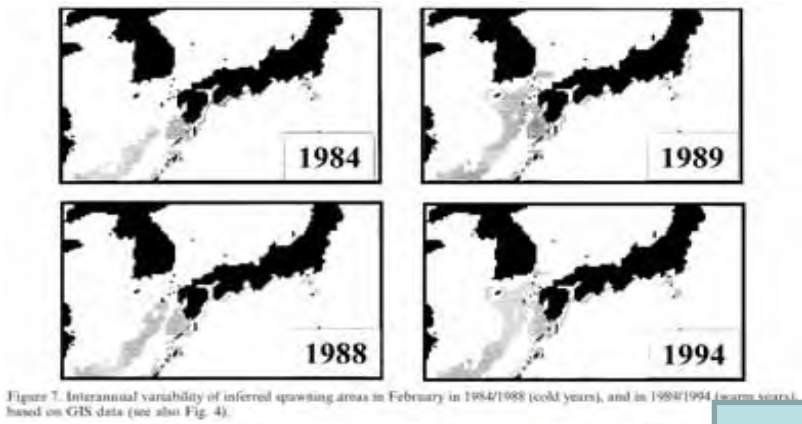
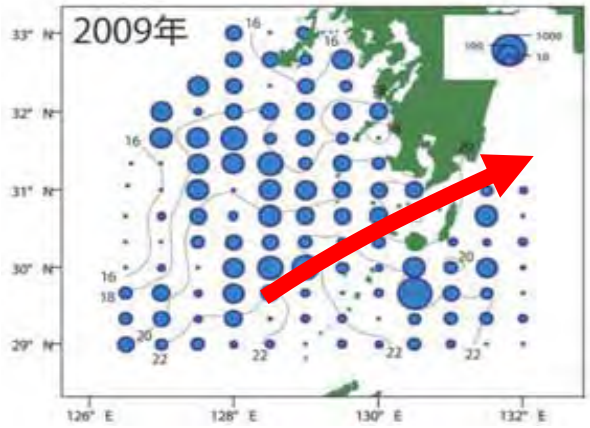
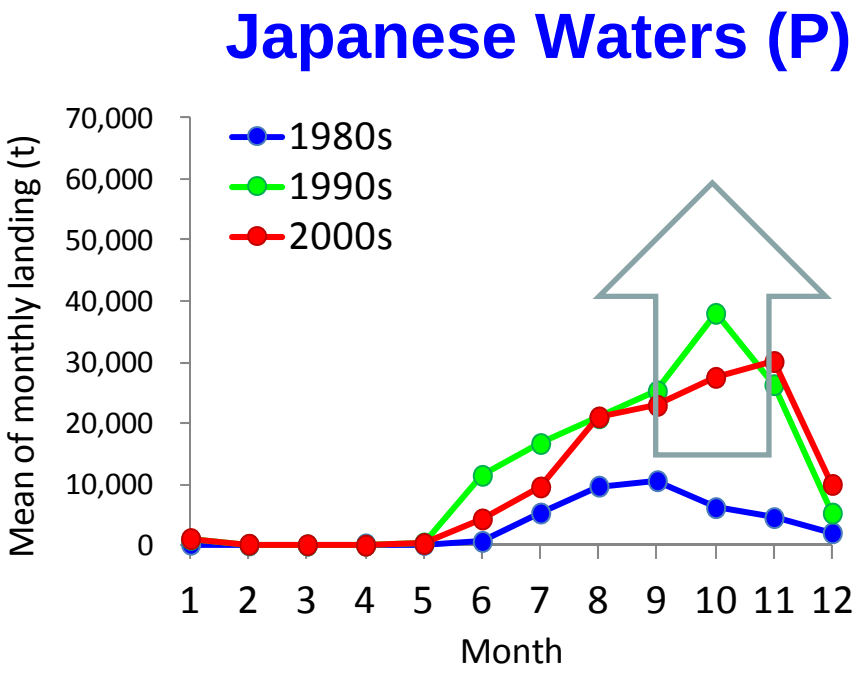
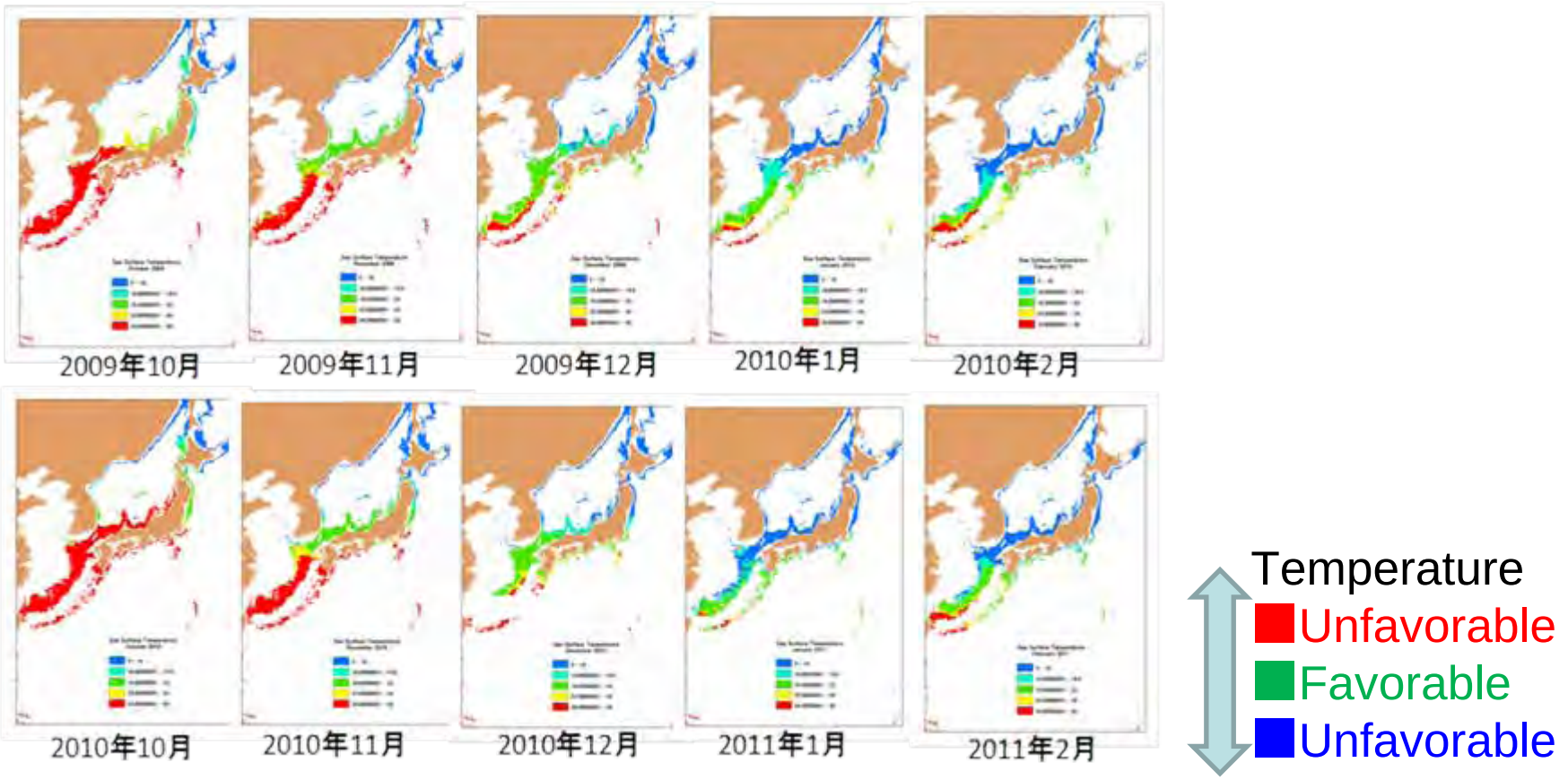


