THE EFFECT OF TYPHOON MUJIGAE ON FISHERY IN THE NORTHERN SOUTH CHINA SEA

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ABSTRACT:

The northern South China Sea (NSCS) is a traditional fishing region in China. Although the high frequency of typhoons in the region, the response of fishery to typhoons are now not well studied. Based on catch data from a dual-trawl boat and environment data from satellite remote sensing in offshore region of NSCS, the effect of typhoons on fishery were analyzed. In October 2015, typhoon Mujigae passed through the western part of the NSCS. We analyzed variations of the fish catch, fishing ground and major target fish species before and after typhoon. The result show that an obviously increase in the total catch emerged in region S (20.5-21 ℃N, 112.5-113 ℃E). The total catch in region S in October 2015 was 607250 kg net^{-1}, was 7.28 and 17.42 times to that in October 2014 and October 2013. The total catch in region S reach maximum of 22600 kg net^{-1} on October 6th 2015 2 days after Mujigae. Sardine and Anchovy are two major captures in dual-trawl boat. Sardine exhibited dramatically increase in both catch and proportion in total catch. The amount of Sardine in October 2015 was 961 t, was 6.89 and 13.16 times compared to that in October 2014 and October 2013. The proportion between the amount of Sardine and total catch increased from 89.24% in October 2013 to 98.97% in October 2015. The amount of Anchovy in September and December 2015 was 18.5 t and 9.05 t, while there was no Anchovy caught in October and November 2015. These showed the positive effect of typhoon on Sardine, but passive effect of typhoon on Anchovy. The increase in primary production in region S associated with typhoon may be the main reason induced the changes in fish production and location of fishing ground.

1. INTRODUCTION

Typhoon is an atmospheric phenomenon which may cause serious damage to nature and human society especially in coastal regions. Besides direct damage to artificial infrastructure, typhoon related heavy fall, intense wind, storm tide, strong current, monster ocean wave and turbid of water lead to indirect negative impact on economic activity, result in significant loss of fish production and economic loss (Boesch, et al., 1976; Kaufman et al., 1983; Guo et al., 2000; Hagy et al., 2006; Alford et al., 2010; Chen et al., 2013).

Due to great changes in oceanic environment after typhoon, marine fish are forced to seek more safety and fertile domain for survival. The response of fish to typhoon behaves in various ways. The different react of fish to typhoon have relationship with their ecological characteristics. Changes in fish composition and replacement of major target fish species occurred (Chang, et al., 2014). Although several studies found that the impact on some species were minor (Chuang et al., 2008; Alford et al., 2010), Tew et al (2002) revealed some fish species affected most by typhoon. Some species can be well adapted to the new habit after typhoon (Tew, et al., 2002). Some fish species were absent in the catch or population crashed after typhoon (Chen et al., 2015). While in reef region, many fish species may be buried directly by broken reef after typhoon (Adams and Ebersole, 2014).

Long term and short term effect of typhoon on fishery were focused considering the above-mentioned complicated fish migration (Greenwood et al., 2006). Fish assemblages related to typhoon was studied by many scientists (Greenwood et al., 2006; Yu et al., 2013; Yu et al., 2014). The study of Qiu et al (2010) indicated that typhoon have positive impact on fishery based on long term data (Qiu et al., 2010). Juvenile recruitment of Atlantic croaker was found coincide with hurricane activity (Montane and Austin, 2005). Houde et al (2005) showed the enhancement in fishery production and increase in fish abundance. Our previous also depict the increase in fish catch and the changes in catch composition near Pearl River Estuary (Yu et al., 2013; Yu et al., 2014). The effect of typhoon on fishery in region far from continent are not well studied due to the difficulty in data sampling. In the present study, abundant fishery and satellite data are used to found the changes in the production and composition of fishery catch. These can give us further knowledge about typhoon and its effect on marine fish.

