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**Working Paper**

## The impact of tropical cyclones on fishing activities in the Philippines

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# THE IMPACT OF TROPICAL CYCLONES ON FISHING ACTIVITIES IN THE PHILIPPINES

*Ilan Noy, Miloud Lacheheb, and Madhavi Pundit*

**NO. 691**

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## ABSTRACT

In this paper, we identify the main fishing grounds and track the response of fishing vessels' activity to tropical cyclones (TCs) in the Philippines' Exclusive Economic Zone during 2012. We use satellite imagery from the National Oceanic and Atmospheric Administration to locate fishing vessels and identify the main fishing grounds; in conjunction with data on TCs' speed and trajectory from the International Best Track Archive for Climate Stewardship database. We use kernel density functions to identify fishing grounds and Vector Generalized Linear Model and Bayesian Time-Varying Parameter to assess the impact of TC speed on the location of fishing vessels during and after the TC. Our quantifications reveal the overall negative impact of TCs on the number of active boats during and 2 days after the TC. The fishing grounds located within the Sibuyan Sea, Visayan Sea, and Panay Gulf are the most affected areas. Daily reduction in the commercial fishing production in Western Visayas alone for every day a TC passed through was estimated at 7,800 tons per day, affecting more than 188,000 families.

**Keywords:** fisheries, Philippines, tropical cyclone, satellite imagery, economic impact

**JEL codes:** Q22, Q54

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## 1. Introduction

Natural hazards are phenomena that may have a significant impact on people's lives, livelihoods, and well-being. Tropical cyclones (TCs) are the second most devastating disaster after the flood. A total of 121 events were recorded in 2021 compared to 102 on average from 2001 to 2020 (CRED 2021). There were 1,876 total deaths and more than 17 million people were affected by the storms in 2021, which amounted to \$137.7 billion in losses (CRED 2021). The Philippines is in the top 10 of the most vulnerable nations to disasters (United Nations University et al. 2014). The country is located within the TCs' intensity area (Cardenas et al. 2015), facing an average of 20 TCs a year.<sup>1</sup> For instance, TC Rai in December 2021 caused 457 deaths and affected 10.6 million people (CRED 2021).

One of the sectors most affected by TCs is fisheries. TCs damage coastal infrastructure, including roads and houses, and fishing gear, including boats. For example, Monteclaro et al. (2018) reported that 94% of stationary fishing gear had significant damage due to typhoon<sup>2</sup> Haiyan in the New Washington–Batan area, and this led to 7–29 days of halted fishing. In the longer term, TCs are associated with heavier rainfall and mud flows that reduce the production of corals, seagrasses, and seaweeds (Santos 2021).

Governance and disaster management play an important role in avoiding and mitigating the economic loss from TCs. Within the Philippine context, Yonson et al. (2018) found a negative linear relationship between socioeconomic development and disaster fatalities, and the same for good governance. Similarly, provinces with a higher income, on average, have fewer fatalities. Kahn (2005) found a similarly negative association in an international panel (also Cavallo and Noy 2011).

This paper, to our knowledge, is the first to measure the effect of TCs in the Philippines on fisheries activities using the daily Visible and Infrared Imaging Suite (VIIRS) Day-Night Band (DNB). We use remote sensing data used to identify information on fishing vessels based on light sharpness following Elvidge et al. (2015). Using this data with spatial kernel density analysis, we identify the main fishing grounds in the Philippines. Then, using TC trajectories and information about fishing vessels in these fishing grounds, we employ a Vector Generalized Linear Model

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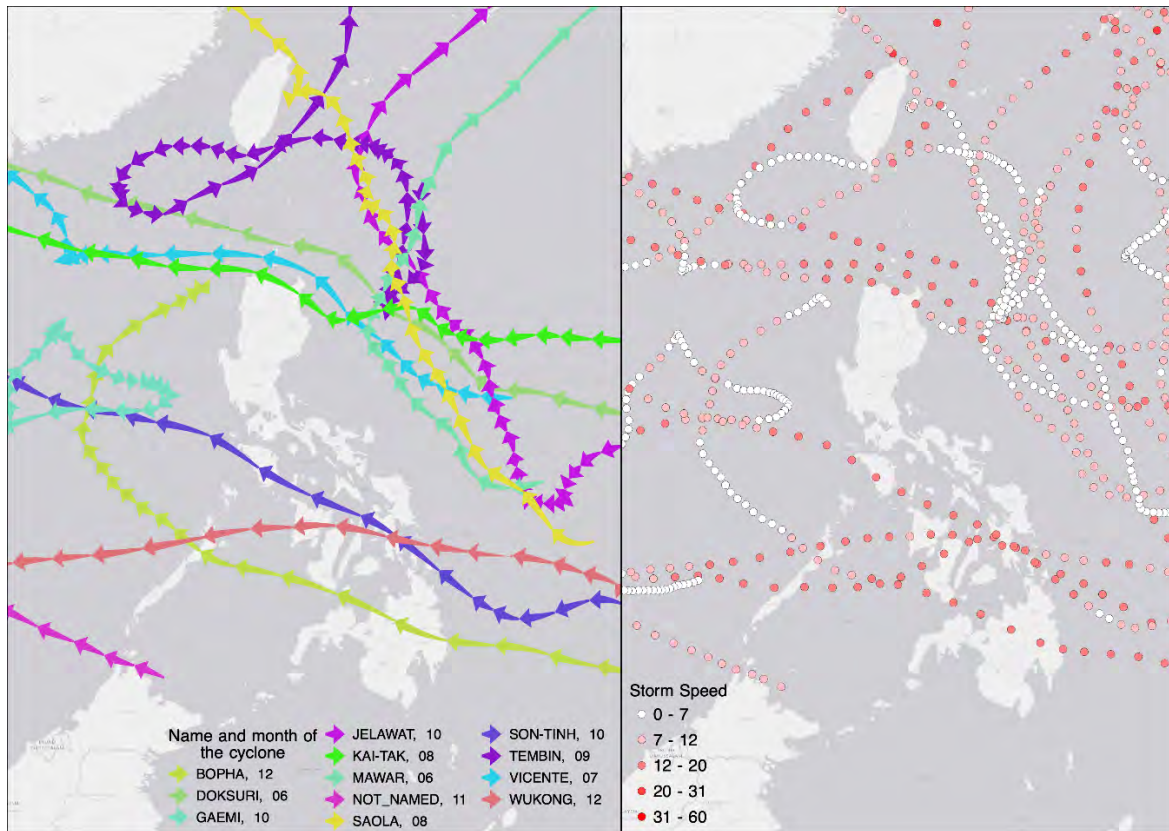
<sup>1</sup> TCs are usually defined as cyclonic storms that have wind speed that exceeds 120 kilometers per hour. They almost exclusively originate in tropical zones, though not around the equator (Cinco et al. 2016).

<sup>2</sup> Typhoon is the name given to a tropical cyclone or storm that develops in certain latitudes in the northern hemisphere like in the Philippines.

(VGLM) and Bayesian shrinking Time-Varying Parameters (TVP) methods to measure the loss caused by TCs to the fisheries sector by province.

We used the 2012 Census of Agriculture and Fisheries (CAF) to determine TCs' impact on households at the regional and provincial levels. CAF data on the fishing sector provides more than 27 million observations, including the number and socio-demographic characteristics of households engaged in fishing, the type and number of fishing boats, as well as the ownership and tonnage of the fishing boats and gears. We used this detailed data to quantify the impact of the TCs in 2012. In 2012, the Philippines experienced several severe TCs where at least five made landfall, with wind speeds that exceeded 30 knots (Map 1).

**Map 1: Tropical Cyclones in the Philippines, 2012**



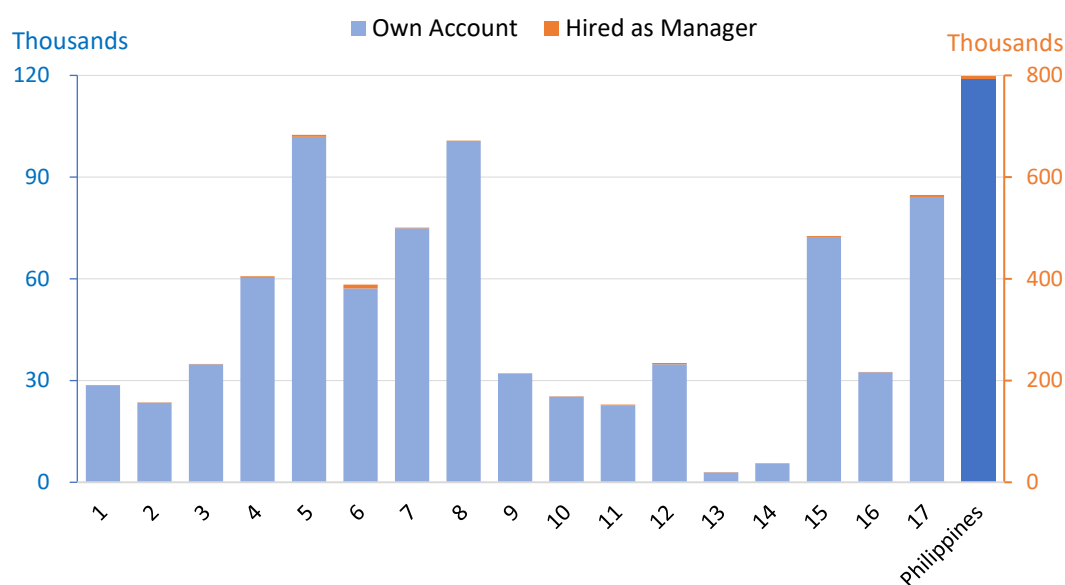
Source: International Best Track Archive for Climate Stewardship (IBTrACS).

## Fishing in the Philippines

The Philippines benefits from a coastal line length of 36,289 kilometers (km) and abundant fish stock. This attracts a relatively large share of the population to engage in the fishing industry. In 2012, the fishing industry contributed 1.8% to the country's gross domestic product (BFAR 2012).

In the Philippines, there were around 800,000 fishing operators in 2012 and a major portion of them were fishing on their own accounts (Figure 1). A quarter of these operators were from the Bicol and Eastern Visayas regions. A fishing operator is a person who is responsible for the daily fishing operation and responsible for making major decisions; they could be working on their own or for others' boats. A hired manager is paid a wage by private individuals, corporations, cooperatives, or institutions to operate a daily fishing operation. Interestingly, only a small number of about 4,700 fishing operators were hired as managers of other household's fishing operation or of a fishing establishment.

**Figure 1: Fishing Operators**



Note: The Philippines has 17 regions represented as numbers in the chart; the name and corresponding number of each region are detailed in the Appendix of this report.

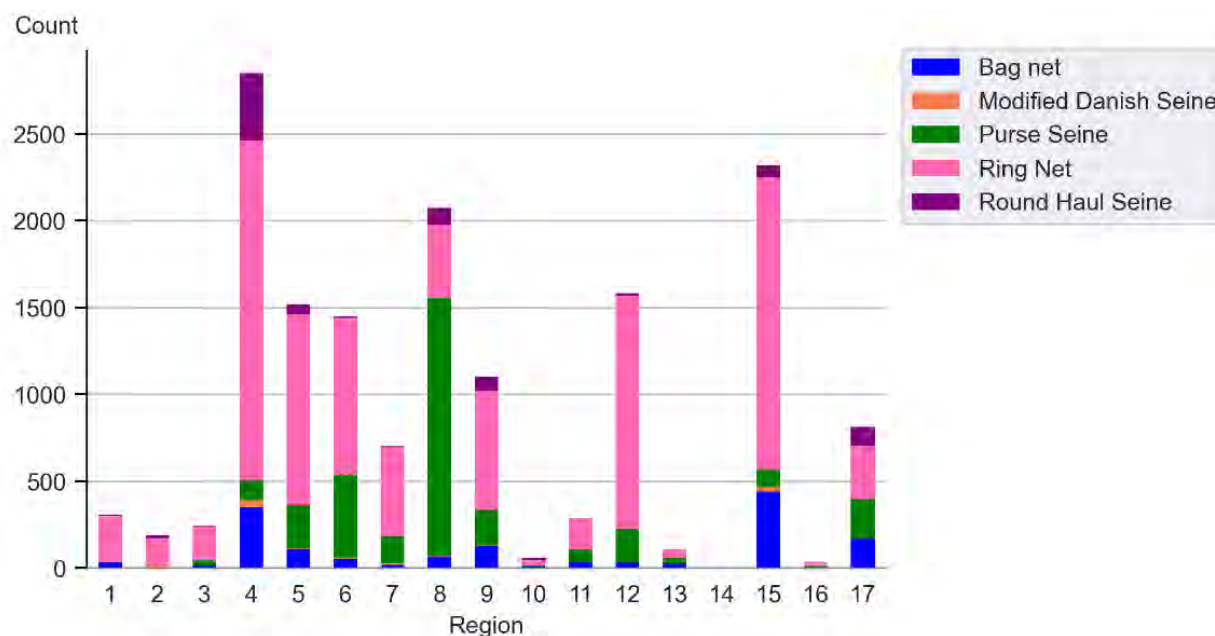
Source: Philippine Statistics Authority. 2012. [Census of Agriculture and Fisheries](#).

Fishing gear types in the Philippines range from gill net and hook and line to large vessels such as purse seine and bag. Vessels are usually categorized into less than 3 gross tons and



more than 3 gross tons gears. Fishing boats that use lights are categorized as more than 3 gross tons type. Main fishing boats that use light to attract fish in the Philippines are ring net, small pelagic purse seine, bag net, and commercial round-haul seine (Fishing Gear and Methods in SEA: III. Philippines Part 2 n.d.; Figure 2). Overall, there are more boats that are less than 3 gross tons than heavier boats (Figure 3, panel A and B). Four regions have more than 1,000 boats that are more than 3 gross tons: Calabarzon (Southern Tagalog Mainland), SOCCSKSARGEN (Central Mindanao), Bangsamoro Autonomous Region in Muslim Mindanao, and MIMAROPA (Southwestern Tagalog). Moreover, the number of fishing gears differs from one province to another. Palawan, Basilan, and Samar have the highest number of fishing gears with an average of 75,000 used gears, followed by Occidental Mindoro, Oriental Mindoro, Quezon, Batangas, Camarines Sur, Iloilo, and Negros Occidental with an average of 34,000 used gears in 2012 (Map 2). The gears' fishing capacities differ from one to another and from one region to another.

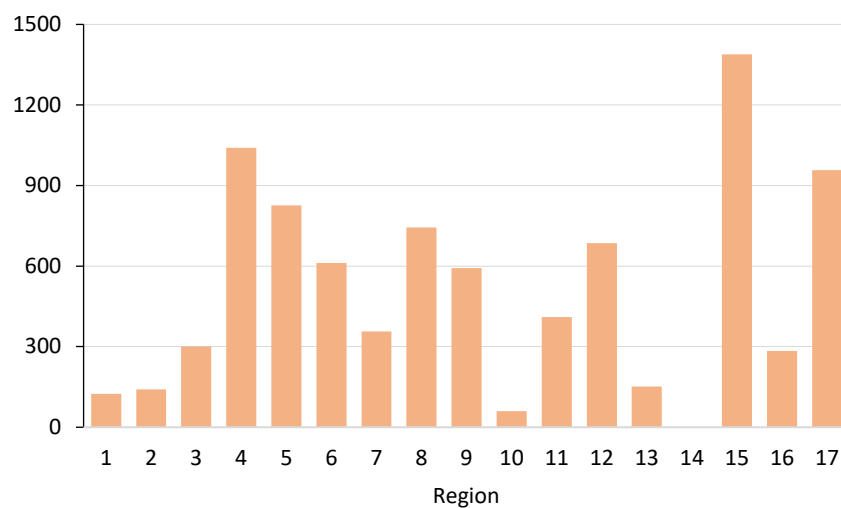
**Figure 2: Fishing Boats Using Lights in the Philippines, by Region**



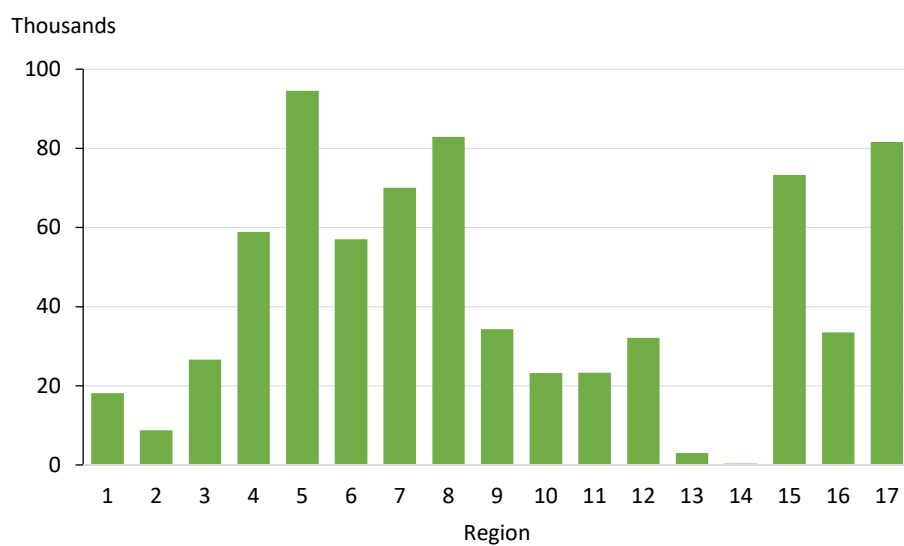
Source: Philippine Statistics Authority. 2012. [Census of Agriculture and Fisheries](#).

**Figure 3: Fishing Boat Types in the Philippines**

Panel A. More than 3 gross tons

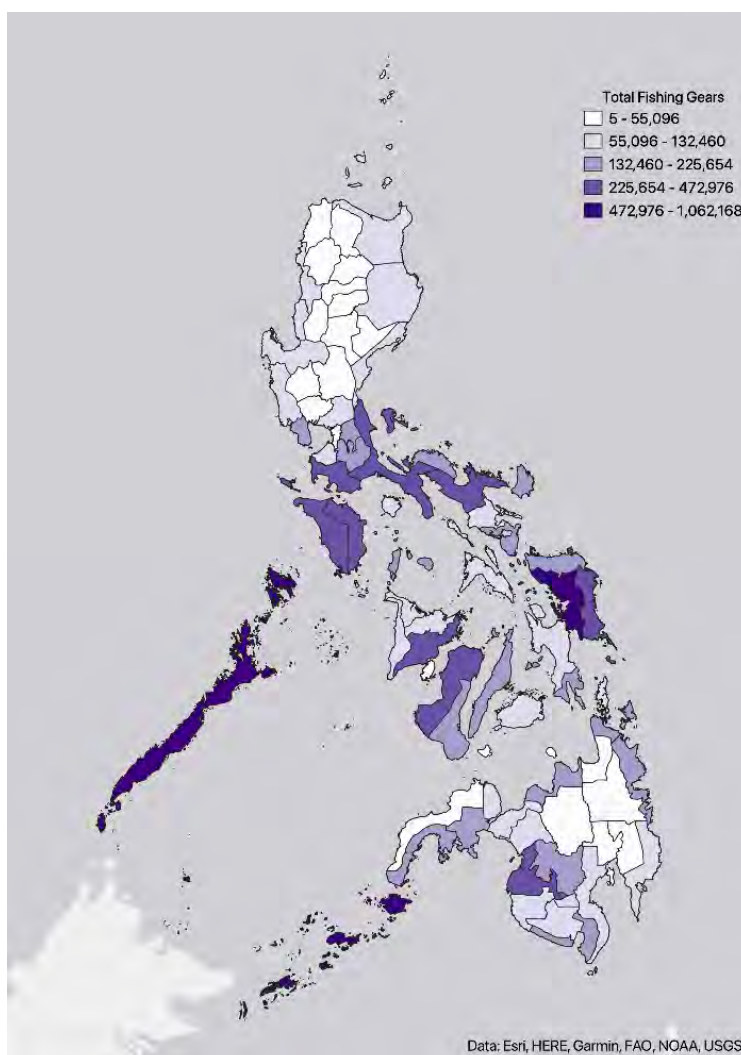


Panel B. Three gross tons or less



Source: Philippine Statistics Authority. 2012. [Census of Agriculture and Fisheries](#).