Figure 7. Interannual variability of inferred spawning areas in February in 1984/1988 (cold years), and in 1989/1994 (warm years), based on GIS data (see also Fig. 4).



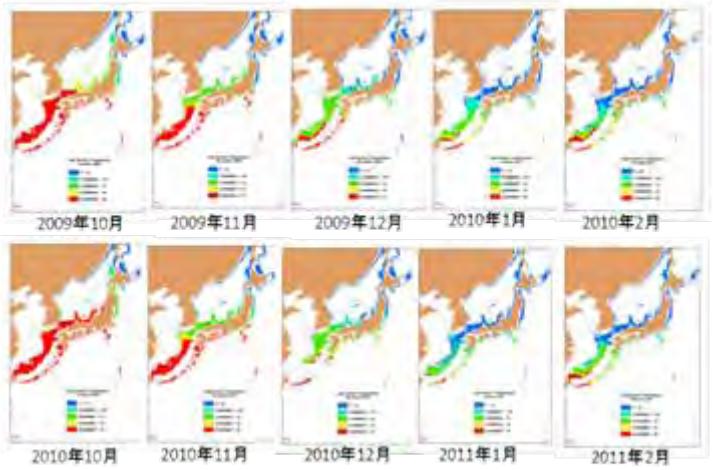




Sakurai et al. (Unpublished data)