2. DATA AND METHODS

2.1 Typhoon Data

Typhoon data was get from historic dataset of Typhoon Information Real Time Display System developed by Taizhou Bureau of Meteorology. Typhoon path, wind speed, and transition speed were used to realize the characteristics of typhoon Mujigae.

2.2 Fish Catch Data

Scientific program "Dynamic Acquisition of Information on Oceanic Fish Catch in the South China Sea" is supported by National Finance Special Project Fund. It aims at fishery data collection on the northern continental shelf of SCS. 248 boats with different type, power, and size are included in the program. Until now, more than 10,000 records are gathered since 2009. Dual-trawl boat DWB01 is one of the sample boats with power of 877 kW. Fishery information of this boat was from October 2003 to April 2016. Fish catch monthly variation from October 2013 to April 2016, daily variation from October 1th to 31th in 2013, 2014, and 2015 were plotted to investigate temporal variability. To understand the typhoon impact on catch composition, we compared the variations in fish species in October 2013, 2014, and 2015. The proportion of major capture catch in total catch were analyzed and compared from October 2013 to April 2016.

2.3 Satellite Data

Sea level anomaly (SLA) was the merged product of ERS-1/2, Topex/Posedion, ENVISAT, and Jason-1/2, and from AVISO. Seven-day average SLA from September 28th to October 4th, and October 5th to October 11th 2015 was used to realize the impact of typhoon on ocean dynamics. To study the variation in sea surface geostrophic current (SSC) after typhoon, SSC was calculated from SLA. SLA and SSC have spatial resolution of 1/3 °x1/3 °.

Daily composited SST was from microwave and infrared satellites (Advanced Microwave Scanning Radiometer – Earth Observing System (AMSR-E), Tropical Rainfall Measuring Mission microwave imager (TMI), Moderate Resolution Imaging Spectroradiometer (MODIS)) with resolution of 0.25 ° x0.25 ° came from http://www.remss.com/. Ten-day average SST from 25th September to October 4th and October 5th to October 14th 2015 were conducted to depict the cold water induced by typhoon. Time series of SST from September 1th to November 30th 2015 were plotted using Excel.

The daily blended Chlorophyll a (Chl-a) is based on the merging of Medium-resolution Imaging Spectrometer (MERIS), Sea-Viewing Wide Field-of-View Sensor (SeaWiFS) and MODIS level-2 data over the entire globe with a resolution of 4.6 km. Ten-day integrated Chl-a during October 5th to October 14th 2015 was compared with Chl-a from September 25th to October 4th. Temporal variation of Chl-a during September 1th to November 30th 2015 were also compiled using Excel. Average Chl-a of 5-day, 10-day, 15-day, 20-day, 25-day, 30-day, 35-day, 40-day before and after typhoon in 2015 were analyzed and compared with that average during the same period in 2013 and 2014 using Excel.

3. RESULTS

3.1. Typhoon Mujigae

Typhoon Mujigae is originated in 15.8 °N, 121.1 °E near Philippines, and travelled northwestern with increasing wind speed until reach Chinese mainland during October 2th to 5th 2015 (Fig. 1(a)). It passed through the region near fishing domain (S in Fig. 1(b)) in 00:00 to 8:00 October 4th with wind speed from 45 m s^{-1} to 48 m s^{-1} and transition speed from 20 km h^{-1} to 25 km h^{-1}. Enhance in wind speed and fall in transition speed were observed when typhoon pass nearby the region S in figure 2(a).

3.2. Conditions of SLA, SSC, SST, and Chl-a

Fig. 3(a) and 3(b) were SLA and SSC before and after typhoon. Decrease in SLA can be clearly observed in Fig. 3(b) compared to Fig. 3(a). A strong anticyclonic SSC in agree with SLA decrease was presented right of typhoon track after typhoon which was not seen before typhoon. Region S were located in the region where the low SLA meet high SLA. SSC passed across region S from southeast to northwest, showed opposite direction with that before typhoon. The typhoon related variation in SSC will originate changes in nutrient distribution.