**Map 2: Used Gears in the Philippines, by Province**



Source: Philippine Statistics Authority. 2012. [Census of Agriculture and Fisheries](#).

Catch Per Unit Effort (CPUE) measures boat productivity. CPUE is the average harvested fish in a single fishing effort (kilogram per day [kg/day]). Several studies have attempted to quantify the CPUE level in the Philippines. CPUE level, which measures the amount of fish caught per unit of effort, varies across different fishing areas in the Philippines and depends on factors such as the specific fishing session and the abundance of fish in each location.

According to Ramiscal et al. (2014), purse seine average fishing production ranges between 2 tons/day and 9.5 tons/day in the Moro Gulf and Honda Bay. CPUE level for ring net is lower than purse seine due to fishing capacity differences (Table 1). The ring net CPUE level in Sulu Sea is estimated at 1,000 kg/day from small pelagic species only.

**Table 1: Catch Per Unit Effort**  
(ton/day)

Boat Type	Fishing Ground		
	Sulu Sea	Moro Gulf/ Celebes Sea	Honda Bay
Purse seine	15.00	9.50	2.00
Ring net	1.00	6.50	0.25

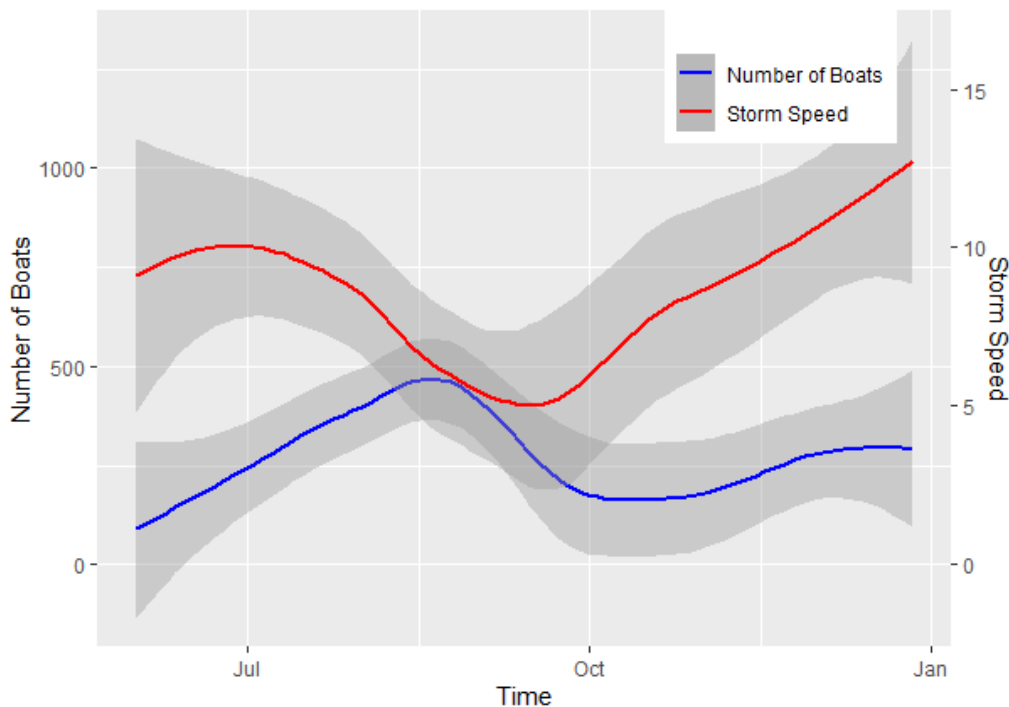
Source: Ramiscal, Rafael V., Alma C. Dickson, William S. de la Cruz, Isidro Tanangonan, Marlo Demoos, and Jonathan O. Dickson. 2014. Analysis of Purse Seine / Ring Net Fishing Operations in Philippine EEZ. Western and Central Pacific Committee Scientific Committee Ninth Regular Session; Mamalangkap, Macmod D., Usop K. Mokamad, and Sammy M. Ayub. 2018. Assessment of Small Pelagic Species Landed in ARMM, Sulu Sea. *The Philippine Journal of Fisheries*, 25 (1): 183–192. <https://doi.org/10.31398/tjpf/25.1.2017c0016>; Government of the Philippines, Department of Agriculture, Bureau of Fisheries and Aquatic Resources (DA-BFAR). 2015. Establishment of a Closed Season for the Management of Galunggong (Roundscads; Decapterusspp.) in Northern Palawan (Issue 360).

## 2. Tropical Cyclone Data Description

Daily TC data were retrieved from the International Best Track Archive for Climate Stewardship (IBTrACS) covering June to December 2012. In 2012, the Philippines had a total of 21 TCs of which 6 were intense (with wind speed of more than 100 kph). TC Mawar occurred over the Pacific Ocean in early June and entered the Philippine area of responsibility (PAR) over the coast of Luzon. Mawar's wind speed ranged between 5 to 40 knots/hour and caused heavy rains at 15 to 25 millimeters (mm)/hour. Antipolo City and the surrounding mountainous area were the most affected (ReliefWeb 2012). TC Saola centered within East Northeast of Borongan on 28 July and developed into a tropical depression and then moved toward north–northwest, with an estimated loss in the fisheries sector of \$418,568 (NDRRMC 2012a). TC Helen (internationally known as Kai-Tak) originated from a low-pressure area on 11 August east of central Luzon and moved toward extreme northern Luzon, with estimated damage cost on the fisheries sector at \$248,921 (NDRRMC 2012b). TC Jelawat on 10 September moved from Palau toward the Philippines Area of Responsibility (PAR) but remained distant from the coastal area. The TC later intensified and moved northward. In October, TC Son-Tinh was located east of Surigao Del Sur and then crossed the country, heading west–northwest toward Surigao Del Norte and eventually left the PAR on 26 October. TC Bopha (locally known as Pablo) entered the PAR on 2 December and made landfall in Baganga, Davao Oriental on 4 December. Documented wind speed ranges from 60 to 100 knots/hour. According to the NDRRMC, more than 6 million people were affected, 1,067 died, 2,666 were injured, and 216,817 houses were damaged. The total cost of damage to the agriculture infrastructure amounted to \$610,113,259 and \$1,166,228 in the fisheries sector (NDRRMC 2012c).

Storm speed and the number of detected boat relationships appear to be negative. The higher the storm speed the lower the number of fishing boats (Figure 4). The initial increase in the storm speed between June and September led to a significant decrease in the number of fishing boats. The number of boats increased following the decrease in the storm speed between September and November.

**Figure 4: Number of Boats and Storm Speed, June to December 2012**



Source: Authors' calculation.

Table 2 shows the descriptive statistics of the main variable associated with the TC between June and December 2012. The storm speed has a mean of 9.4 knots, 4.6 standard deviations, and minimum and maximum values of 1.5 and 29.0 knots, respectively. The maximum speed is the maximum sustained speed of the storm, with an average of 59.5 mean value, 35.0 knots and 110.0 knots minimum and maximum sustained speed, respectively. Minimum and maximum distance show the minimum and maximum estimated distance between TCs and boats. The minimum distance estimated between TCs and boats was 5.4 km with a standard deviation of 24. The number of boats has a mean value of 1,509.2 and a standard

deviation of 1,186 boats. The minimum and maximum detected number of boats counted at 92 and 4,792 boats, respectively.

**Table 2: Descriptive Statistics**

<b>Variable</b>	<b>Mean</b>	<b>SD</b>	<b>Minimum</b>	<b>Maximum</b>	<b>Range</b>	<b>SE</b>
Storm speed	9.4	4.6	1.5	29.0	27.5	0.4
Maximum speed	59.5	20.8	35.0	110.0	75.0	2.0
Distance to land	371.3	255.8	0.0	1,114.2	1,114.2	22.6
Minimum distance	437.8	271.0	5.4	1,254.0	1,248.6	24.0
Maximum distance	3,755.9	1,669.1	1,417.5	8,320.0	6,902.5	147.5
Boats	1,509.2	1,186.0	92	4,792	4,700.0	104.8

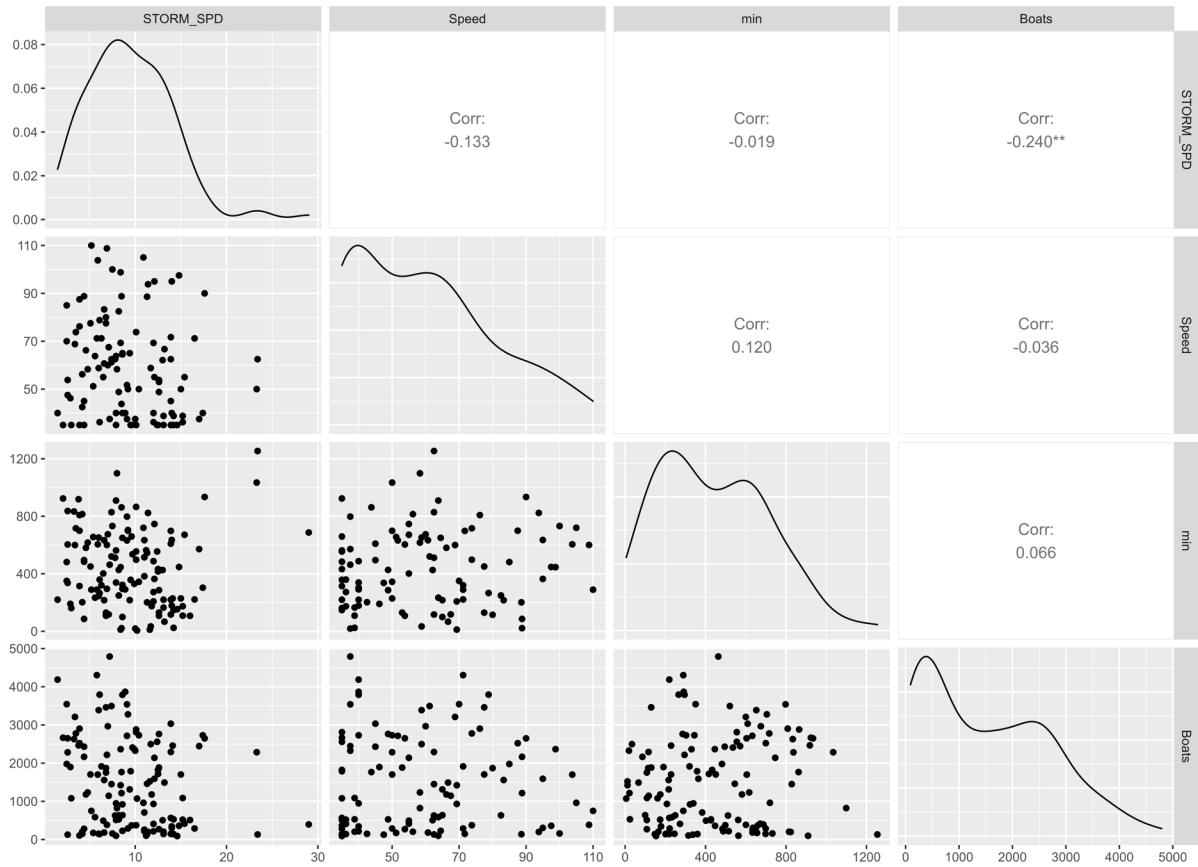
SD = standard deviation, SE = standard error.

Source: Authors' calculation.

Figure 5 shows the variables distribution plot as well as the correlation matrix among variables. The number of boats appears to have a statistically significant negative correlation with the storm speed at -0.24; the other variables do not appear to be correlated. Maps 3 to 9 track TCs within the exclusive economic zone (EEZ) from their minimum distance from boats until reaching their estimated maximum speed. The number of boats decreased from 827 on 18 June to 254 boats on 21 June (Map 3).<sup>3</sup> The following month, TC Saola decreased the number of boats from 693 boats to 202 boats on 19 July (Map 4). TC Sanba had a greater impact on the Philippines' fishing boats, where the number of boats decreased from 635 on 20 August to 87 boats on 29 August (Map 5). The number of boats was reduced from 726 on September 20 to 162 on September 23 due to TC Jelawat (Map 6). TC Son-Tinh (Map 7) caused a sharp decrease in the number of boats on 18–25 October. There were only 119 boats once the TC made landfall in the Philippines. As soon as TC Pablo made its way away from the EEZ of the Philippines, the number of boats increased from 105 to 712 boats on 8 December (Map 8).

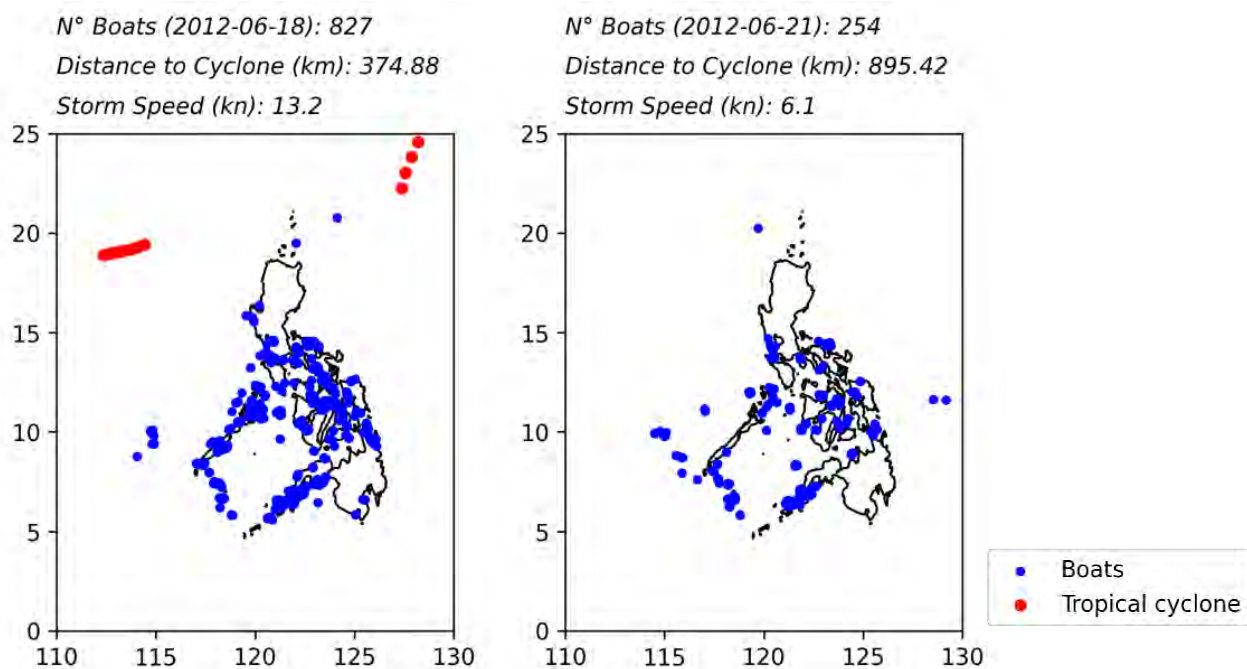
<sup>3</sup> GIF version of the maps can be accessed here: <http://dx.doi.org/10.22617/WPS230291-2>.

Figure 5: Matrix Plot

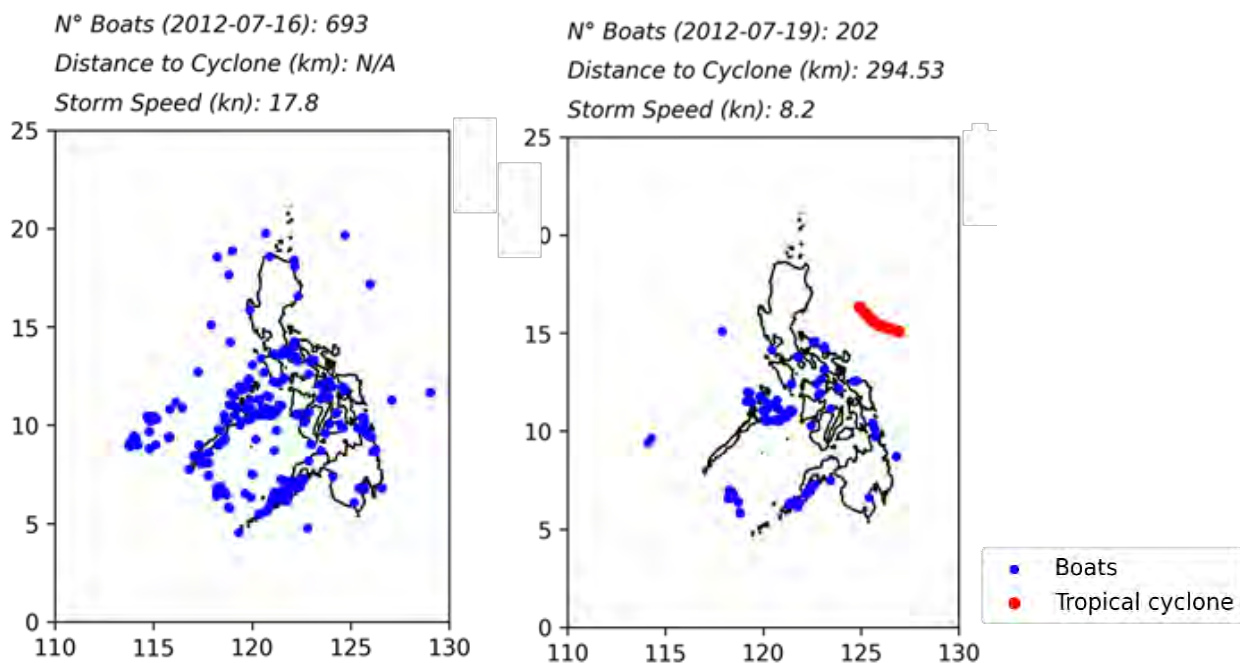


Source: Authors' calculation.