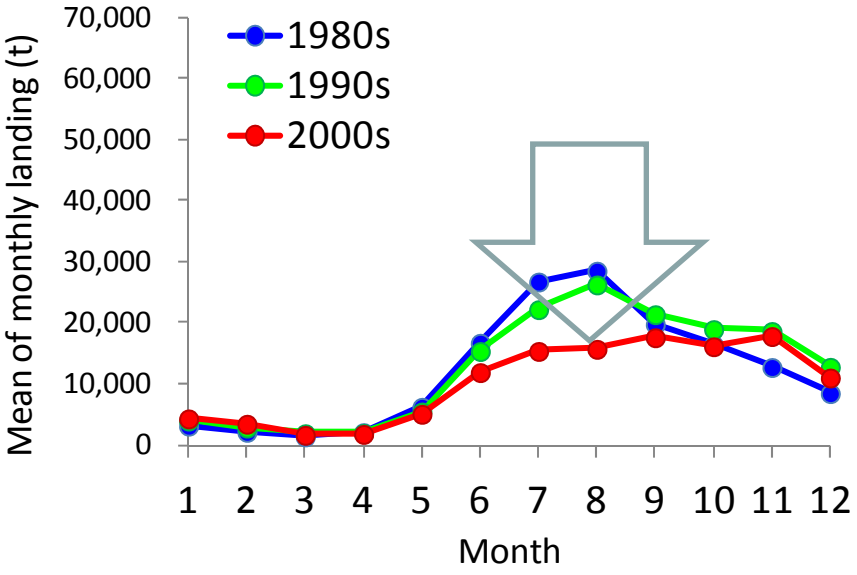
It was also suggested that in recent years in the southwestern part of the Sea of Japan, unfavorable temperature conditions might occur for the spawning grounds of Japanese common squid in October based on the inference by favorable temperature conditions on the reproduction of Japanese common squid.

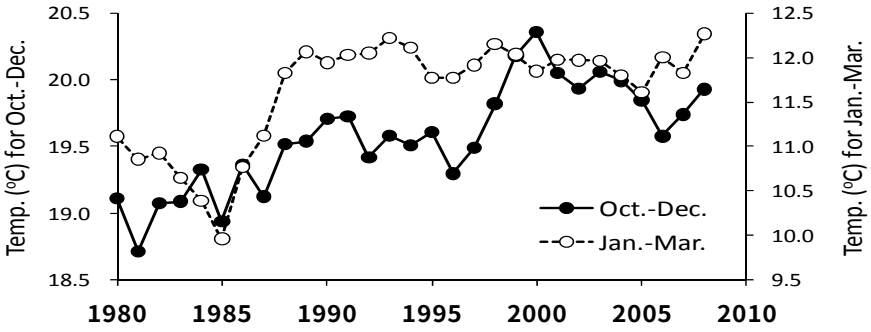
The warming in the 2000s might cause a decrease in the stock size of autumn spawning stock and a decline of catches on the Japan Sea side of Japanese waters in the summer.



Sakurai et al. (Unpublished data)

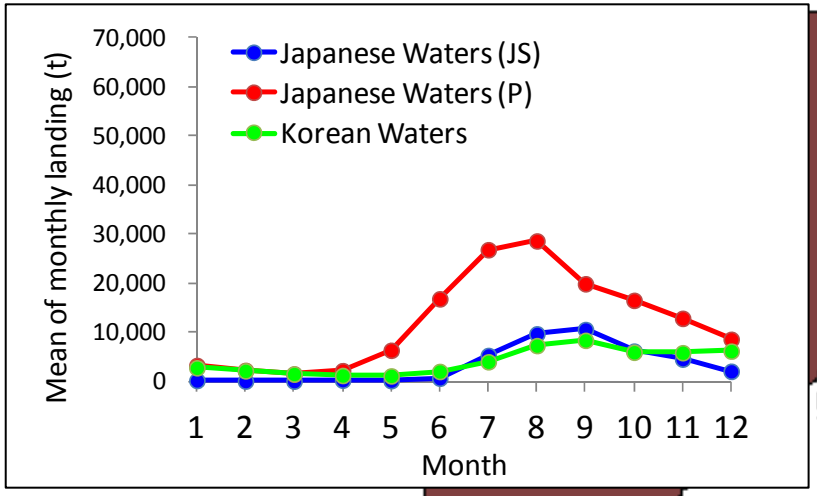
Japanese Waters (JS)