SST before and after typhoon were presented in Fig. 3(c) and 3(d). Obvious cold water mass appeared right of typhoon track with large area range from north coast of SCS in north to typhoon path in south. Region with SST lower than 27 ℃ covered 26311.96 km^2. A sharp decrease in SST occurred on 4th October in figure 4(a). The decrease in SST before and after typhoon was 1.15 ℃ in region S, larger than the SST decrease in region A, B, and C during the same period (Table 3).

Ten-day composite Chl-a presented large area with date missing ascribe to the cloud in figure 3(f). Figure 4(b) showed the time series of Chl-a during 1th September to 30th November in 2013, 2014, and 2015, where maximum Chl-a of 0.67 mg m-3 on October 8th 2015 4 days after typhoon Mujigae can be seen. The increase rate of ten-day average Chl-a after typhoon over that before typhoon was 320.03% in region S. The enhance in Chl-a after typhoon and Chl-a before typhoon in region S was larger than that in region A, B, and C (Table 3). The enhance in Chl-a a recover to the value during the same period in 2013 for 25 days after Mujigae.

3.3. Increase in Number of Fishing Days and Fish Catch

The number of fishing days in region S was 4 days in October 2013 and 10 days in October 2014, and enhance to 21 in October 2015, while the total number of fishing days in region S, A, B, and C were 17, 16, and 21 in October 2013, 2014, and 2015 (Fig. 2(b)). These showed the migration in fishing region between different years. In October 2015, DWB01 mainly worked in region S.

The total fish catch in the region S was 607250 kg net^{-1} in October 2015 which was 7.42 and 7.28 times over that in October 2013 and 2014. Time series of monthly fish catch from October 2013 to April 2016 in region S presented maximum in October 2015 (Fig. 7). In October 2015, the proportion of catch in region and total catch were 100%, larger than that in October 2013 (26.79%) and 2014 (67.13%) (Table 1). Daily variation of fish catch showed four peaks after typhoon. Two peaks in October 3th 2015 and October 6th 2015 were occurred 1 day and 2 days before and after typhoon separately. The increase rate of fish catch after typhoon compared to the fish catch before was 59.88%.

3.4. The Fishing Ground Distribution and Catch Composition

Figure 8 depicted the distribution DWB01 fishing ground during January to December 2015. Changes in fishing ground were observed from September to Novermber. Fishing ground changed from region S and C in September to S in October 2015, reveal the accumulation of fishing activity in typhoon. In the month after typhoon (November 2015), the fishing ground shifted west to region B and C.

The species composition of DWB01 in October 2013, 2014, and 2015 was shown in table 2. Number of major species recorded was one, three, and one in the gear in which Sardine was represented in the catches in most months during the periods from October 2013 to April 2016. The DWB01 catch was dominated by Sardine, contributing to 98.97% of the total catch in region S in October 2015 (Fig. 9)). The catches of Sardine were 18250 kg net^{-1}, 6750 kg net^{-1}, and 28619.05 kg net^{-1} in October 2013, 2014, and 2015 (Fig.10 (a)). Anchovy was caught in September and November 2015, while was absent in the gear in October 2015 (Fig.10 (b)).

4. DISCUSSION

4.1 Typhoon Affects Fish Catch and Fishing Ground of Dual-trawl Boat

Typhoon result in upwelling and induce the decrease in SST and increase in Chl-a have been researched through many studies (Zhao, et al., 2008; Zhao, et al., 2009; Chen, et al., 2012; Chang, et al., 2014). Enhance in primary production result from typhoon related upwelling is the main reason cause the accumulation of some fish species after typhoons (Yu, et al., 2014; Yu, et al., 2013). Typhoon Mujigae pass through nearby region S in NSCS contributed to enhance in Chl-a, and result in the increase in fish catch. These illustrated the Sardine accumulate to the study region. The same phenomenon was also seen in region out of Pearl River in our previous studies (Yu, et al., 2014; Yu, et al., 2013). The increase of fish catch and abundance varied most in different region. The 10- day mean fish catch was 1.60 times higher than that before Mujigae. In Chesapeake Bay, entrainment of croaker larvae from coastal ocean to centered in lower Bay result in 30 times of fish abundance after hurricane to the mean abundance for the previous decade (Houde et al., 2005).