**Map 3: Tropical Cyclone and Boat Distribution, June 2012**

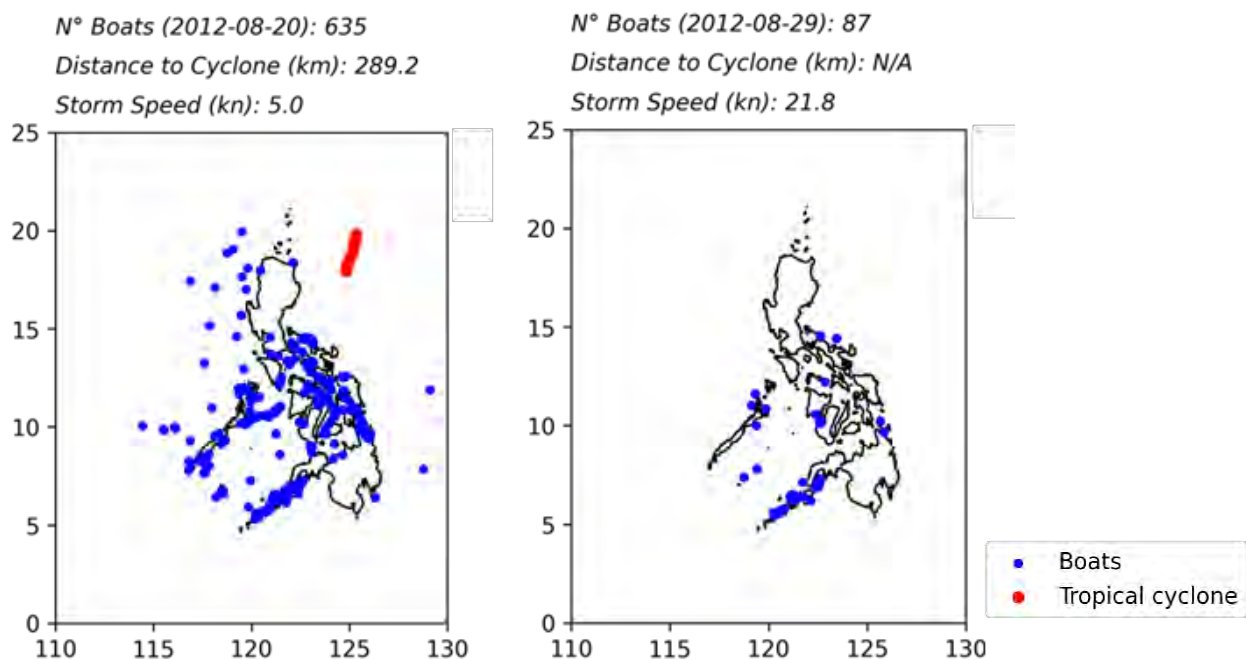


**Map 4: Tropical Cyclone and Boat Distribution, July 2012**



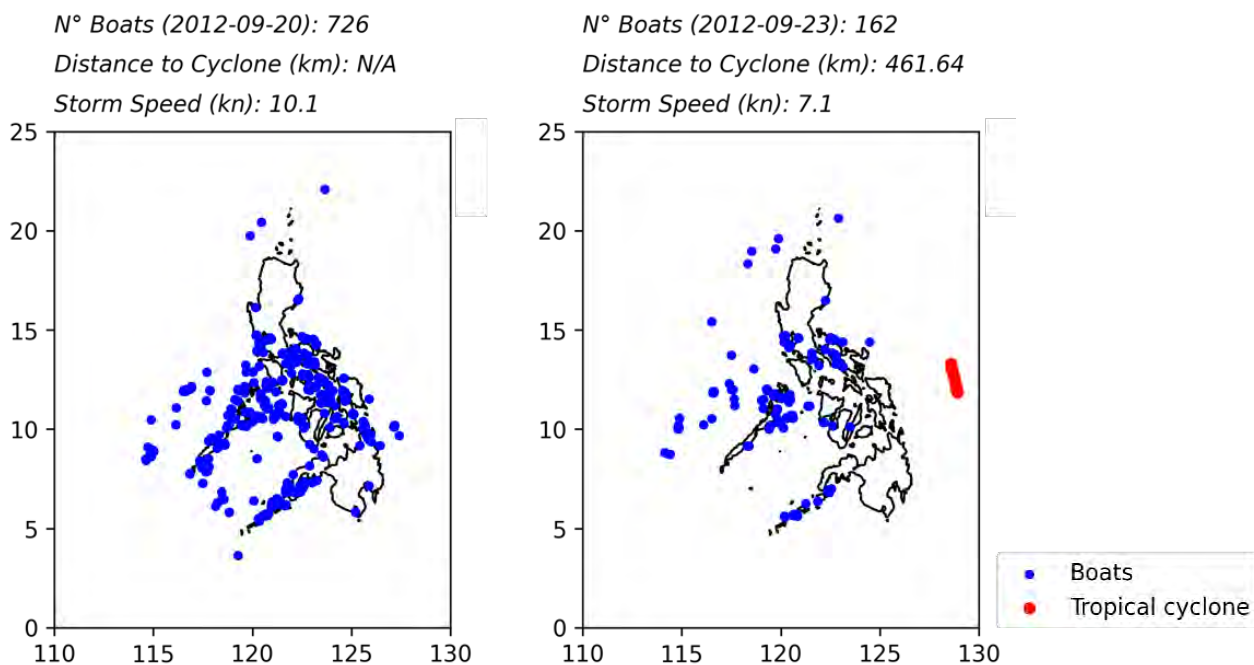


### Map 5: Tropical Cyclone and Boat Distribution, August 2012



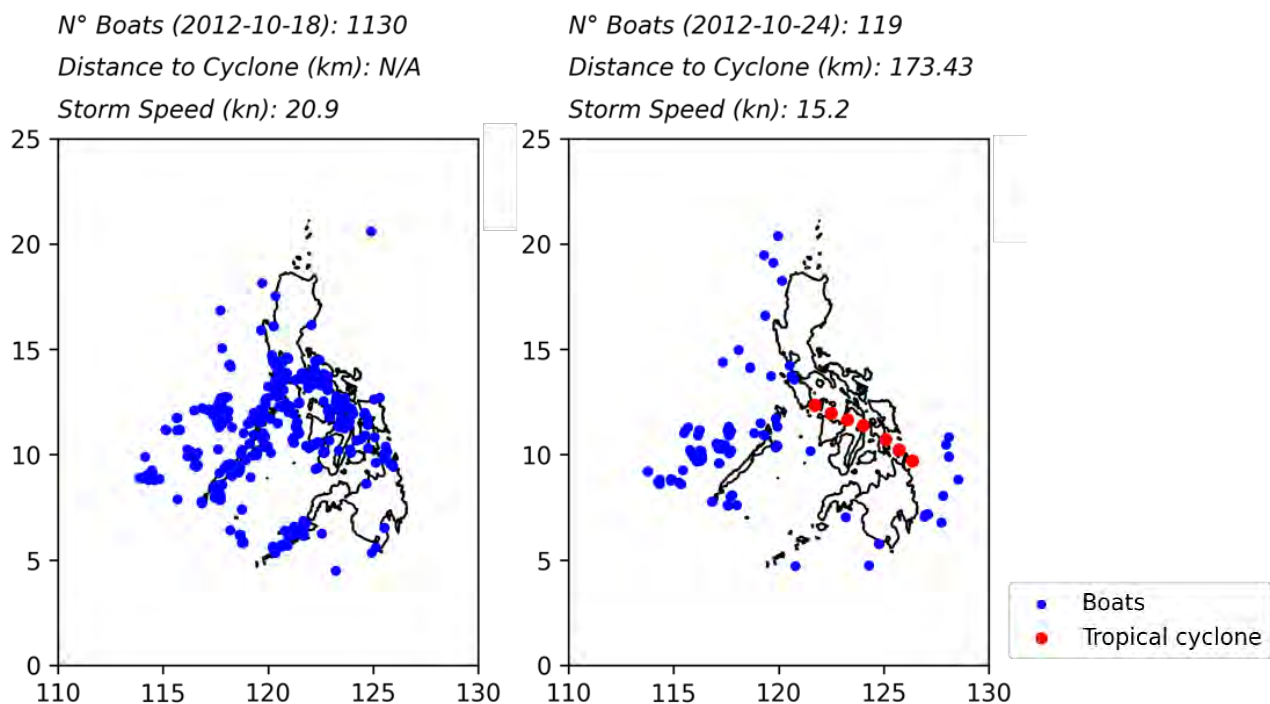
Source: Authors' calculation.

### Map 6: Tropical Cyclone and Boat Distribution, September 2012



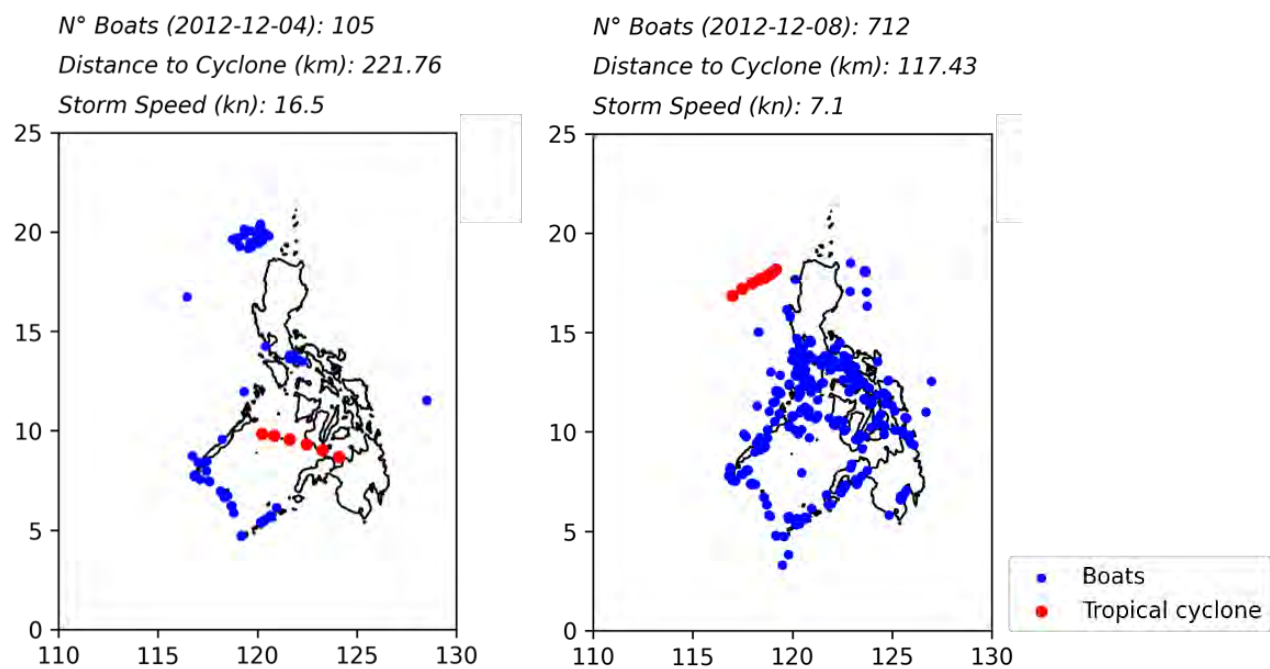
Source: Authors' calculation.

### Map 7: Tropical Cyclone and Boat Distribution, October 2012



Source: Authors' calculation.

### Map 8: Tropical Cyclone and Boat Distribution, December 2012



Source: Authors' calculation.

## **Fishing Grounds**

We cluster main fishing grounds using fishing activity data when no TCs are detected to identify the impact of TCs on these areas. Identifying fishing grounds allows us to track fishing boat movements as they respond to the TC's arrival. Regions and provinces that are closer to the fishing grounds are more likely to be impacted by the reduction in fishing activities in these places. Hence, identifying fishing grounds helps track fishing activities during TCs, and distinguish the most vulnerable provinces and regions to TCs damage to fisheries.

Fishers select the fishing grounds according to their productivity and stock level. Fishing boats tend to cluster within the fishing grounds to increase fishing volume (Saul et al. 2013). Using VIIRS boat detection (VBD) data, we consider the repeatedly visited locations in the fishing activity area, and the number of points detected daily. To avoid excluding small clusters, we apply kernel density within different high-clustered sub-regions to identify smaller fishing grounds.

## **3. Methods**

### **A. Visible Infrared Imaging Radiometer Suite Boat Detection Data Processing**

Data on VBD were retrieved from the Payne Institute for Public Policy at the Colorado School of Mines. The data cover June to December 2012. Initially, the data were collected by the National Aeronautics and Space Administration and National Oceanic and Atmospheric Administration. Boats are detected through nighttime VIIRS. VIIRS data are collected through Suomi National Polar Partnership (SNPP) satellite that was launched in 2011. VIIRS data unit covers an area of 3,000 km and 2,600 km high which resulted in an excessive volume of data to handle. Hence, the development of an automatic system of boat detections has been initialized by Elvidge et al. (2015) to overcome the issue of costly data management and storage.

### **B. Kernel Density Estimation**

Kernel density estimation (KDE) is used for multivariate and univariate probability density employing the Gaussian weighted distance function in Euclidean space. KDE is plotted to allow for cluster visualization across the region. Events that occur more frequently are clustered and known as “hot spots,” while less frequent events are positioned outside clusters. Similarly, densities may be translated into values, where low values represent a less frequent (low probability) event and high values demonstrate a more frequent event. Furthermore, more than one cluster can be detected in the data, but the cluster density may differ from one to another as per the probability density of each cluster.

KDE is applied to estimate the density function at a point  $x$  using neighbouring observations. However, instead of building up the estimate according to bin edges, the naive kernel method (adaptively) uses each point of estimation  $x$  as the centre of the bin of width  $2h$ . Following the work of Samiuddin and El-Sayyad (1990), the kernel density function is developed as follows:

$$f_n(x) = \frac{1}{nh} \sum_{i=1}^n k\left(\frac{x-x_i}{h}\right) \quad Eq(1)$$

Where  $f(x)$  is the density function,  $k()$  is the kernel function,  $h$  represents selected bandwidth, which is always larger than 0, and  $x-x_i$  measures the distance between the estimated point and the neighboring points. The bandwidth  $h$  plays an important role in determining clusters extent; as  $h$  increases, space becomes smoother and, hence, hiding density. Similarly, the decrease in  $h$  leads to having a different density at every point. Choosing the optimal bandwidth is crucial to avoid over-smoothing that may cause including insignificant points and little smoothing lead to excluding significant points. Green et al. (1988) proposed the following formula for bandwidth selection:

$$h = 0.9 \min\left(\delta, \frac{R}{1.34}\right) n^{-\frac{1}{5}} \quad Eq(2)$$

In our study, kernel density is applied to, firstly, detect main fishing grounds within the Philippines EEZ employing VBD data, and secondly, once the wind reached its maximum speed and during the captured minimum distance between TCs and boats. Fishing grounds are detected through clustering high-density fishing areas when no TCs are observed. Identifying fishing grounds helps to observe the fishing area distribution during the TC and, hence, define the heavily affected region.

### C. Generalized Linear Model Analysis

Generalized Linear Model (GLM) holds the concept of linear regression model allowing for non-normal distribution of the response variable. Exponential distributions of the response variable such as Poisson distribution are assumed within GLM. Also, GLMs are useful in dealing with nonnegative values and highly skewed data when the normal assumption is not met (Myers et al. 2012). Under these conditions, GLMs provide consistent results compared to an ordinary linear model.

We next estimate the impact of storm speed on the number of boats within the Philippines EEZ during the TC. The data cover 1 June to 31 December 2012. Since the TCs hit the Philippines at different time intervals during this period, days with no TCs have been excluded and days of

TCs detected within the Philippines EEZ are retained. Fishing grounds detected through kernel density are used to investigate the impact of the storm speed on the main detected fishing ground.

To capture the impact of TC speed on the number of boats, the following equation has been formulated:

$$y = c + \sum_{k=0}^n \partial + \varepsilon$$

Where  $y$  is the daily number of detected boats within EEZ,  $c$  is the intercept,  $\partial$  is the estimated variable storm speed coefficient, and  $\varepsilon$  is the error term. Then, we include distance which reflects the daily average distance between TC and each fishing ground:

$$y_t = c + \beta_1 speed_t + \beta_2 distance_t + \varepsilon_t$$

where *speed* is the daily average storm speed of a TC within EEZ. *Distance* is the daily average estimated distance between TCs and fishing grounds.

To identify the total duration of interrupted fishing activities, lagged variable is included in our model. The lagged independent variable of TC speed allows capturing the impact of the TC on the number of boats after moving away from the Philippines area. Different lag length has been applied following the TC. Allowing TC speed lag in our model allows us to determine the number of days of interrupted fishing activities and the period until fishing activities are resumed. Our model is specified as follows:

$$y_t = c + \beta_1 speed_{t-i} + \varepsilon_t$$

Where  $y$  is the number of boats at time  $t$ , and  $speed_{t-i}$  is the storm speed at lag length  $t - i$

To estimate our models, we have applied Vector Generalized Linear Models (VGLM). This method allows for multivariate analysis via inverse link function i.e., Gaussian family, and negative binominal family, as well as allows for incorporating Poisson regression within the model (Lindsey 2000, Yee and Hastie 2003). Our dependent variable is the count of the daily observed boats and therefore we allow for Poisson distribution into our model.

#### **D. Bayesian Time-Varying Parameter**

To estimate our models, we have applied the Bayesian Shrinking Time-Varying Parameter (TVP). This method allows the coefficient to vary over time and the possibility to detect nonlinearity in the model and overcomes the overfitting issue (Bitto and Frühwirth-Schnatter 2019). TVP allows us to trace the coefficient changes over time temporarily and permanently. TVP is

developed to accommodate a complex relationship such as nonlinearity and shocks within the model such as gradual change and structural break (Lanza and Linden-Carmichael 2021, Nakajima et al. 2011). Response to disasters may vary over time depending on the disaster's nature and strength (Cheong 2022).

The Bayesian approach deals with model estimation differently compared to the frequentist approach. Fundamentally, within the Bayesian approach, uncertainties such as randomness and lack of knowledge about parameters are embedded within the model through prior information. Parameter estimation is the estimated probability distribution reflected through posterior distribution. Hence, parameter estimation within the Bayesian approach reflects both observed data and prior information. Bayesian inference is determined based on the posterior distribution credible interval. Credible interval summarizes possible values of the estimated posterior density. Probable values of the estimated posterior density fall within 95% of the credible interval are considered in this study.

Posterior probability density of the parameters summarizes data and prior information. Posterior mean  $E(\beta|y)$  is used to infer the parameters coefficient and posterior standard deviation  $var(\beta|y)$  measures uncertainty in the estimated point. The Bayesian approach provides better results than the ordinary least squares (OLS) as it combines the weighted average of OLS and prior mean proportional to their precisions (variances inverse) (Koop 2003).

Shrinkage in prior would pull varying parameters towards static ones and allow for stochastic volatility using the Least Absolute Shrinkage and Selection Operator (LASSO) method within the Bayesian and hierarchical Bayesian framework. Time-varying parameters are assumed to follow independent random walks. Priors are placed on standard deviations as well as the mean initial value of  $\beta_1$  and  $\beta_2$ . Priors are specified as follows with variance gamma distribution:

$$\sqrt{\theta_j} \mid \xi_j^2 \sim N(0, \xi_j^2), \quad \xi_j^2 \mid a^\xi, k^2 \sim G(a^\xi, \frac{a^\xi k^2}{2})$$

$$\beta_j \mid \tau_j^2 \sim N(0, \tau_j^2), \quad \tau_j^2 \mid a^\tau, \lambda^2 \sim G(a^\tau, \frac{a^\tau \lambda^2}{2})$$

Priors  $\xi_j^2$  and  $\tau_j^2$  influence the strength of the shrinkage in parameters. Shrinkage parameters  $k^2$  and  $\lambda^2$  control how strongly the parameters are pulled to a static value.  $a^\xi$  and  $a^\tau$  are the pole parameters that control the mass density around zero. Various prior specification has been supplied to enhance results including hierarchical Bayesian LASSO, Bayesian LASSO, and stochastic volatility.