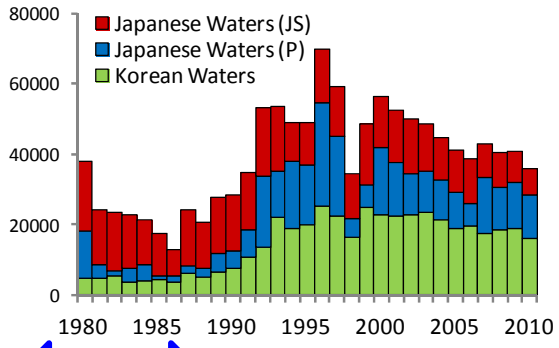




Annual fluctuations in water temperatures at 50 m depth in the western area of the Sea of Japan.

Hypothesized diagram of the migration pattern and fishing grounds of Japanese common squid in 1980s





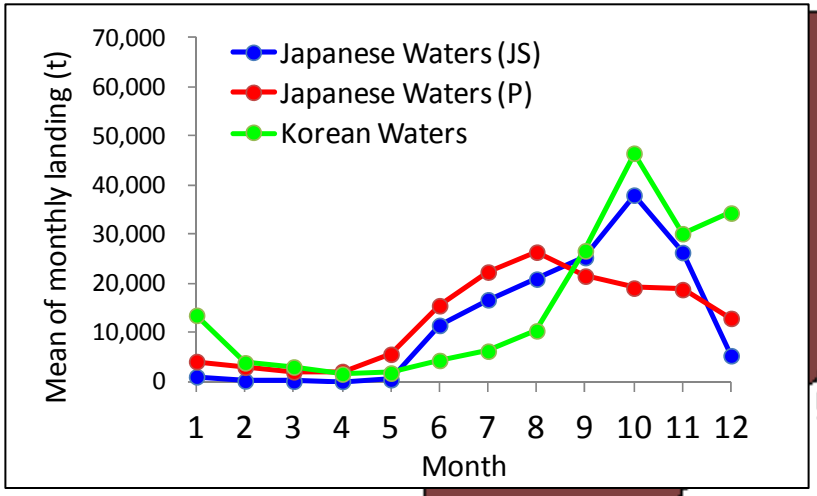
1980s

Oct

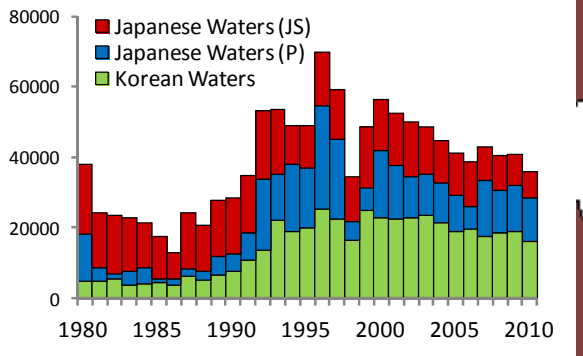
In the 1980s, the main spawning season was inferred to be in October, and spawning grounds were located in the Sea of Japan. Most catches were obtained in the Sea of Japan.

1980s

Main spawning season was October



Hypothesized diagram of the migration pattern and fishing grounds of Japanese common squid in 1990s



1990s

Oct

Nov-Dec

Jan-Feb

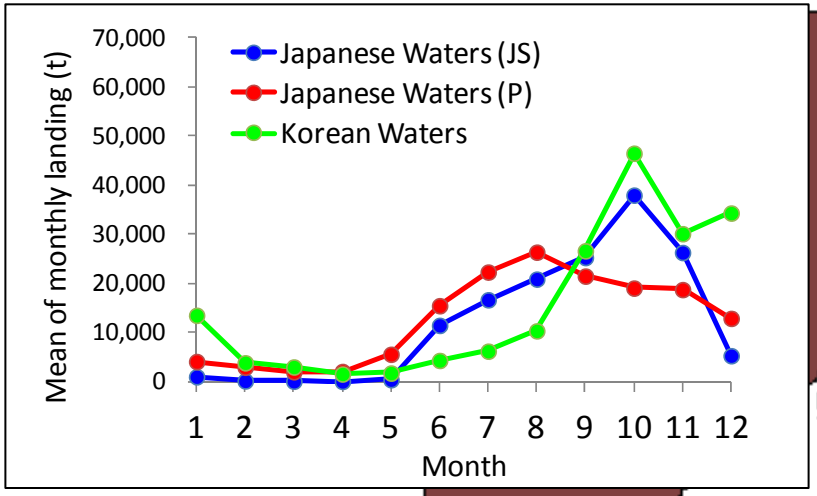
In the 1990s, the spawning migration pattern changed in the Sea of Japan and fishing grounds were formed in the Korean waters.