NSCS has been subjected to historic dual-trawl fishery ground in China (Wang et al., 2010; Liu et al., 2011). Shift of fishing ground is associated with change in ocean conditions ascribe to typhoon (Chang, et al., 2014). To gain maximum fish catch, fishermen often change the fishing ground in which they anticipate (Osamu et al., 2012). In this study, the fishing ground of dual-trawl fishery was found accumulate in region S which presented highest Chl-a increase compared to region A, B, and C.

4.2 Fish Species Behave Positive and Negative Reaction to Typhoon

Typhoon may significantly alert the environment, but the impact on fish behavior could be relatively different due to the ecological characteristics of species (Letourneur et al., 1993; Tew, et al., 2002). Our previous study found increased records of *Lophius*, J*ohnius,Harpodon*, *Collichthys*, *Portunidae*. *Sillago*, *Nibea*, I*lisha* after typhoon (Yu, et al., 2013). Primary production enhancement and supplying of abundance food resource may be the main reasons behind the fish assemble (Walker and Leben, 2005; Lohrenz et al., 2008; Lin 2012; Tscuhiya et al., 2013. During typhoon Mujigae month, the catch of major target specie Sardine in region S enhanced compared to that in no typhoon period in October 2013 and 2014. Sardine showed great fluctuation in its proportion to total catch before and after Mujigae. Sardine resource is abundant in NSCS, and regularly caught in this region by fishermen (Li, 2005). The positive reaction to typhoon illustrated that the specie can adapt to the strong flow.

Typhoon changed the habit temperature and nutrient distribution, resulting in spatial migration of fish species to region in which these species can get better survival (Kawabata et al., 2010; Yu, et al., 2013; Chang, et al., 2014). Some fish species were found decrease and absent after typhoon (Tew, et al., 2002; Paperno et al., 2006). In the present study, Anchovy was absent in typhoon Mujigae month. The loss of habitat was the main reasons behind the Anchovy population decline, as suggested in Chen et al (2015).

5. Summary

Our study found decrease in SST and increase in Chl-a following the passage of typhoon Mujigae. Significant enhance in fish catch in the region consistent with the domain with Chl-a increase was revealed in the study. Our researched revealed the shift of fishing ground and accumulation of fishing activity after typhoon. Sardine the major catch of dual-trawl boat behaved positive react to typhoon, while Avchovy was absent in the catch in typhoon month. We suggested that the changes in fish catch, fishing ground and catch composition may be associate with habit change result from typhoon.

Acknowledgements

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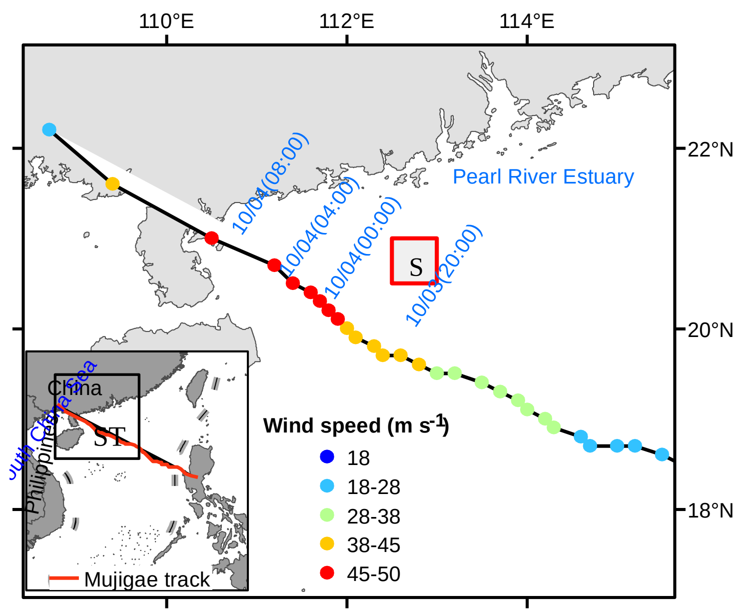