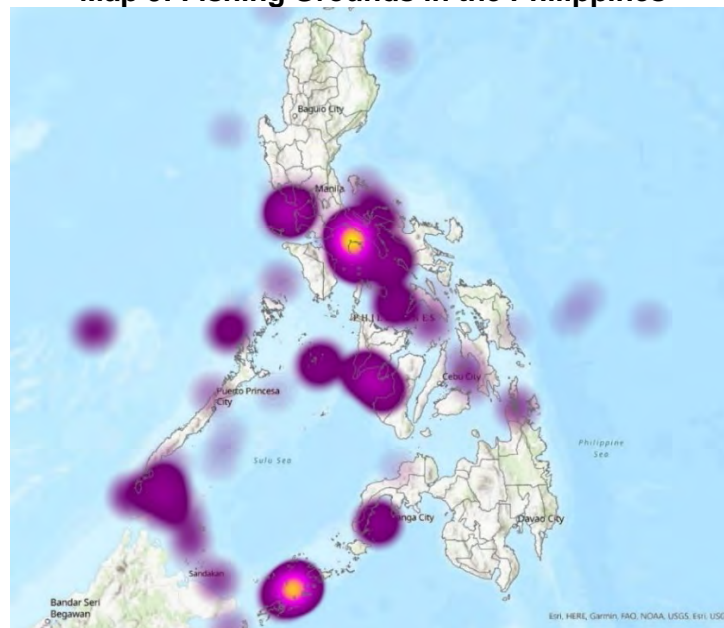
Results are gauged through the Markov Chain Monte Carlo (MCMC) Gibbs sampling algorithm. Parameters posterior distribution are drawn from MCMC using Metropolis-Hastings steps (Babalos et al. 2015).

## 4. Results

### A. Kernel Density Results

The kernel density method is applied to cluster the main fishing ground using VBD data source. The data is daily from June to December 2012. The analysis was made when no TCs were detected in the Philippines EEZ. Main fishing grounds are detected within Sibuyan Sea and Sulu Sea (Map 9). Sibuyan Sea has several large fishing grounds located mainly north of the Marinduque and Masbate provinces. Unlike Sibuyan Sea, Sulu Sea fishing grounds are located in different places. Main fishing grounds in the Sulu Sea are found between the provinces of Sulu and Tawi-Tawi and other large fishing grounds are also observed between Panay Gulf and southwest Palawan.

**Map 9: Fishing Grounds in the Philippines**



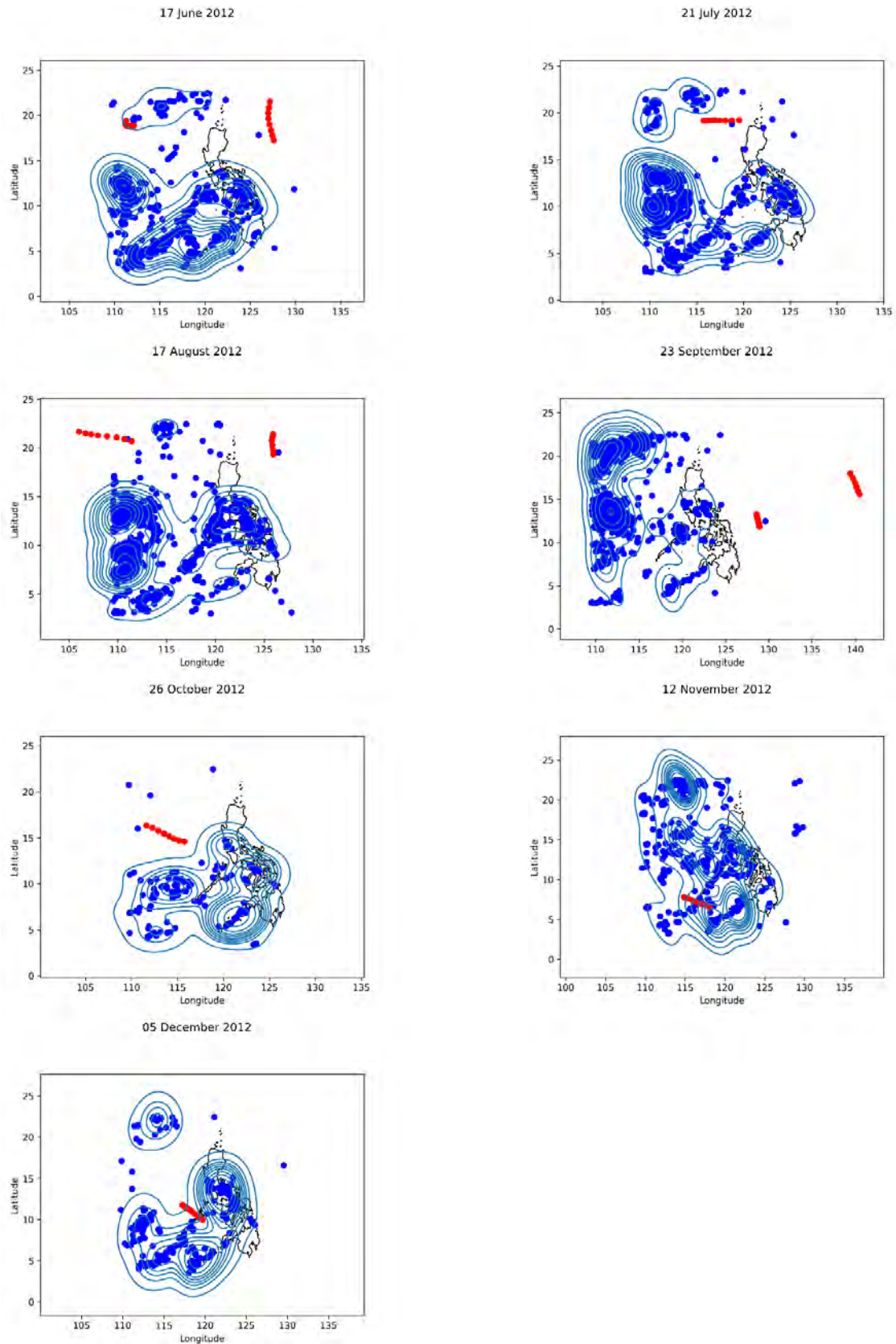
Source: Authors' calculation.

KDE has been applied to the detected boats within the Philippines 200nm area, for the analysis with regard to the TCs. Results of the kernel density plot (Figure 6) reveal clusters area weakened once the TC hit PAR. Kernel density is estimated according to the monthly minimum distance between boats and TCs. Table 3 reveals the observed minimum distance observed between TCs and detected boats every month. The minimum distance captured from June to

December is observed on 12 November at 5.4 km with total detected boats of 1,072, and an average storm speed of 10 knots. Compared to other months, November was less hazardous to the Philippines. The minimum estimated distance in June was 12 km captured on the northwestern side of the Philippines on 17 June while there were more than 1,400 boats. The close distance between the TC (Talim) and boats was due to the low speed of the storm at 4 knots. TC Talim centered east of Hainan, People's Republic of China, and later weakened and entered PAR. On 21 July, the minimum distance was estimated at 18 km with a speed average of 10 knots. Kernel density (Figure 6) shows the cluster movement due to the TC. Clusters were shifted toward the southwest with a 5% decrease in the detected boats. The minimum calculated distance the following month is on 17 August at almost 34 km with an average speed of 11 knots. TC Kai-Tak (locally known as Helen) hit the north of the Philippines on 13 August (Figure 6) and the minimum distance reflects the recovery of fishing boats while the TC weakened and moved away from PAR. On 23 September, the estimated minimum distance between TC Jelawat and boats was 86 km at 11 knots storm speed. However, TC Son-Tinh at 12.6 knots wind speed had a higher impact on the fishing boat distribution and significantly decreased the number of fishing boats on 26 October (Figure 6). While the November TC had an insignificant impact on the fishing boats due to the low speed, TC Pablo had a significant impact on the fishing boats on 5 December.



**Figure 6: Kernel Density at the Captured Minimum Distance**



Source: Authors' calculation.

**Table 3: Monthly Minimum Distance**

<b>Date</b>	<b>Storm Speed</b>	<b>Maximum Speed</b>	<b>Distance to Land</b>	<b>Minimum Speed</b>	<b>Number of Boats</b>
17 June 2012	8.4	69.3	313.7	12.0	1,422
21 July 2012	10.0	37.5	315.0	18.9	2,326
17 Aug 2012	11.7	58.8	201.5	33.9	2,498
23 Sep 2012	7.1	88.8	908.1	86.1	2,165
26 Oct 2012	12.6	53.8	448.5	108.0	271
12 Nov 2012	10.2	35.0	77.8	5.4	1,072
5 Dec 2012	8.6	65.0	118.4	99.5	638

Source: Authors' calculation.

On the other hand, the higher wind speed leads to a decrease in the number of boats and an increase in the calculated minimum distance to the boats. The average calculated distance between boats and TC is around 600 km. Regardless of the TC that occurred in November, which is considered less hazardous, the minimum distance dropped to 11.7 km (Table 4). The higher the wind speed, the larger the distance between boats and the TC. For instance, on 21 June, the captured TC at speed of 29 knots was 687 km away from the nearest boat. Kernel density (Figure 7) shows the boats' density is concentrated within the southwestern side of the Philippines.

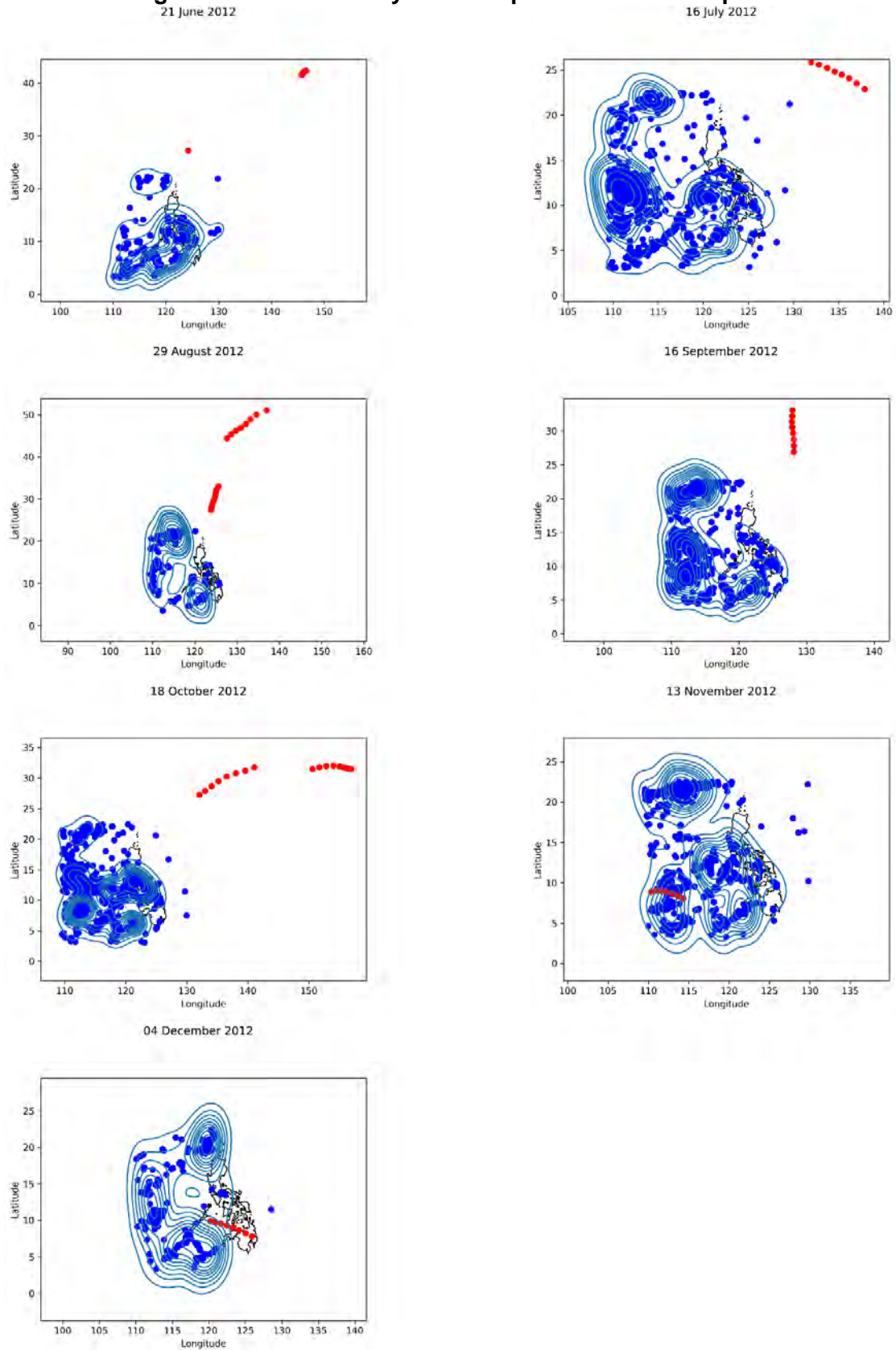
**Table 4: Storm Speed and Distance**

<b>Date</b>	<b>Average Storm Speed (knots)</b>	<b>Maximum Storm Speed (knots)</b>	<b>Distance, Storm to Land (km)</b>	<b>Minimum Distance, Storm to Boat (km)</b>	<b>Number of Boats</b>
21 June 2012	29.0		283.0	687.1	396
16 July 2012	17.0	37.5	680.0	571.7	2,446
29 Aug 2012	15.4	55.0	235.8	671.3	415
16 Sep 2012	17.6	90.0	352.6	934.1	2,649
18 Oct 2012	23.3	50.0	414.7	1,034.5	2,286
13 Nov 2012	11.6		381.2	11.7	1,522
4 Dec 2012	16.5	71.2	47.9	221.4	289

Source: Authors' calculation.

Similarly, from July to October, the maximum storm speed ranged from 37-90 knots and the minimum distance of boats to TC were from 570 km to 1,000 km. On 4 December, TC Pablo reached its maximum speed at 71 knots and the nearest boats were captured at 221 km away from the TC. Kernel density reflects the existence of TC Pablo and shows how boat distribution has been split and spread away from the TC (Figure 7).

**Figure 7: Kernel Density at the Captured Maximum Speed**

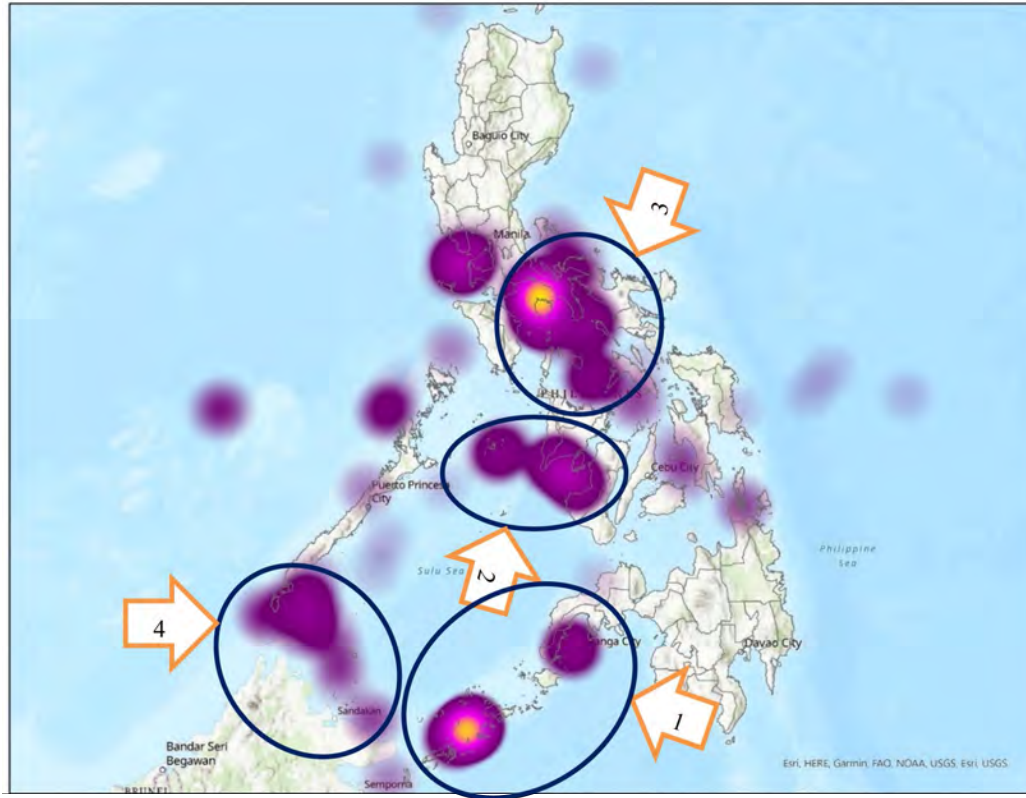


Source: Authors' calculation.

## B. Generalized Linear Model Results

The VGLM model is estimated to capture the impact of a TC on the number of boats. First, the storm speed is applied to the entire EEZ of the Philippines to evaluate how boats are impacted by the TC track. Second, the impact of storm speed is applied to the main four detected fishing grounds (Map 10).

**Map 10: Fishing Grounds in the Philippines**



Source: Authors' calculation.

Table 5 presents the VGLM regression estimation results. The model reveals a negative impact of TCs' storm speed on the number of boats.

**Table 5: Generalized Linear Model Estimation**

Dependant Variables	Model (1)	Ground 1	Ground 2	Ground 3	Ground 4
<b>Intercept</b>	5.845*** (0.022)	3.213*** (1.023)	3.676*** (0.207)	4.475*** (0.1349)	2.21634*** (0.16828)
<b>Speed</b>	-0.03658*** (0.0024)	0.009364* (0.0045)	-0.09156*** (0.009845)	-0.08059 (0.007119)	0.0123591 (0.00840)
<b>Distance</b>		0.0008933*** (0.000061)	0.0000678 (0.00013)	-0.000166 (0.0000875)	0.000757 *** (0.00010)

Standard error in parentheses. "\*\*\*\*" and "\*\*\*" denote significance levels at 1 and 10%, respectively.

Source: Authors' calculation.

However, the impact of storm speed on the number of boats varies within each fishing ground. Fishing grounds 3 and 4 are less vulnerable to TC impact as the storm speed appeared to be insignificant, fishing ground 1 gained a bit given the positive and significant coefficient of storm speed as some boats may have shifted their activities towards it, and ground 2, on the other hand, seemed to be highly impacted by the TC at a 1% significance level.

The GLM model is estimated employing lagged variable to examine the time effect of TC speed on the number of boats. Different lags are applied on the storm speed to examine the recovery of fishing activities following the TC. Overall, fishing activities needed some time to recover from the TC. However, recovery period is different among each fishing ground (Table 6).

