Assessing the oceanographic variability impact on swordfish catch in the northwest Pacific using FORA-WNP30

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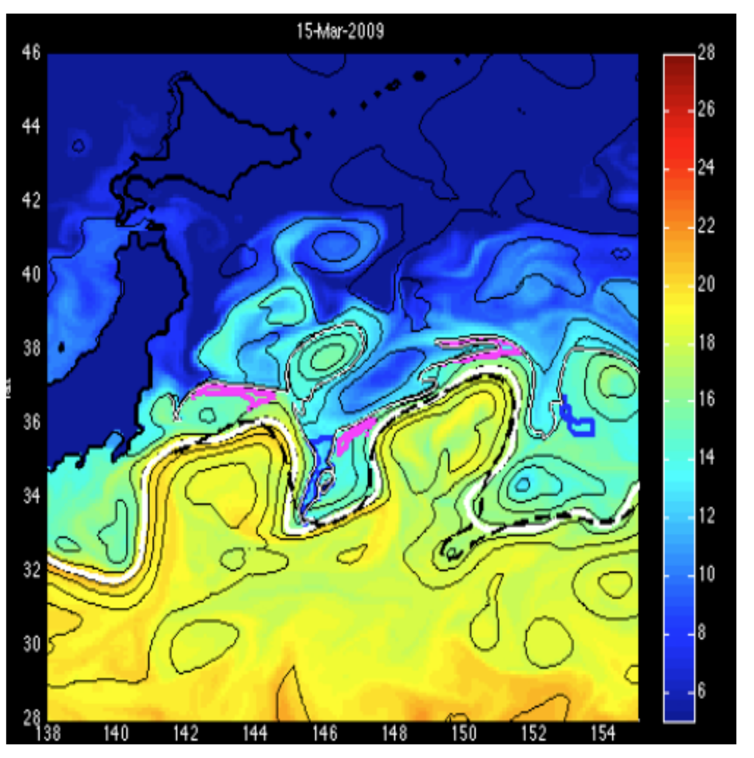
Introduction

The Kuroshio Extension (KE) is the downstream of the Kuroshio, a western boundary current of the subtropical gyre in the North Pacific. After the Kuroshio current separates from the coast of Japan near 140°E and 35°N (Kawai, 1972), it continues to flow eastward between 140°–180°E. The KE region is one of the most dynamic regions in the North Pacific with rich meso- and submesoscale eddies and filaments, and the region of the largest heat loss from the ocean to the atmosphere (Qiu et al., 2004). The inter-annual variability of the dynamic parameters such as SST and SSH is due to the evident decadal modulation between a stable and an unstable state through the KE system (Qiu and Chen, 2005; Taguchi et al., 2007; Sugimoto and Hanawa, 2009) which, at the same time, can influence over the fishing grounds around this area off Tohoku region, one of the best fishing grounds near Japan (Ito, 2012).



The fact that pelagic longline fisheries in the northwest Pacific Ocean are located in this region of high variability provides us a chance to investigate a correlation between several dynamic parameters, such as relative vorticity, the Okubo-Weiss parameter and divergence of Q-vector, and the catch-per-unit-effort CPUE from swordfish catch data. Although these dynamic parameters could modulate with the decadal variabilities of the KE state, how the CPUE responds to the decadal change is still unclear. In this study, using the state-of-the-art ocean reanalysis product, FORA is used to fill this gap.

Fig. 1. FORA's sea surface temperature image and contour of sea surface height on March 15, 2009. Warm streamer is shown as magenta contours, white line is the daily Kuroshio axis, and black dotted line shows its 20 days moving average.