Figure 1 Location of the study area (box ST) with typhoon track (a) and typhoon Mujigae characteristics (b). Box S is the fishing ground

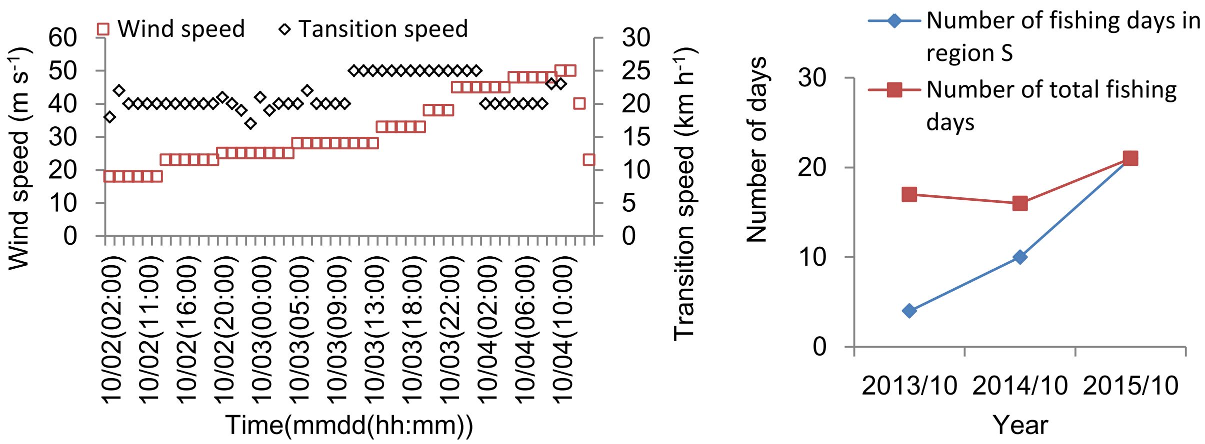
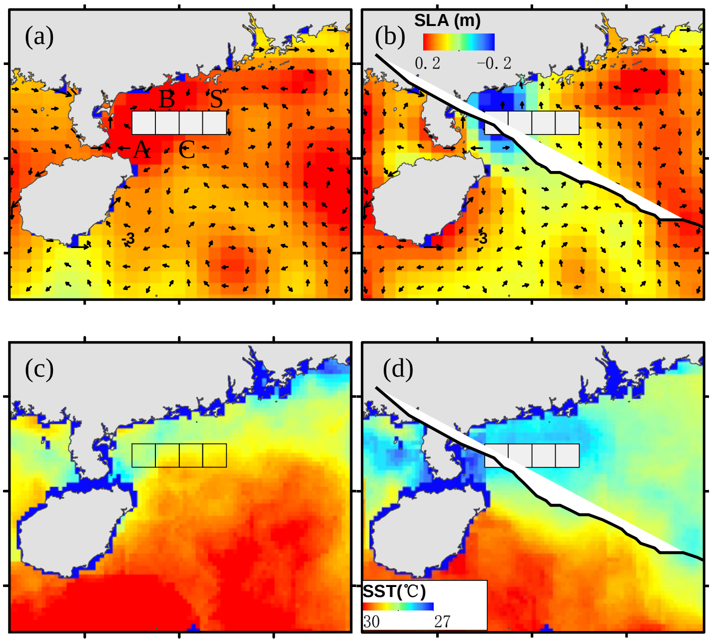


Figure 2 (a)Variations of typhoon speed and transition speed. (b) Number of fishing days.