**Table 6: Generalized Linear Model Lagged Storm Speed**

<b>Lag/fishing ground</b>	<b>Ground 1</b>	<b>Ground 2</b>	<b>Ground 3</b>	<b>Ground 4</b>
<b>Speed (1)</b>		-0.041*** (0.0113)		
<b>Speed (5)</b>			-0.024*** (0.0059)	
<b>Speed (7)</b>				-0.0371*** (0.0093)
<b>Speed (15)</b>	-0.0256*** (0.0064)			

Standard error in parentheses. “\*\*\*” denotes significance level at 1%.

Source: Authors' calculation.

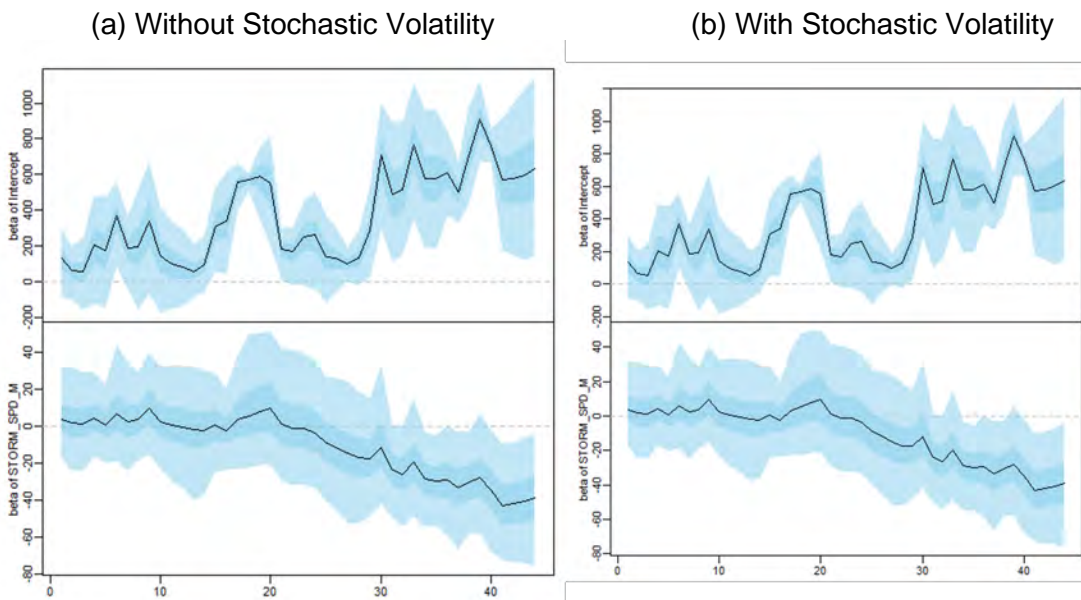
Fishing grounds 2 and 3 needed relatively less time to recover from the TC. While ground 3 recovered from the TC after 5 days, ground 2 returned to its normal fishing activity 1 day after the TC. On the other hand, grounds 1 and 4 recovered after 15 and 7 days, respectively. This is likely because of the fishing grounds 1 and 4 location as well as the TC track. Unlike grounds 2 and 3, grounds 1 and 4 are southwest of the country and TCs moved away from the Philippines EEZ are closer to grounds 1 and 4 compared to grounds 2 and 3. TCs that occurred between October and December were mainly moving from east to west making grounds 1 and 4 the last crossed area in the country.

### C. Bayesian Time-Varying Parameters Results

The TVP approach is employed to infer the impact of storm speed on the number of boats. A different prior specification is applied allowing for Bayesian LASSO and hierarchical Bayesian LASSO approaches with and without stochastic volatility.

Hierarchical Bayesian LASSO without stochastic volatility is presented in Figure 8. Average storm speed (STORM\_SPD\_M) reflects the time-varying impact on the number of boats during the TCs (Figure 8). First, the storm speed tends to follow static behavior, then, the storm speed appears to decrease the number of boats within the Philippines EEZ. The TCs that occurred between October and December are the main drive for lowering the number of boats. This is due to the high strength and extent of the TCs that occurred during this period.

**Figure 8: Hierarchical Bayesian LASSO with and without Stochastic Volatility**



LASSO = Least Absolute Shrinkage and Selection Operator.

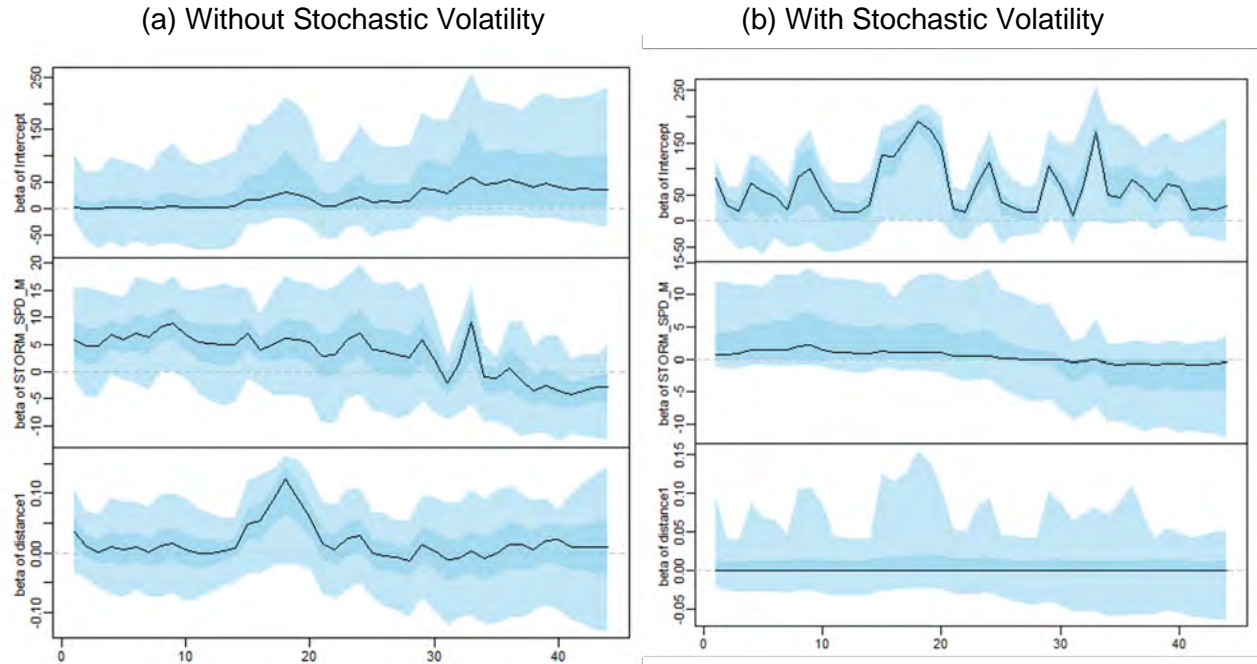
Notes: x-axis reflects the time, y-axis displays the coefficient magnitude. The median is displayed as a black line, and the shaded areas indicate the pointwise 95% and 50% posterior credible intervals.

Source: Authors' calculations.

On the other hand, storm speed within fishing ground 1 has had an overall constant impact using Bayesian LASSO with stochastic volatility (Figure 9). The TC Wukong and Son-Tinh that occurred in October and December had a significant negative impact on fishing in fishing ground 1. In contrast, TCs that occurred between June and September led to an increasing the number of boats as more boats are shifted away from the TC toward the fishing ground 1.



**Figure 9: Ground 1 Hierarchical Bayesian LASSO and Bayesian TVP with Stochastic Volatility**

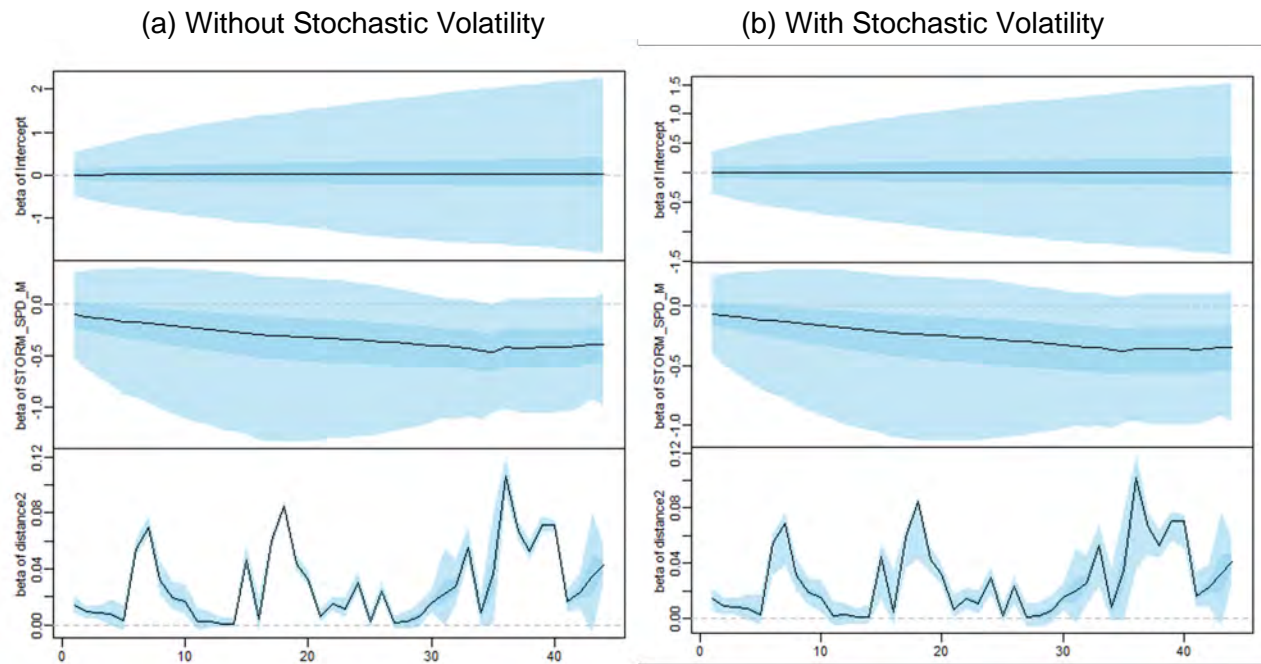


LASSO = Least Absolute Shrinkage and Selection Operator.

Notes: x-axis reflects the time, and the y-axis displays the coefficient magnitude. The median is displayed as a black line, and the shaded areas indicate the pointwise 95% and 50% posterior credible intervals.

Source: Authors' calculations.

Since fishing ground 2 is located in the center, all TCs had a significant negative impact on the number of fishing boats using Bayesian LASSO with and without stochastic volatility (Figure 10). TC Son-Tinh had the highest impact on the fishing boats as it crossed the fishing ground.

**Figure 10: Ground 2 Bayesian LASSO and Bayesian LASSO with Stochastic Volatility**

LASSO = Least Absolute Shrinkage and Selection Operator.

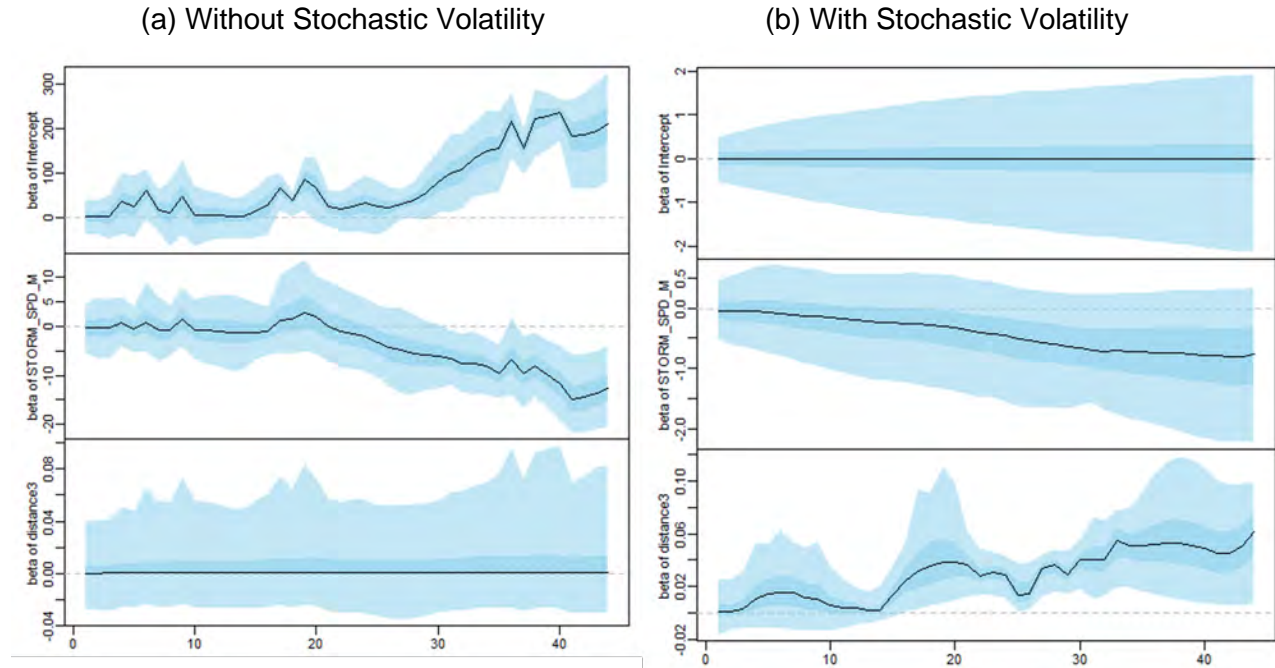
Notes: x-axis reflects the time, and the y-axis displays the coefficient magnitude. The median is displayed as a black line, and the shaded areas indicate the pointwise 95% and 50% posterior credible intervals.

Source: Authors' calculations.

Within fishing ground 3, on the other hand, only TCs occurred after September lowered the number of fishing boats. Bayesian LASSO with stochastic volatility has shown that the storm speed had a negative impact on the number of fishing boats from late July to December (Figure 11).



**Figure 11: Ground 3 Bayesian LASSO without Stochastic Volatility and Bayesian LASSO with Stochastic Volatility**



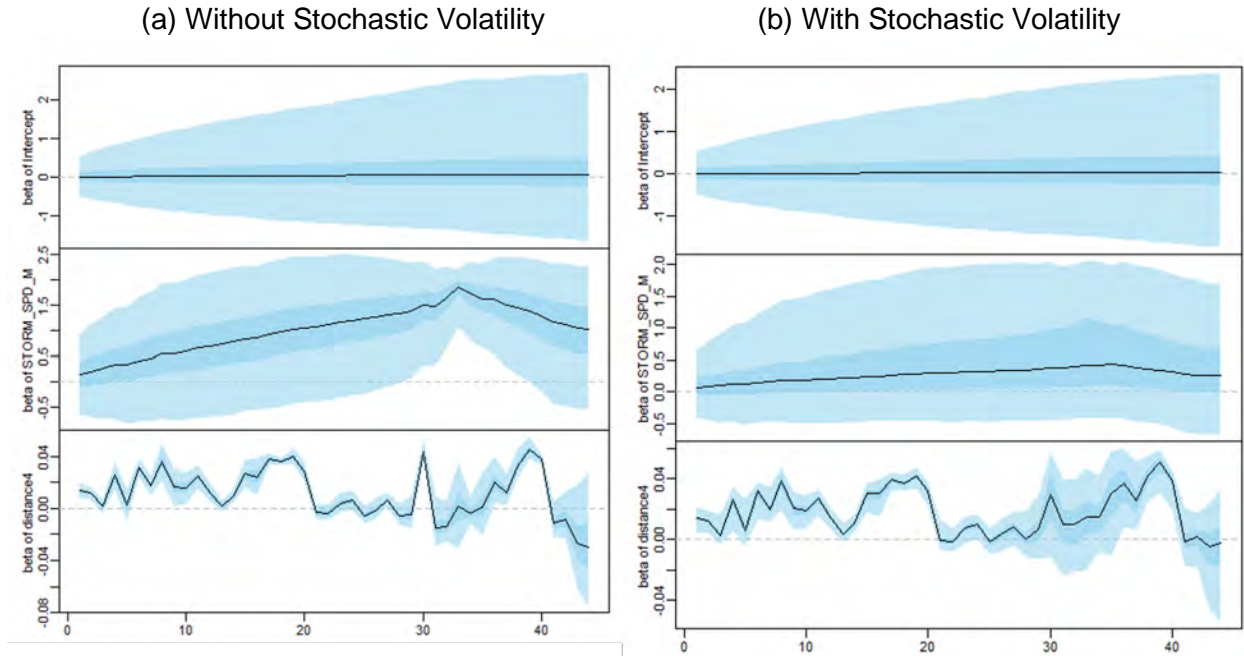
LASSO = Least Absolute Shrinkage and Selection Operator.

Notes: x-axis reflects the time, and the y-axis displays the coefficient magnitude. The median is displayed as a black line, and the shaded areas indicate the pointwise 95% and 50% posterior credible intervals.

Source: Authors' calculations.

Fishing ground 4 is on the distant west side of the EEZ of the Philippines. TCs crossed or passed nearby fishing ground 4 witnessed a low storm speed. Also, fishing ground 4 observed an increase in the number of boats during October as more boats are shifted towards fishing ground four sourcing from different areas due to TC Son-Tinh (Figure 12).

**Figure 12: Ground 4 Bayesian LASSO with Stochastic Volatility and Bayesian LASSO without Stochastic Volatility**



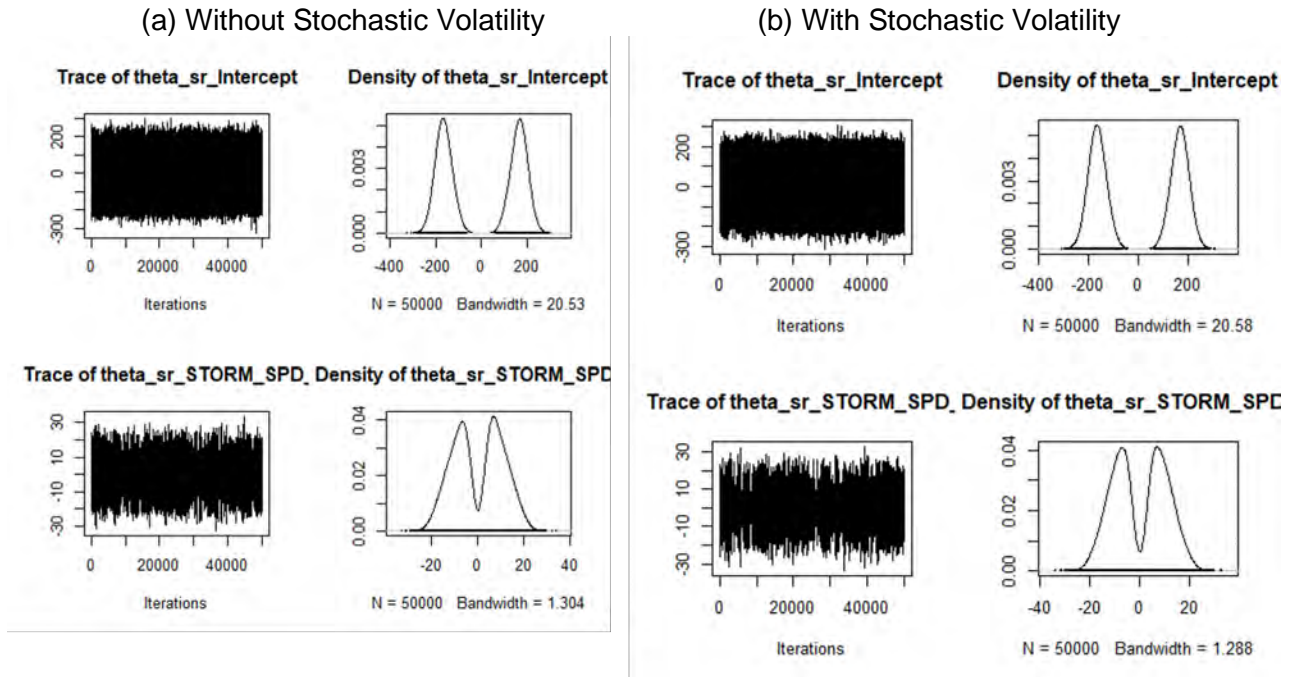
LASSO = Least Absolute Shrinkage and Selection Operator.