Interannual Modulation of the KE in FORA

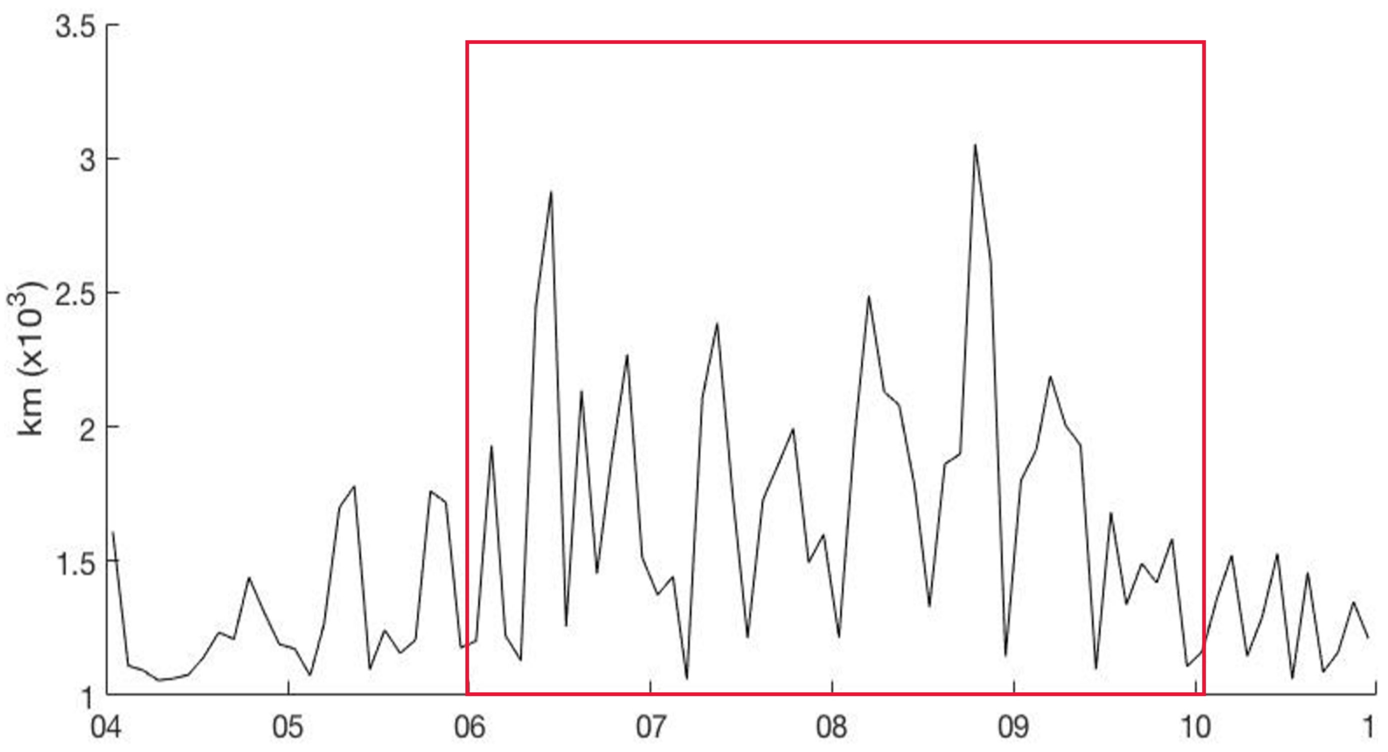


Fig. 2. Time series of the KE path length integrated from 142°E to 153°E.

The variation of the KE path length can indicate the variation of its state. In Figure 2, the KE path length along the years 2004-2010 reached its peak during the unstable period (2006-2009), reaching up to 3x103 km of path length in the mid of the years 2006 and 2009, with decreasing tendency during the stable period (2004-2005, 2010).

Methodology

Fishery data

The source of fishery data consisted of catch and effort data collected by 36 commercial longline vessels in the north western pacific in the region 25-45°N, 138°E-160°W from 2004 through 2010. Using a total of 27366 records, we focused our analysis on the swordfish catch.

Table 1. Number of fishery records for the period 2004-2010

Year	2004	2005	2006	2007	2008	2009	2010
#Records	1715	4776	4439	5355	5014	4066	2001

The nominal catch-per-unit-effort (CPUE) is calculated using

$$CPUE=(\text{Total of catch fish})/(\#Hooks*\#Sheets)*1000$$

FORA-WNP30 data

Four-dimensional variational Ocean Re-Analysis for the Western North Pacific over 30 years (FORA-WNP30) consists of a horizontal resolution of 1/10° data per day in the western North Pacific including Japan surroundings (model area: 117°E - 160°W, 15°N - 65°N). In this study, comparisons between CPUE from swordfish catch data and dynamic parameters are carried out using depth, water temperature, salinity, east-west and north-south current velocity data. Data were used for the period of the swordfish data set (July, 2004 – December, 2010), the region of the fishing location is from 140 to 195°E and from 25 to 45°N.