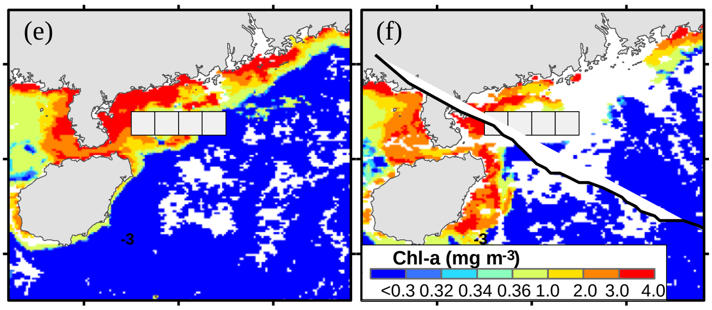


Figure 3 SLA (cm) and geostrophic currents (m/s) from September 28th to October 4th 2015 (a) and October 5th to October 11th 2015 (b). SST from September 25th to October 4th 2015 (c) and October 5th to October 14th 2015 (d). Chl-a from September 25th to October 4th 2015 (e) and October 5th to October 14th 2015 (f).Black regtanclt indicates the fising ground. Black line indicates typhoon Mujigae track.

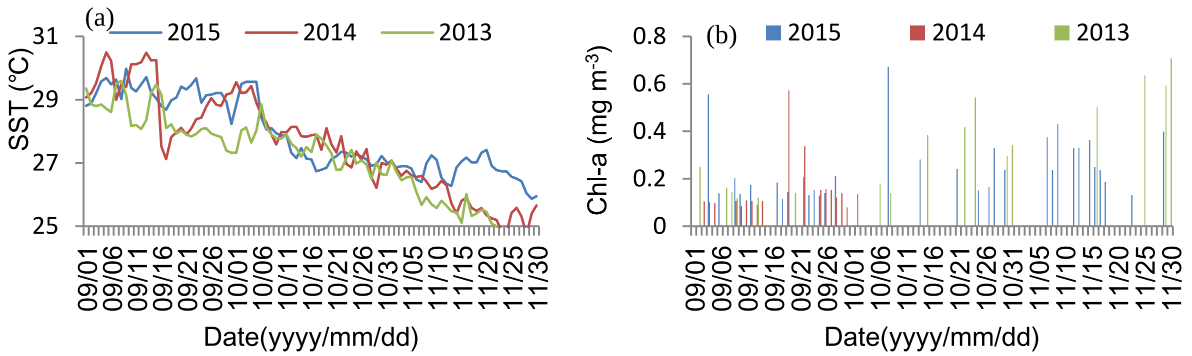


Figure 4 Time series of SST (a) and Chl-a (b) in September 1th to Novermber 31th 2013,2014, and 2015.

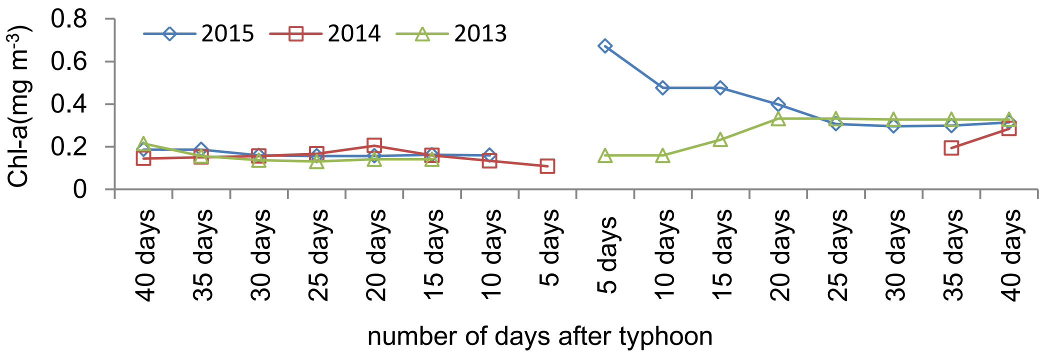


Figure 5 Chl-a averaged 5days to 40 days in 5 day interval before and after typhoon.