Notes: x-axis reflects the time, and the y-axis displays the coefficient magnitude. The median is displayed as a black line, and the shaded areas indicate the pointwise 95% and 50% posterior credible intervals.

Source: Authors' calculations.

To probe the model fit, we compute MCMC posterior for each model. A trace plot is used to demonstrate the convergence and mixing of the sampler. Fast convergence and a strong mixture of the model advocate the model fit (Plummer et al., 2006). The trace plot (left) and posterior densities (right) of the total detected boats are presented in Figure 13.

**Figure 13: Markov Chain Monte Carlo posterior for the Hierarchical Bayesian LASSO with and without Stochastic Volatility**



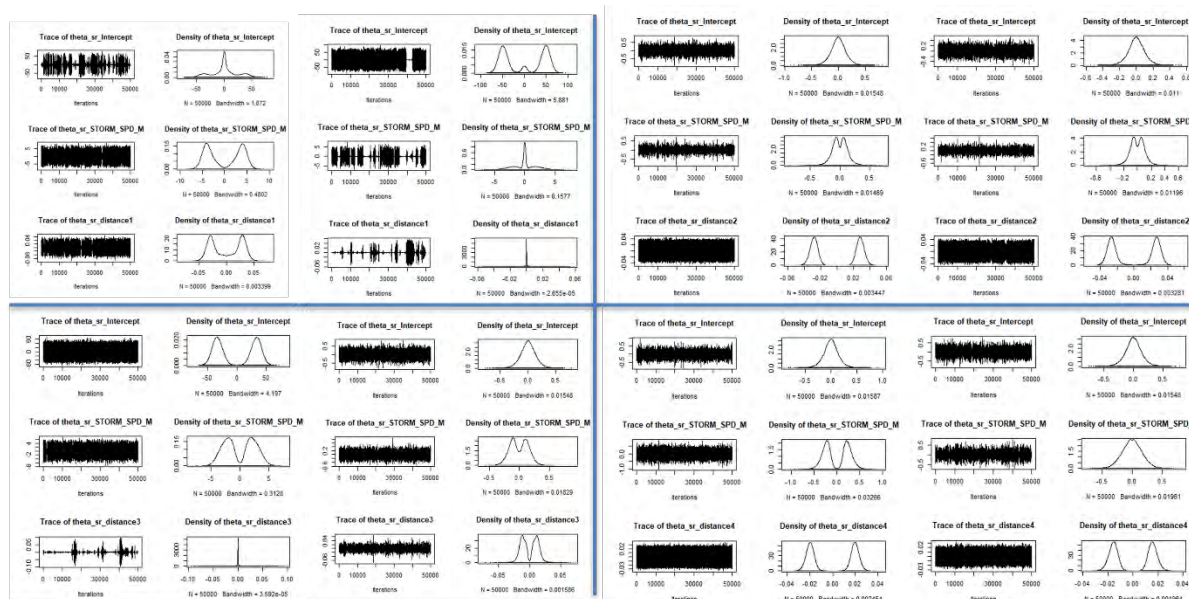
LASSO = Least Absolute Shrinkage and Selection Operator.

Notes: Trace plot (left column) and kernel density estimates of the posterior density (right column).

Source: Authors' calculations.

The storm speed density plot is bimodal. This is because of the non-identifiability of the standard deviation sign. Bimodality in the density plot of the posterior distribution is an additional indication of the time variation in the associated variable. The number of boats within the four fishing grounds is shown to follow bimodal distribution (Figure 14) except fishing ground 2, which tends to have a static coefficient allowing for stochastic volatility within the model.

**Figure 14: Markov Chain Monte Carlo Posterior of Four Fishing Grounds**



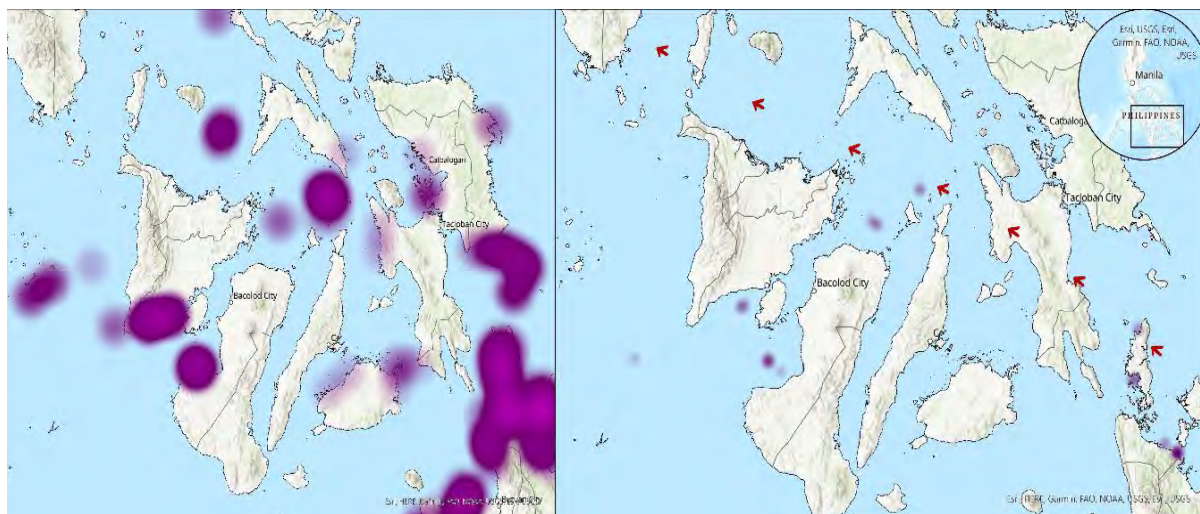
Notes: Fishing ground one (top left), fishing ground two (top right), fishing ground three (bottom left), and fishing ground four (bottom right). Trace plot (left column) and kernel density estimates of the posterior density (right column).

Source: Authors' calculations.

## 5. Impact of Tropical Cyclone Son-Tinh on Western Visayas Region

TC Son-Tinh (locally known as Ofel) entered PAR on 23 October 2012 and crossed Caraga, Surigao del Norte on 24 October 2012. Documented wind maximum speed ranges from 35 to 75 knots/hour. According to the NDRRMC, more than 108,000 persons were affected, and 2,525 houses were damaged. The total cost of damage to the agriculture and infrastructure amounted to \$1,311,340 (NDRRMC 2012c). The fishing grounds faded during the TC (24 October) and as soon as the TC Son-Tinh left the Philippines, the number of fishing boats increased (27 October), and fishing grounds are noticed (Map 11).

**Map 11: Fishing Boats Density During and After Tropical Cyclone Son-Tinh, October 2012**

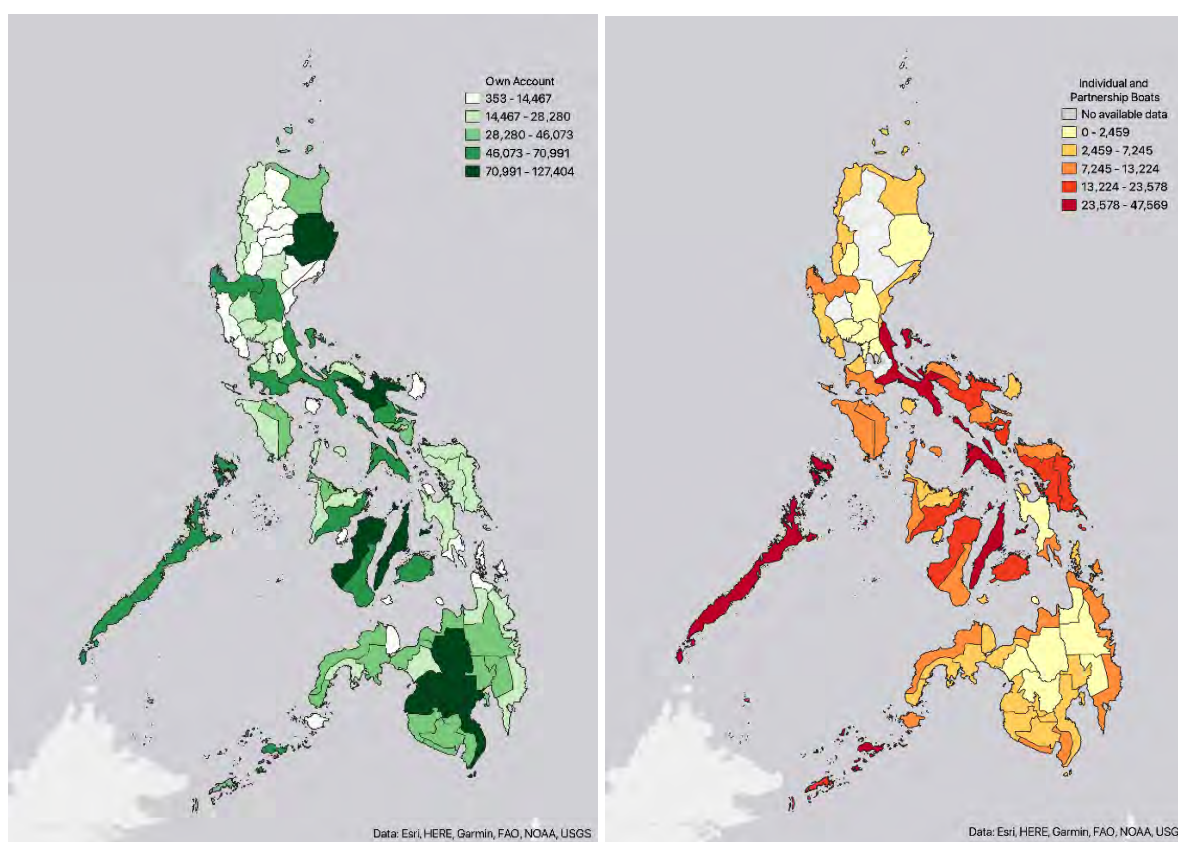


Source: Authors' calculations.

Iloilo, Negros Occidental, Guimaras, and Antique were highly affected by Son-Tinh. These provinces are part of the Western Visayas region where there are more than 400,000 people engaged in fishing. More than 330,000 people are engaged in fishing in Iloilo, Negros Occidental, Guimaras, and Antique, and just around 230,000 individuals in Negros Occidental province alone. Hence, the TC that hit Western Visayas had a direct impact on household income. Moreover, the fishing sector is the main source of income for people engaged in fishing in these regions (Map 12). Fishing is the main source of income for more than 90% of the total families engaged in fishing (Figure 15). The halt and damage to the fishing activity and gears have a significant impact on household daily revenue.

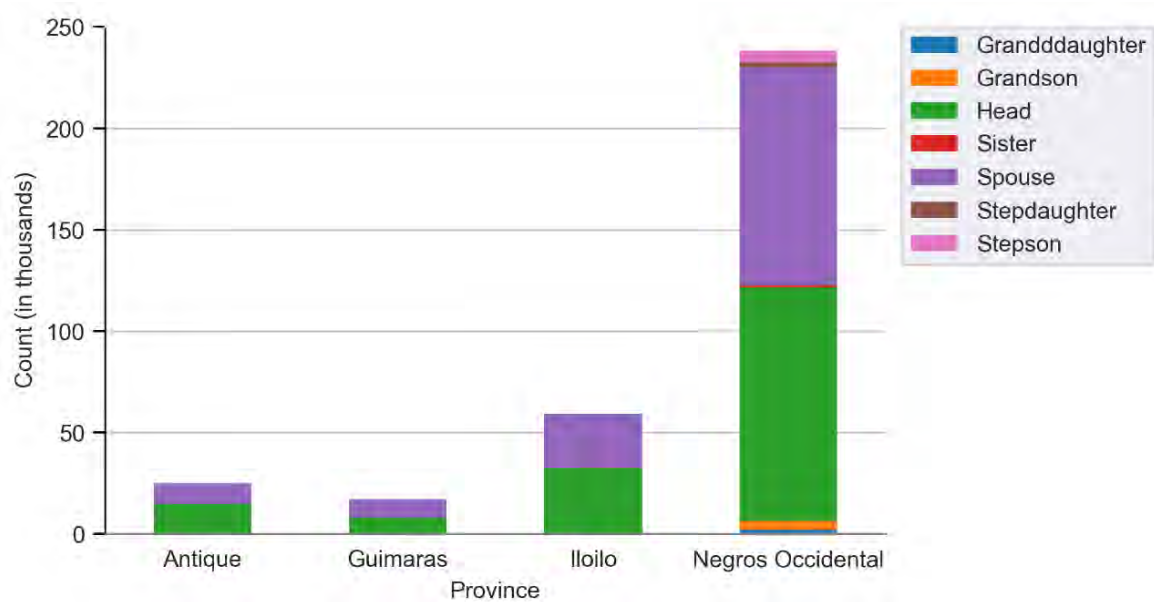


**Map 12: Boat Ownership in the Philippines**



Source: Philippine Statistics Authority. 2012. [Census of Agriculture and Fisheries](#).

**Figure 15: Family Members Engaged in Fishing in Western Visayas, Philippines**



Note: Any other family members whose count is less than 1,000 were excluded from the graph.

Source: Philippine Statistics Authority. 2012. [Census of Agriculture and Fisheries](#).

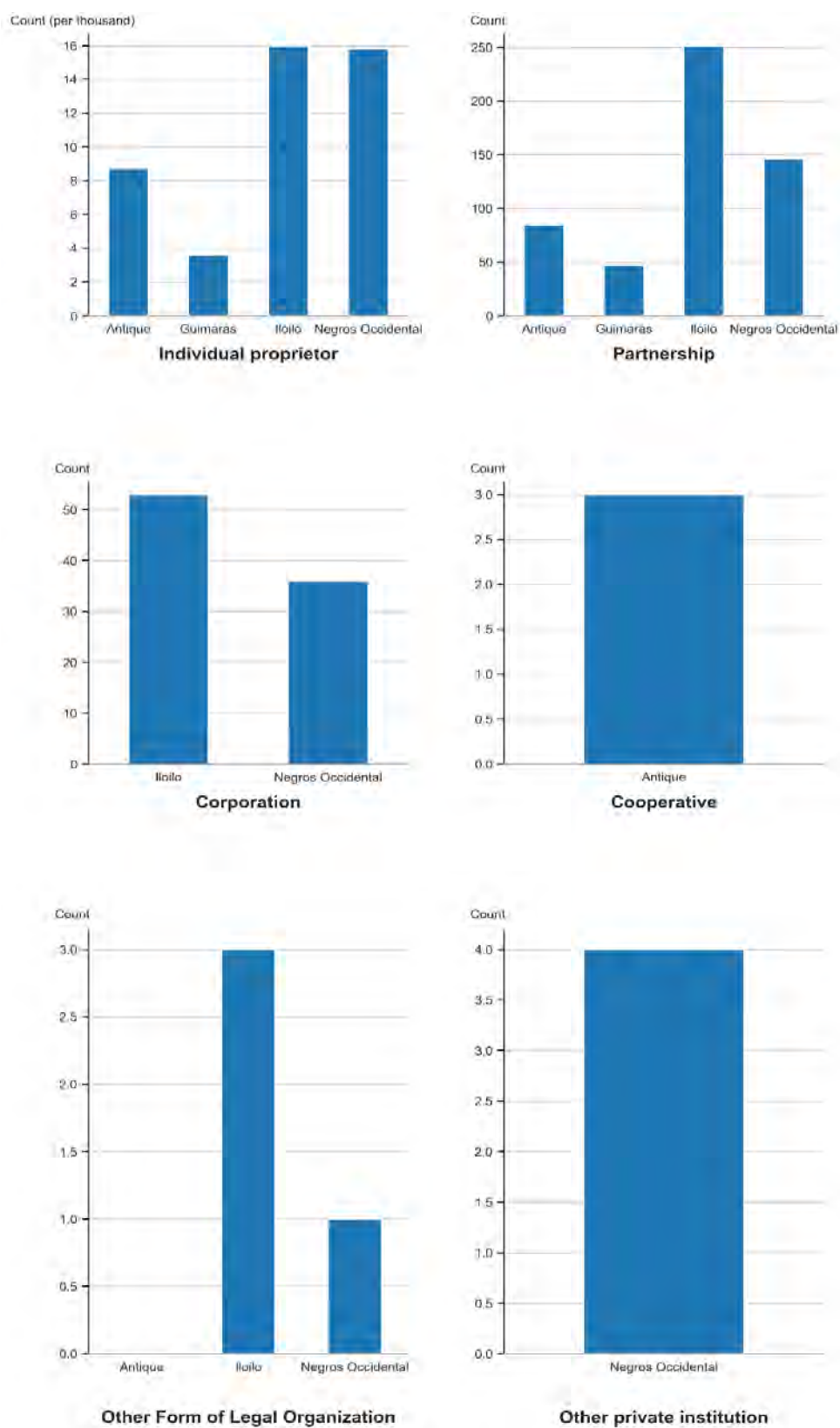
The main fishing boats that utilize lights to attract fish are ring net, bag net, purse seine, modified Danish seine, and round-haul seine. The boats are unequally distributed among provinces. Negros Occidental dominates the larger number of boats in Western Visayas with more than 800 fishing boats, followed by Iloilo and Antique with more than 400 and 120 fishing boats, respectively (Table 7). Most people engaged in the fishing industry are working on their own businesses and are less dependent on the government and large organizations. Western Visayas is no exception, individual proprietor is the main legal form of the fishing organization in Guimaras, Iloilo, and Negros Occidental (Figure 16). The partnership is the second most employed legal form of fishing organization within these provinces. Both individual proprietors and partnerships account for more than 95% of the legal fishing organization form (Figure 16).

**Table 7: Fishing Boats Using Lights**

<b>Boat Type</b>	<b>Antique</b>	<b>Iloilo</b>	<b>Negros Occidental</b>
Purse Seine	28	47	385
Ring Net	100	387	417
Bag net		3	11
Round Haul Seine			9
Modified Danish Seine			2

Source: Philippine Statistics Authority. 2012. [Census of Agriculture and Fisheries](#).