Relative vorticity $\zeta = \partial v/\partial x - \partial u/\partial y$

Okubo-Weiss $OW=4\{(\partial u/\partial x)^2+\partial v/\partial x \ \partial u/\partial y\}$

Divergence of the Q-vector

$$\nabla_h \cdot Q=-\partial/\partial x\,(\partial u/\partial x\ \partial b/\partial x+\partial v/\partial x\ \partial b/\partial y)-\partial/\partial y\,(\partial u/\partial y\ \partial b/\partial x+\partial v/\partial y\ \partial b/\partial y)$$

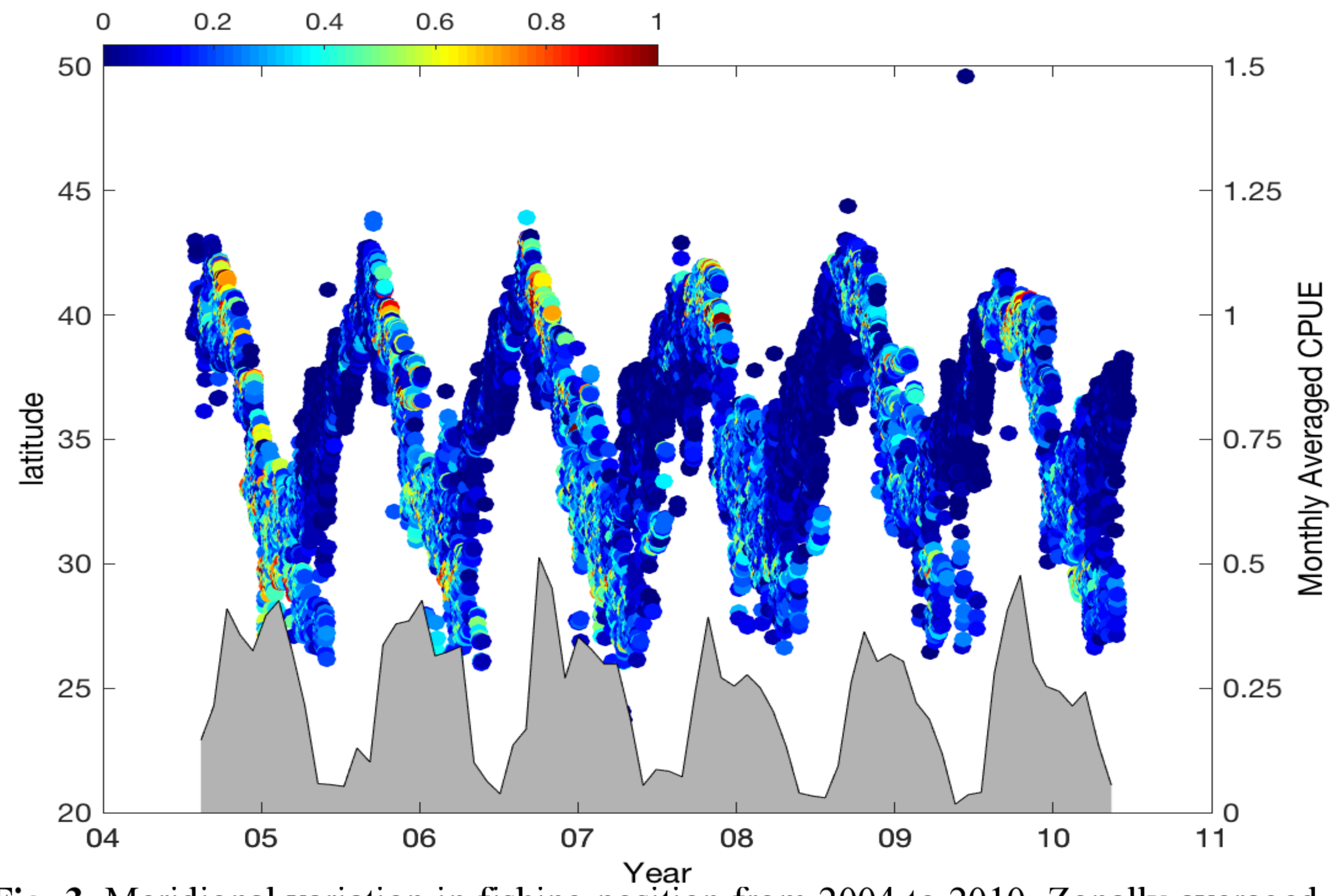


Fig. 3. Meridional variation in fishing position from 2004 to 2010. Zonally averaged meridional position of the CPUE in the western North Pacific. Shading shows monthly averaged CPUE.

Meridional positions of fishing operation clearly show seasonal North-South excursions (Figure 3). The highest monthly averaged CPUE is found during the fall, after this season these peaks start to decrease in winter time and the lowest averaged CPUE is found in spring.