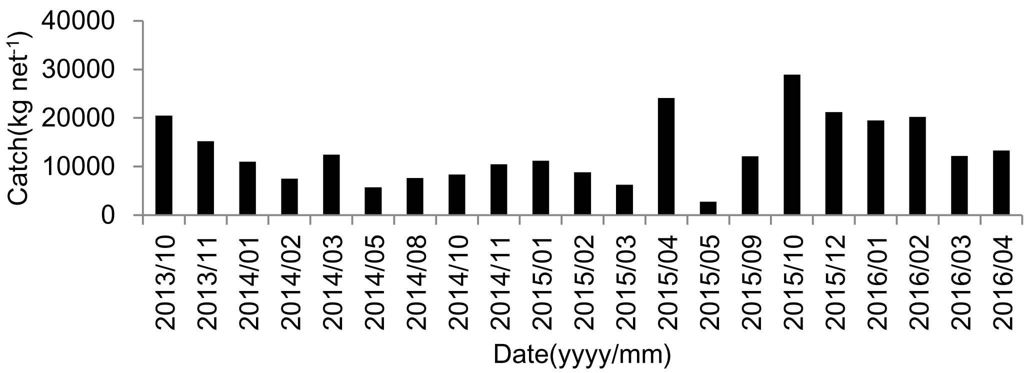


Figure 6 Monthly variation of fish catch in region S during January 2013 to April 2016.

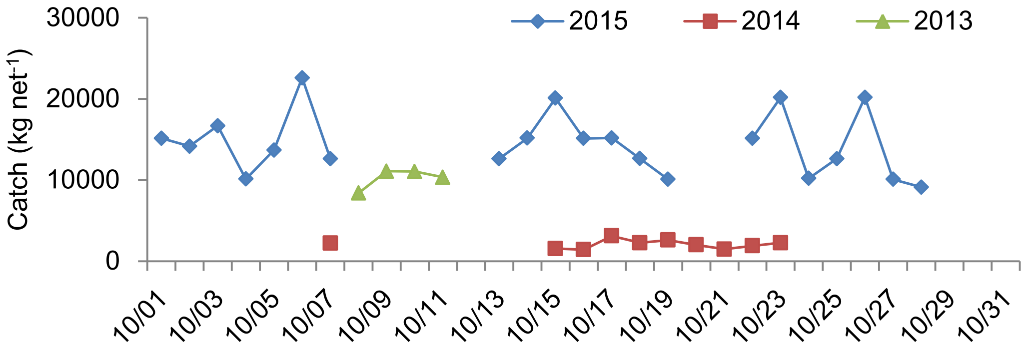


Figure 7 Daily varation of fish catch in region during October 1th to 31th 2015.

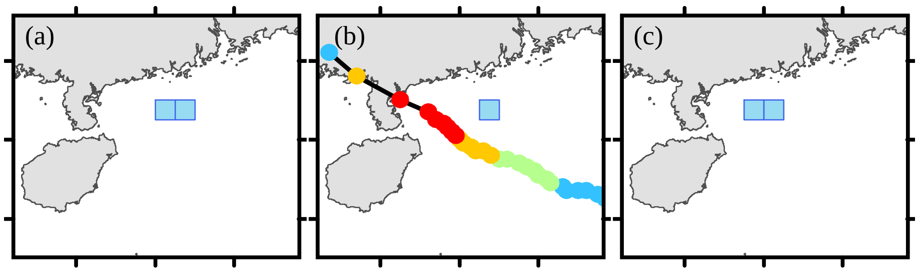


Figure 8 Fishing distibution in September (a), October (b), and Novermber(c).