**Figure 16: Fishing Boats' Legal Form in Western Visayas, Philippines**



Source: Philippine Statistics Authority. 2012. [Census of Agriculture and Fisheries](#).



The estimated loss is calculated based on the average CPUE level adapted from Ramiscal et al. (2014), Mamalangkap et al. (2018), and BFAR (2015) (Table 1). Based on the TC duration and number of boats for each province, the estimated production reflects loss level due to inactive fishing activities during the TCs. Purse seine and ring net fishing boats are the primary commercial fishing boats in the Philippines, and account for more than 98% of the total commercial fishing boats in Western Visayas.

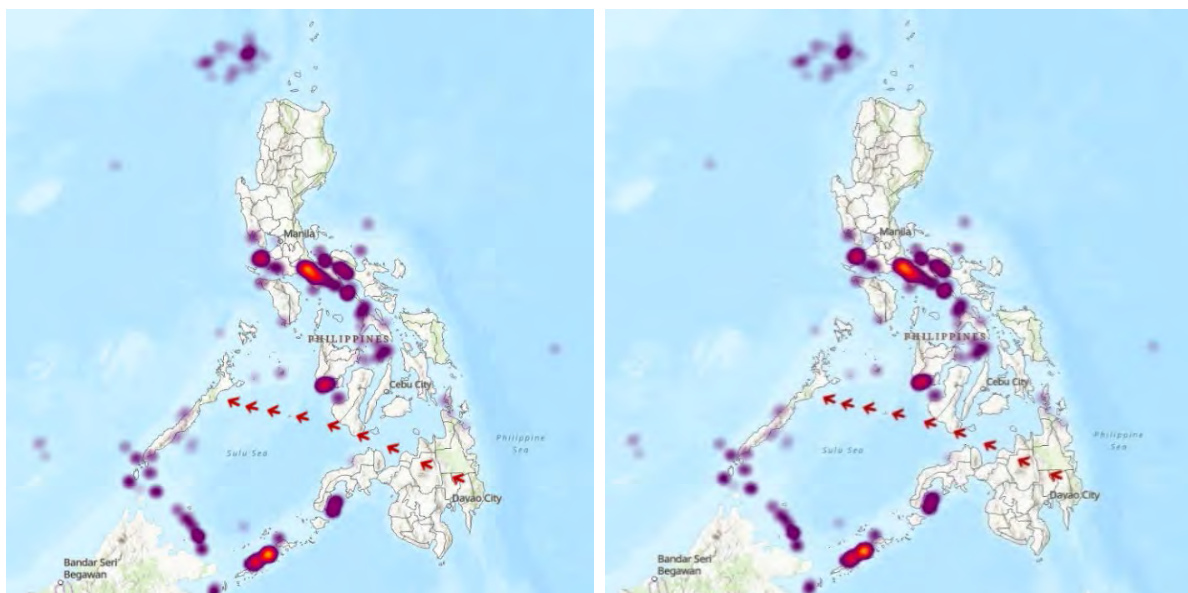
De Guzman et al. (2018) estimated purse seine and bag net CPUE level within Sulu Sea at 15 tons and 1 ton per fishing day. Antique, Iloilo, and Negros Occidental provinces were estimated to have losses of around 6,900 tons and 900 tons daily from purse seine and ring net. The 3 days of TC Son-Tinh led to a total of 23,400 tons reduction in production value in three provinces only. Moreover, the TC damage to the fishing gears ceased fishing activities and would increase daily loss following the TC.

## **6. Impact of Tropical Cyclone Bopha on Zamboanga Peninsula and the Autonomous Region in Muslim Mindanao**

TC Bopha (locally known as Pablo) entered PAR on 2 December 2012 and made its landfall in Baganga, Davao Oriental on 4 December 2012. Documented wind speed ranges between 60 to 100 knots/hour. According to the NDRRMC (2012d), more than 6 million people were affected, 1,067 died, 2,666 were injured, and 216,817 houses were damaged. The total cost of damage to the agriculture and infrastructure amounted to \$874,372,640 and \$1,201,554 to the fisheries sector (NDRRMC 2012d).

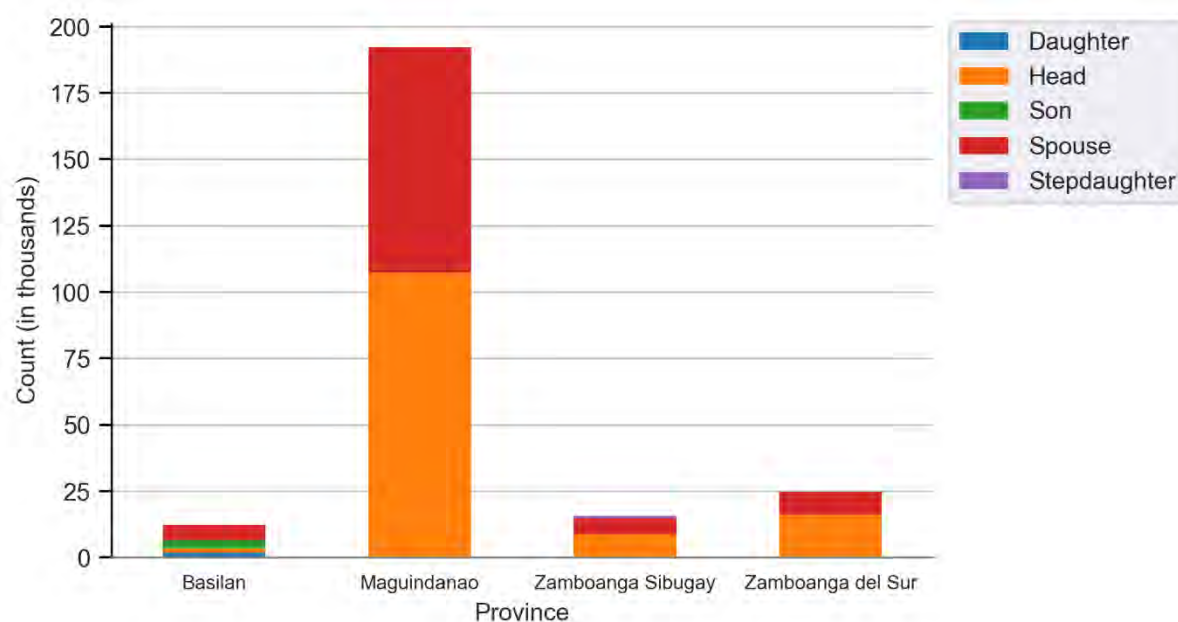
Map 13 shows that TC Bopha had an impact on the fishing ground. Provinces such as Zamboanga Sibugay and Zamboanga del Sur within the Zamboanga Peninsula, as well as Basilan and Maguindanao in Bangsamoro Autonomous Region in Muslim Mindanao (ARMM), were significantly affected. Fishing is the main source of income for families of a large portion of the individuals engaged in fishing (Figure 17). Thus, the TC has a direct impact on a large number of families who depend on daily fishing activities. Moreover, Zamboanga del Sur has the highest number of fishing boats that attract fish utilizing lights, followed by Maguindanao.

**Map 13: Tropical Cyclone Bopha, 2 to 5 December 2012**



Source: Authors' calculations.

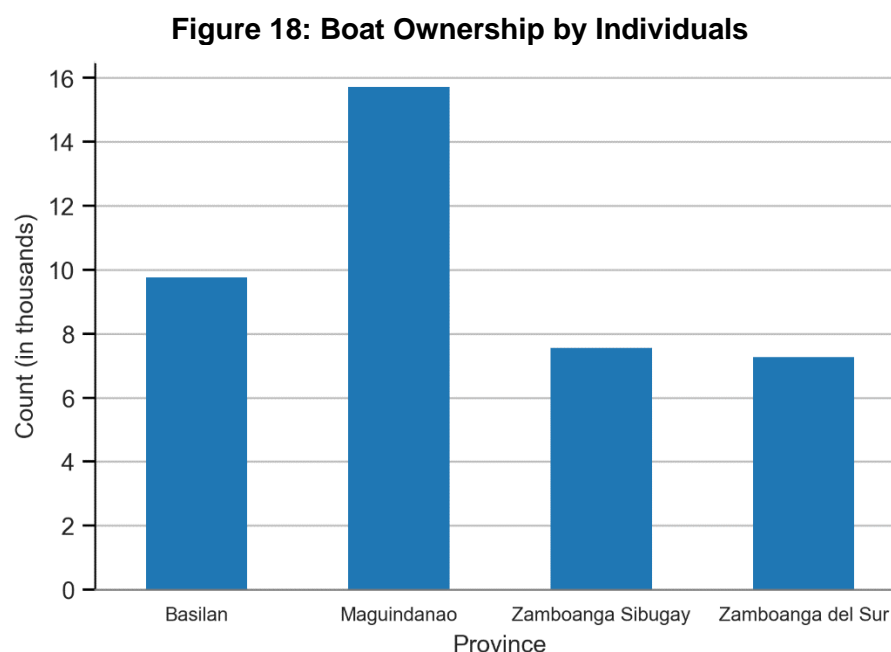
**Figure 17: Family Members Engaged in Fishing**



Note: Any other family members whose count is less than 1,000 were excluded from the graph.

Source: Philippine Statistics Authority. 2012. [Census of Agriculture and Fisheries](#).

Similarly, people engaged in fishing mainly own the fishing boats and are responsible to maintain and cover the damage caused by the TC (Figure 18). Therefore, people and families in these provinces are at high risk of losing their income during, and even after the TC. The TC Bopha led to a decrease in production level in the Zamboanga Peninsula and ARMM regions. The estimated daily production level in ARMM is 9.5 tons/day from purse seine and 6.5 tons/day from ring net (Ramiscal et al., 2014). The ring net boat is the dominant type of fishing boat in ARMM and Zamboanga Peninsula (Table 8). The estimated daily reduction in fishing capacity is estimated at 2,000 tons/day from purse seine boats and 4,180 tons/day from ring net boats. The estimated loss due to interrupted fishing activities during the TC Bopha within Basilan, Maguindanao, Zamboanga del Sur, and Zamboanga Sibugay provinces is 18,538 tons for the 3 days of TC.



Note: Boat ownership by corporation, partnership, and other private institution whose count is less than 1,000 were excluded from the graph.

Source: Philippine Statistics Authority. 2012. [Census of Agriculture and Fisheries](#)

**Table 8: Number of Boats**

Boat/Province	Basilan	Maguindanao	Zamboanga del Sur	Zamboanga Sibugay
Purse Seine	2	55	141	13
Ring Net	146	9	404	84
Bag net	10	278	11	85
Round Haul Seine		1	2	
Modified Danish Seine			2	

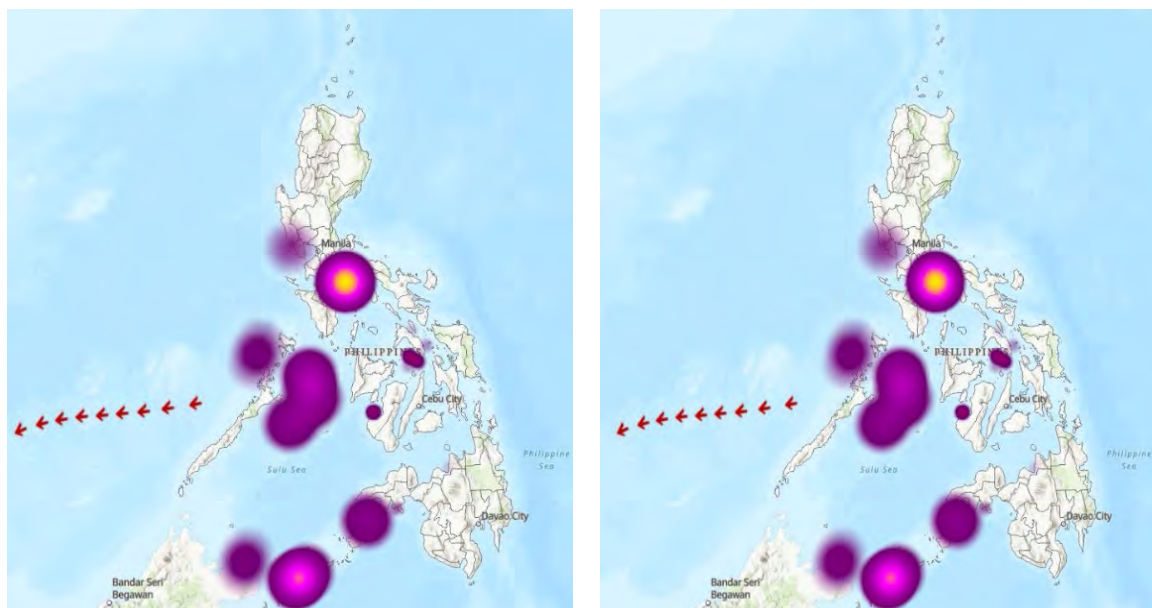
Source: Philippine Statistics Authority. 2012. [Census of Agriculture and Fisheries](#).

## 7. Impact of Tropical Cyclone Wukong on MIMAROPA Region

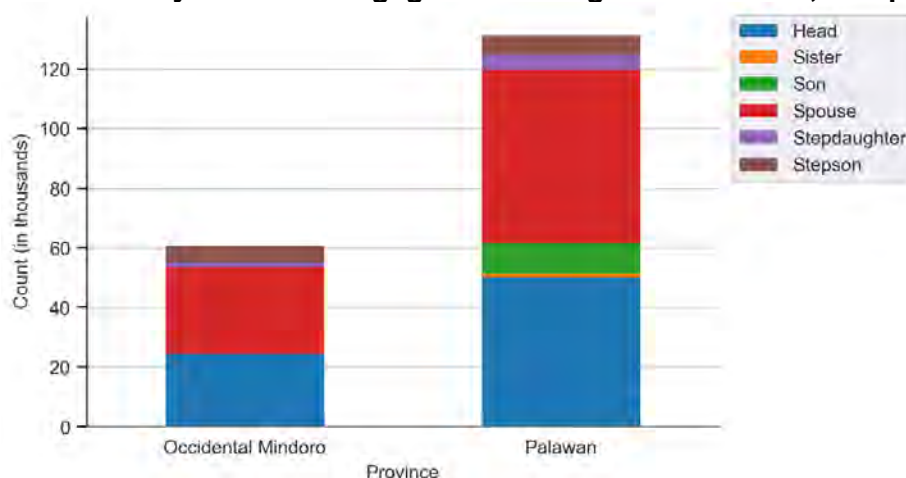
The TC Wukong (locally known as Quinta) entered the Philippines area on 25 December east of Northern Mindanao and moved toward Eastern Visayas, then toward Northern Palawan. Wukong impacted more than 240,000 people and destroyed 5,097 houses. The total damage cost to the agriculture sector was \$3,480,006 and \$1,849,739 on infrastructure (NDRRMC 2012e).

Palawan and Occidental Mindoro in MIMAROPA region were affected by TC Wukong (Map 14). Spouses and fathers are considered the main engaged family members in the fishing sector (Figure 19).

**Map 14: Tropical Cyclone Wukong (Quinta), 26 to 27 December 2012**



Source: Authors' calculations.

**Figure 19: Family Members Engaged in Fishing in MIMAROPA, Philippines**

MIMAROPA = Mindoro Occidental, Mindoro Oriental, Marinduque, Romblon, Palawan.

Note: Any other family members whose count is less than 1,000 were excluded from the graph.

Source: Philippine Statistics Authority. 2012. [Census of Agriculture and Fisheries](#).

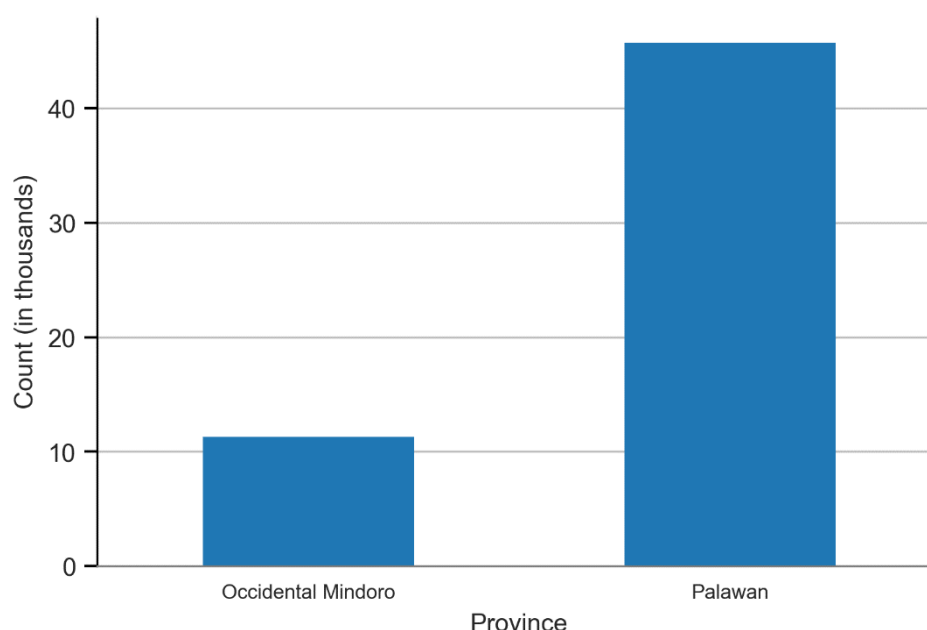
Even though Palawan has a higher number of people engaged in fishing compared to Occidental Mindoro, the number of fishing boats that utilize lights to attract fish in Occidental Mindoro is higher than in Palawan (Table 9 and Figure 20). This is because fewer people operate boats of more than 3 gross tons type for fishing activities in Palawan. On the other hand, the estimated daily commercial fishing production from purse seine boats is 4,000 kg per fishing day and 400 kg per fishing day from ring net boats in Occidental Mindoro and Palawan (BAS 2013). Hence, a halt in fishing activities results in a decrease of more than 280,000 kg/day in Occidental Mindoro and 69,600 kg/day in Palawan (BFAR 2015 and BAS 2013).

**Table 9: Number of Fishing Boats**

Boat Type	Occidental Mindoro	Palawan
Purse Seine	57	13
Ring Net	95	79
Bag net	145	24
Round Haul Seine	25	5
Modified Danish Seine		1

Source: Philippine Statistics Authority. 2012. [Census of Agriculture and Fisheries](#).

**Figure 20: Fishing Boat Ownership by Individual**



Note: Boat ownership for Corporation and Partnership whose count is less than 1,000 were excluded from the chart.