CPUE & Oceanographic parameters

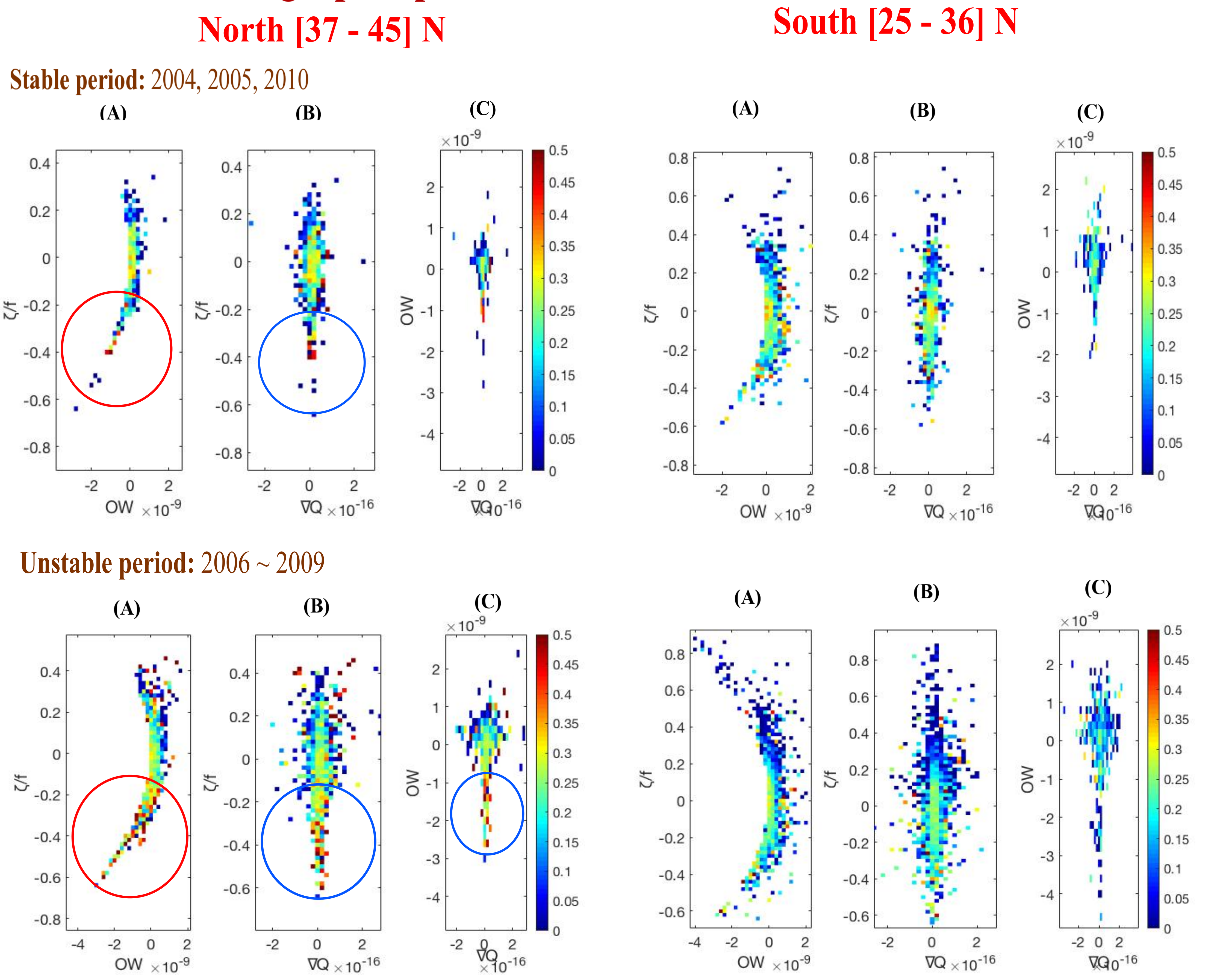
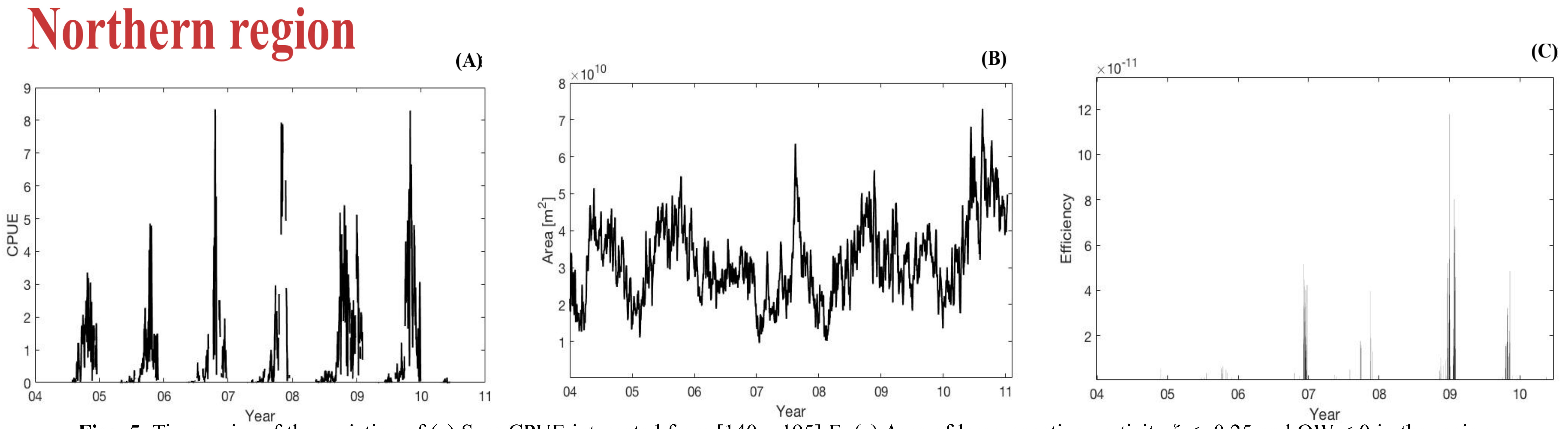