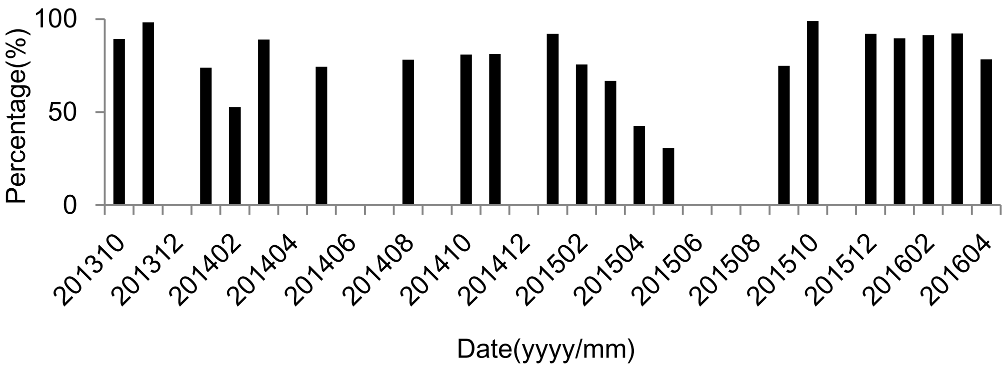


Figure 9 Time series of the proportion of Sardine catch of toatl catch during October 2013 to April 2016.

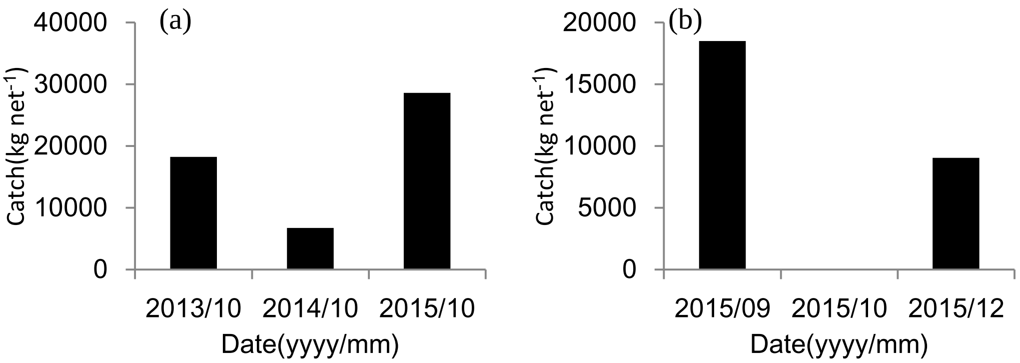


Figure 10 (a) Sardine catch in October 2013, 2014, and 2015. (b) Anchovy catch in September, October, and December 2015.

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Total catch in region A, B, C, and S in October 2013, 2014, and 2015.

Date	Total catch in region A (kg net^{-1})	Total catch in region B(kg net^{-1})	Total catch in region C(kg net^{-1})	Total catch in region S(kg net^{-1})
2013/10			305345	81800
2014/10	14070	12850	13950	83450
2015/10				607250

Table 2

Catch Composition in October 2013, 2014, and 2015.

Date	catch composition
2013/10	Sardine
2014/10	Sardine, Carangidae, anchovy
2015/10	Sardine

Table 3 Comparison of SST, Chl-a, and fish catch in region S, A, B, and C before and after typhoon, the decrease in SST and the increase in Chl-a and fish catch.

Region		S	A	B	C
ST(℃)	Before typhoon	29.13	29.10	29.06	28.61
	After typhoon	27.98	28.01	28.04	27.92
	Decrease in SST	1.15	1.09	1.03	0.69
Chl-a(mg m-3)	Before typhoon	0.16	0.56	0.79	2.15
	After typhoon	0.67	0.60	1.26	2.87
	Increase rate	320.03	8.45	59.82	33.99
Fish catch(kg net-1)	Before typhoon	18752.00			
	After typhoon	29980.00			
	Increase rate (%)	59.88			