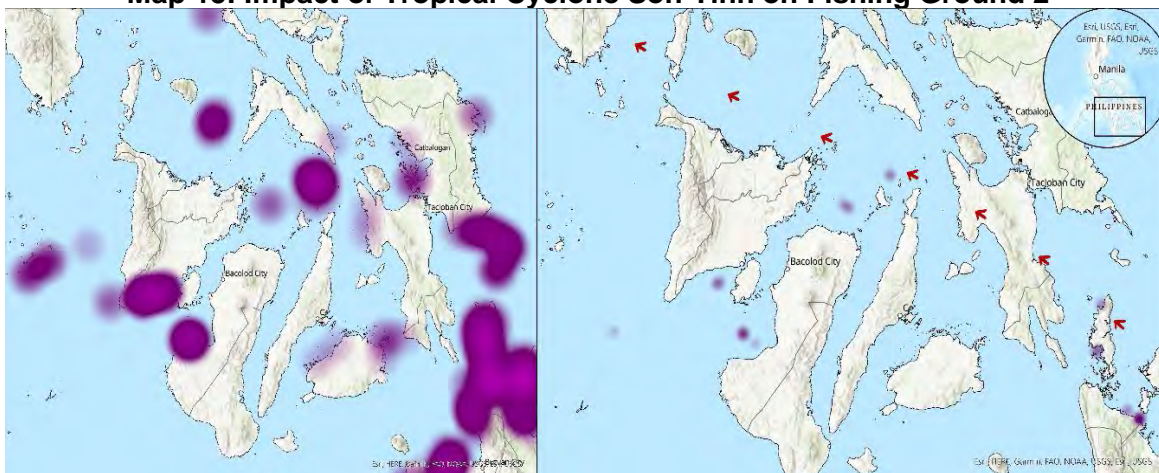
Source: Philippine Statistics Authority. 2012. [Census of Agriculture and Fisheries](#).

Overall, the impact of TCs on fisheries is two-fold. Firstly, TCs reduce daily fishing activities, and as a result, daily revenue is dropped due to strong wind speed and heavy precipitation within the hit area. The number of people who stopped working due to the TC is large and the reduction in daily revenue has a direct impact on individuals' families. Secondly, the impact of the TC may go beyond the TC period because of the damage to the fishing boats. The majority of the people engaged in fisheries are not receiving a fixed monthly wage, but rather work on their own fishing gear. Hence, any damage to the fishing tools and gears has an extended period of impact before the fishing boats and gears are fixed and utilized again in daily fishing activities.

Unlike other fishing grounds, fishing ground 2 witnessed an overall negative impact of all TCs on the number of boats in 2012. Antique, Guimaras, Iloilo, and Negros Occidental, provinces that are part of the Western Visayas region, are highly affected by the TC Son-Tinh. For instance, TC Son-Tinh had a direct impact on fishing ground 2 within the Western Visayas region (Map 15).



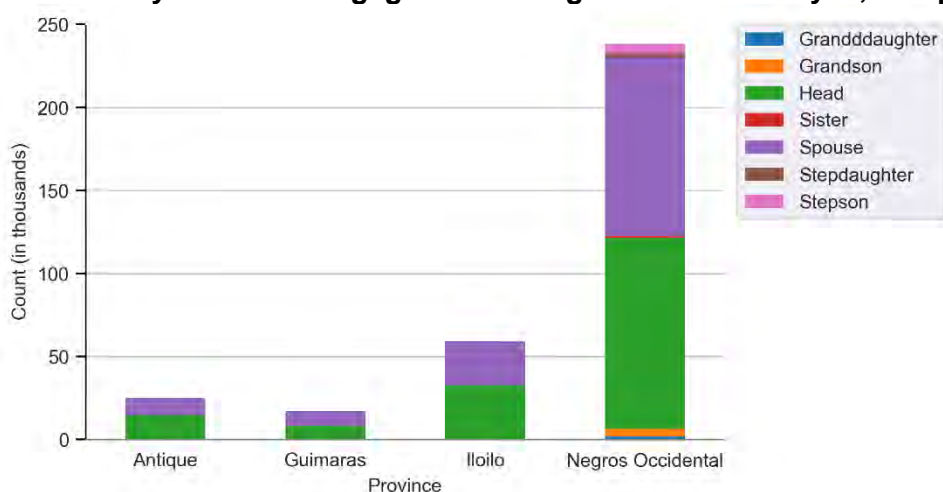
**Map 15: Impact of Tropical Cyclone Son-Tinh on Fishing Ground 2**



Source: Authors' calculations.

TC Son-Tinh's impact is estimated to affect more than 400,000 individuals engaged in fishing in the Western Visayas region (Philippine Statistics Authority 2012 and Figure 21). Moreover, for 90% of people engaged in fishing, it is the key source of income for their families. Hence, the halt in fishing activities and damage to the fishing boats due to the TC put more pressure on a larger number of people in Western Visayas.

**Figure 21: Family Members Engaged in Fishing in Western Visayas, Philippines**



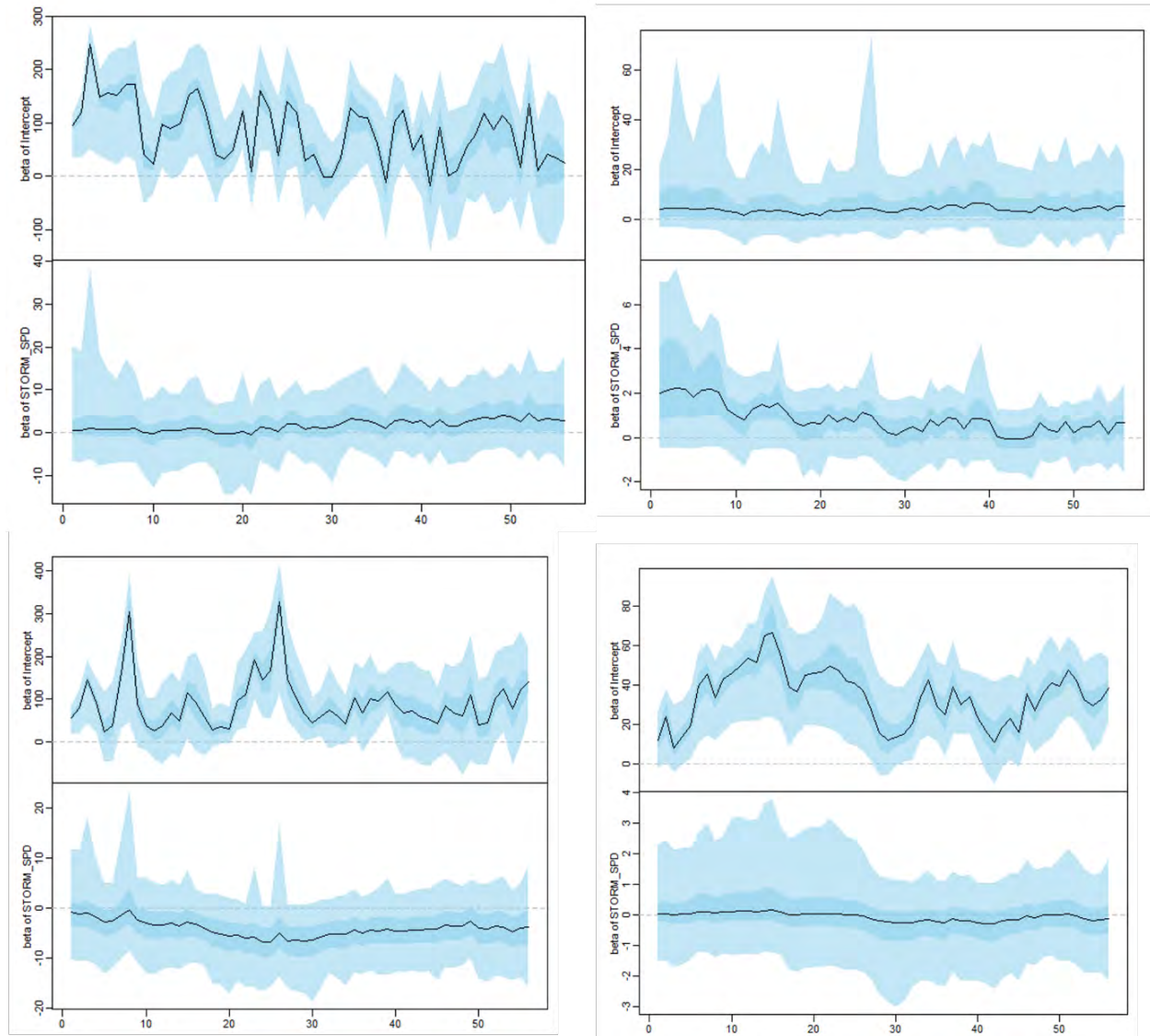
Note: Any other family members whose count is less than 1,000 were excluded from the graph.

Source: Philippine Statistics Authority. 2012. [Census of Agriculture and Fisheries](#).

Overall, the impact of TCs is pronounced within the Philippines area and in each detected fishing ground. Moreover, TCs Wukong and Son-Tinh appeared to have a major impact on all fishing grounds, except ground 4. Most TCs showed to have low storm speed within ground 4, this is because TCs are weakened when crossing the fishing ground.

The impact of storm speed on the number of boats is applied for the year 2020. Results differ from previous ones (Figure 22). Unlike previous results, fishing ground two appeared to be insignificantly impacted by the storm's speed. While fishing grounds one and four seem to be less impacted by the TC, fishing ground three is negatively impacted by the 2020 TC.

**Figure 22: Time-Varying Impact of Storm Speed on the Number of Boats in Four Fishing Grounds, 2020**



LASSO = Least Absolute Shrinkage and Selection Operator.

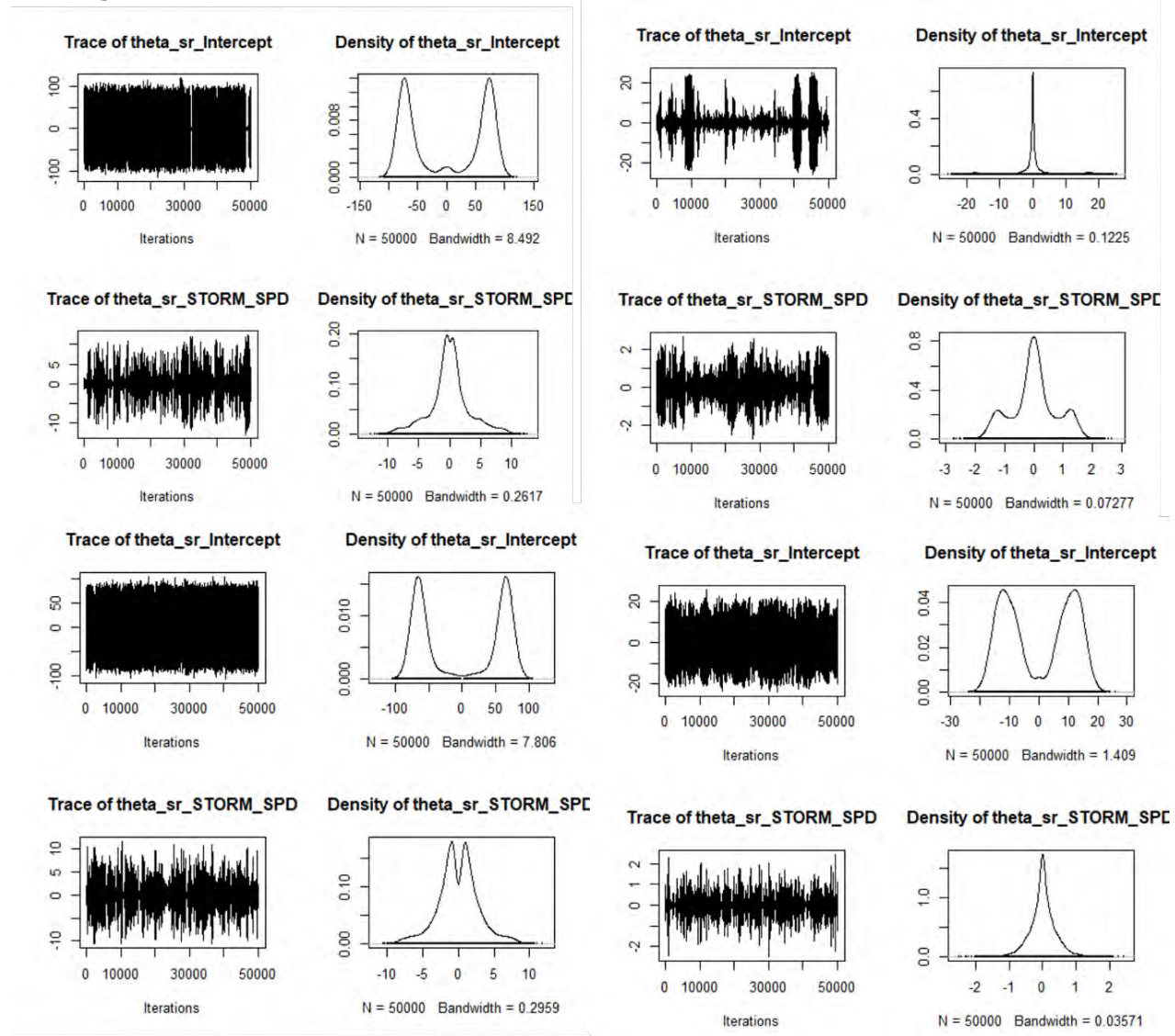
Notes: Hierarchical Bayesian LASSO on Ground one (top left), Hierarchical Bayesian LASSO on ground two (top right), hierarchical Bayesian LASSO ground three (bottom left), and hierarchical Bayesian LASSO on ground four (bottom right). The x-axis reflects the time, and the y-axis displays the coefficient magnitude. The median is displayed as a black line, and the shaded areas indicate the pointwise 95% and 50% posterior credible intervals.

Source: Authors' calculations.



While results of the fishing grounds 2 and 3 differ between 2012 and 2020, both fishing grounds are centered within the Philippines area. Figure 23 denotes storm speed density and trace plot. The bimodal shape of the density plot reflects the non-identifiability of the standard deviation sign.

**Figure 23: Markov Chain Monte Carlo Posterior of Four Fishing Grounds in 2020**



Notes: Fishing ground one (top left), fishing ground two (top right), fishing ground three (bottom left), and fishing ground four (bottom right). Trace plot (left column) and kernel density estimates of the posterior density (right column).

Source: Authors' calculations.

## 8. Conclusion

Since individuals are engaged in fishing activities in the Philippines—800,000 and more than \$1.5 billion of commercial production depended on it in 2012—a halt or interruption of fishing activities has a direct impact on both household income and government revenue. A major threat to fishing activities is TCs. The Philippines witnessed an average of 44 days of TCs in 2012. In this study, fishing grounds are determined using kernel density and VIIRS Boat Detection methods to identify and assess highly impacted regions and provinces.

The main fishing grounds in the Philippines fall within the following regions: National Capital Region, Calabarzon, Central Luzon, MIMAROPA, Bicol, Western Visayas, Zamboanga Peninsula, and Bangsamoro Autonomous Region in Muslim Mindanao. The TC Son-Tinh that occurred on 23 to 25 October 2012 had a direct impact on fishing activities in Antique, Guimaras, Iloilo, and Negros Occidental in the Western Visayas region. About 960,000 people working in the fisheries were affected and there was a 7,800 tons/day reduction in commercial fishing production. TC Bopha, on the other hand, occurred on 2 to 4 December 2012 and impacted fishing activities in several provinces including Basilan, Maguindanao, Zamboanga del Sur, and Zamboanga Sibugay. About 240,000 people working in the fishing sector were affected and there was a decrease of 6,180 tons/day in commercial fishing production. TC Wukong, which occurred on 25 to 27 December 2012 affected 200,000 people who rely on fishing from Occidental Mindoro and Palawan, and the estimated daily loss due to the suspension of fishing activities was 350 tons.

The VGLM and Bayesian TVP were used to assess the storm speed impact of the TCs. VGLM and Bayesian TVP results revealed an overall negative impact of the TCs on the number of fishing boats. Each fishing ground responds differently to the TC as per the TC's speed and distance. Also, fishing grounds may witness an increase in fishing boats due to the decrease in other small fishing areas. However, TCs Son-Tinh and Bopha appeared to significantly reduce the number of boats for all fishing grounds, because of the strength as well as the large area affected by these TCs. Fishing activities appeared to recover at least 2 days following the TC. TCs that occurred in 2020, on the other hand, revealed that fishing ground 3 is the main impacted area. Both fishing grounds 2 and 3 are approximated and centered within the Philippines EEZ.

Notably, for most individuals engaged in fishing, it is the main source of income for their families. The majority of fishing boats are owned by individuals. Hence, suspension and damage to fishing activities and boats have a significant impact on numerous families and are likely to

remain even after the TC, especially if no appropriate insurance plan is applied. Future studies should investigate the role of insurance schemas during and following TCs.

## APPENDIX

**Table A10: The Philippines' Regions**

<b>Number</b>	<b>Region</b>
<b>1</b>	Ilocos Region
<b>2</b>	Cagayan Valley
<b>3</b>	Central Luzon
<b>4</b>	Calabarzon
<b>5</b>	Bicol Region
<b>6</b>	Western Visayas
<b>7</b>	Central Visayas
<b>8</b>	Eastern Visayas
<b>9</b>	Zamboanga Peninsula / Western Mindanao
<b>10</b>	Northern Mindanao
<b>11</b>	Davao Region /Southern Mindanao
<b>12</b>	Soccsksargen / Central Mindanao
<b>13</b>	National Capital Region
<b>14</b>	Cordillera Administrative Region
<b>15</b>	Bangsamoro Autonomous Region in Muslim Mindanao
<b>16</b>	Caraga Region
<b>17</b>	MIMAROPA / Southwestern Tagalog

**Table A2: Detected Fishing Ground Location**

	<b>Province</b>	<b>Region</b>
<b>1</b>	Metropolitan Manila	National Capital Region
<b>2</b>	Cavite	Calabarzon
<b>3</b>	Batangas	Calabarzon
<b>4</b>	Quezon	Calabarzon
<b>5</b>	Bulacan	Central Luzon
<b>6</b>	Pampanga	Central Luzon
<b>7</b>	Bataan	Central Luzon
<b>8</b>	Marinduque	MIMAROPA
<b>9</b>	Palawan	MIMAROPA
<b>10</b>	Romblon	MIMAROPA
<b>11</b>	Oriental Mindoro	MIMAROPA
<b>12</b>	Camarines Sur	Bicol Region
<b>13</b>	Masbate	Bicol Region
<b>14</b>	Albay	Bicol Region
<b>15</b>	Sorsogon	Bicol Region
<b>16</b>	Negros Occidental	Western Visayas
<b>17</b>	Iloilo	Western Visayas
<b>18</b>	Guimaras	Western Visayas
<b>19</b>	Antique	Western Visayas
<b>20</b>	Zamboanga Del Sur	Zamboanga Peninsula
<b>21</b>	Zamboanga Sibugay	Zamboanga Peninsula
<b>22</b>	Basilan	Bangsamoro Autonomous Region in Muslim Mindanao
<b>23</b>	Sulu	Bangsamoro Autonomous Region in Muslim Mindanao
<b>24</b>	Tawi-Tawi	Bangsamoro Autonomous Region in Muslim Mindanao

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## **The Impact of Tropical Cyclones on Fishing Activities in the Philippines**

This study looks at fishing activity in the Philippines' Exclusive Economic Zone in 2012, as well as how it responded to tropical cyclones. The study identifies the main fishing grounds and examines the impact of tropical cyclone speed on vessel position using satellite images and tropical cyclones data. Data suggest that tropical cyclones have a negative impact on fishing activity, with fewer active boats during and after the storm. The most affected locations include the Sibuyan Sea, Visayan Sea, and Panay Gulf. These tropical cyclones were estimated to reduce commercial fishing production by 7,800 tons per day, affecting more than 188,000 families in Western Visayas.

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