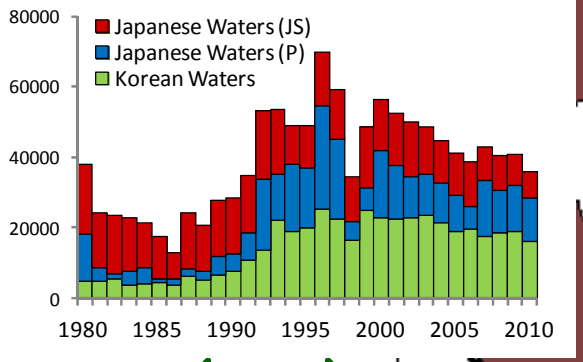
The main spawning season expanded to winter and spawning grounds were formed in the East China Sea.

1990s

Main spawning season extended to February

Hypothesized diagram of the migration pattern and fishing grounds of Japanese common squid in 1990s





1990s

Oct.-Nov.

Nov-Dec

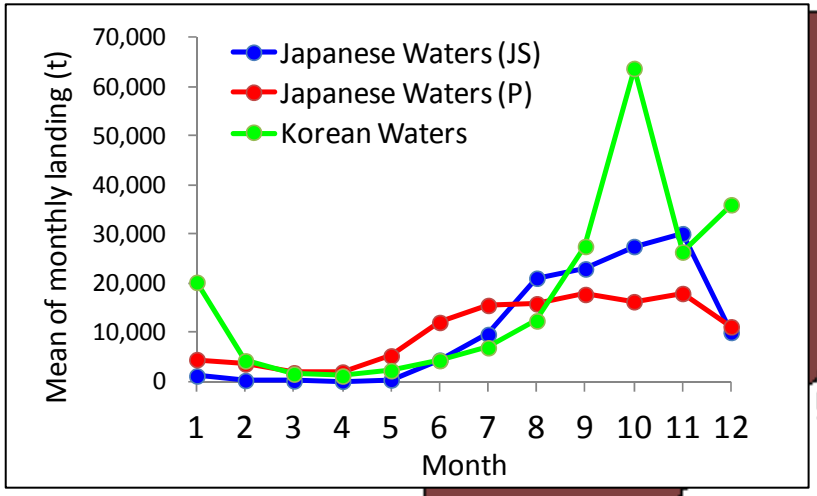
Jan-Feb

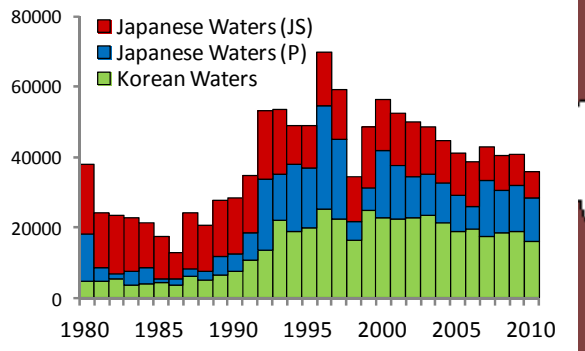
These changes led to the formation of fishing grounds along the Pacific side.

1990s

Distribution range expanded to the pacific side

Hypothesized diagram of the migration pattern and fishing grounds of Japanese common squid in 2000s





2000s

Oct.-Nov.

Nov-Dec

Jan-Feb

In the 2000s, the southwestern part of the Sea of Japan was considered to be too warm for reproduction in October. This might have caused a decrease in the stock size of the autumn spawning stock.

2000s

Distribution range expanded to the pacific side

These changes in the main fishing grounds and fishing season of Japanese common squid with changing environmental conditions emphasize the importance of cooperation in the stock management of Japanese common squid between Japanese and Korean fisheries.

FRA
Fisheries Research Agency

NFRDI
National Fisheries Research & Development Institute

北海道大学
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