Figure 4 indicates that higher CPUE data are mostly associated with anticyclonic vorticity ($\zeta < 0$) in rotating regime ($OW < 0$), as seen on the red circles, suggesting that some physical structures or states associated with the anticyclonic eddies increase the CPUE of the swordfish. On the contrary, averaged and binned CPUE as a function of $\nabla h \cdot Q$ suggests no clear tendency; it shows a slight tendency of high CPUE in convergence zones ($\nabla h \cdot Q > 0$) in anticyclonic eddies (blue circles). This is probably due to the coarse resolution of the FORA data, which cannot resolve the submesoscale. More importantly, this tendency of high CPUE with low vorticity and OW is much clearer in the northern area (Fig. 4left). The highest data are shown especially in the unstable KE period (Fig. 4 bottom) than in the stable period (Fig. 4 top).

Figs. 4. Binned and averaged CPUE as a function of (a) OW vs vorticity ζ, (b) divergence of Q-vector vs vorticity ζ, and (c) divergence of Q-vector vs OW.

Northern region



Figs. 5. Time series of the variation of (a) Sum CPUE integrated from [140 – 195] E. (c) Area of large negative vorticity $\zeta < -0{,}25$ and $OW < 0$ in the region [140 – 195] E. (d) Efficiency (e=(∑CPUE) / Area of negative vorticity $\zeta < -0{,}25$ and $OW < 0$) in the region [140 – 195] E.

In the northern region, there is a trend that the CPUE is relatively lower in the stable KE period, with an exception in 2010. These results suggest that higher CPUE is more found during the unstable state (2006-2009) of the KE path. It is expected that the dynamic parameters, vorticity and OW also modulate with the KE decadal variability. However, the area covered by the low vorticity and low OW do not show clear inter-annual variations corresponding to the decadal KE path modulation. Besides that, the efficiency (Fig. 5 right) turns to be higher during the years 2007-2009, showing the highest peak in the beginning of 2009 (winter time).

Conclusions

Table 2. Averaged CPUE per year for the period 2004-2010

Year	2004	2005	2006	2007	2008	2009	2010
Averaged CPUE	0,15	0,13	1,80	2,37	1,96	2,21	1,72

1. The maximum averaged CPUE is found in 2007 with 2.37, and the minimum is found in 2004 with 0.15 averaged CPUE.

2. The swordfish can be targeted more efficiently in the northwest Pacific at anticyclonic vorticity areas with rotating regimes ($\zeta < -0{,}25$ and $OW < 0$), warm-core eddies, especially in the northern area [37 – 45] N during the unstable period (2006 - 2009).

3. Our results regarding the distribution of swordfish in relation to physical oceanography have potential implications for fisheries management.