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Research Article

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Changing of Sea Surface Temperature Affects Catch of Spanish Mackerel *Scomberomorus Commerson* in the Set-Net Fishery

Khanh Q Nguyen[1,2] and Vang Y Nguyena[1]

[1]*Fisheries and Marine Institute, Memorial University of Newfoundland, 155 Ridge Road, St. John's, NL, A1C 5R3, Canada*

[2]*Institute of Marine Science and Fishing Technology, Nha Trang University, 9 Nguyen Dinh Chieu, Nha Trang, Vietnam*

***Corresponding author:** Khanh Q Nguyen, Fisheries and Marine Institute, Memorial University of New foundland, 155 Ridge Road, St. John's, NL, A1C 5R3, Canada,Tel: +1 709 7780630; E-mail: khanh.nguyen@mi.mun.ca

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Abstract

This paper reviews the Spanish mackerel *Scomberomorus commerson* landing status of the set-net fishery and changing sea surface temperature (SST) in Nha Trang city, Vietnam in the 12th year period. The observation of both catch and individual weight showed a general trend of declining between 2005 and 2016. Catch yield of set-net fishery significantly depended on season and moon phase resulting from highest harvesting in April and May, as well as in the new moon and last quarter of phases. SST in the Nha Trang bay was significant increase of 0.0520C per year, while the catch and SST were also significantly related, with a negative parameter of slope. Results from General Linear Model using Bayesian Model Average showed that the moon phase, year and SST factors explained the variation in catch of Spanish mackerel.

Keywords Spanish mackerel; Climate change; Sea surface temperature; Catchability; Set-Nets

Introduction

Nha Trang is a coastal city located in Khanh Hoa province, in south central Vietnam. Nha Trang bay includes hundreds of islands and two marine protected areas, and is situated in the upwelling region [1,2], that is a good advance for stationary fisheries (e.g. set-net) operating. Fisheries represent a major contributor to the economy and employment of this city, especially in coastal communities [1]. Landings in 2016 were approximately 93,049 metric tons corresponding with US $ 251 million in landed value [3]. Multiple fishing methods (e.g. purse seining, trawling, longlining, gill netting, trapping and set-net) exist in this place [4,5].

Set-Net is a passive kind of stationary, environmentally friendly, and energy-saving fishing gear designed to catch multiple pelagic fish on the basis of fish behaviour [6-8]. The harvesting performance of set-nets therefore depends on fish abundance attracted in the setnet trap [6]. The set-net fishery is considered one of the traditional fishing industries in Nha Trang city mostly catching Spanish mackerel *Scomberomorus commerson*, accounting for 86%, followed by skipjack tuna Katsuwonus pelamis, Indian mackerel Rastrelliger kanagurta, and others, accounting for 7%, 4% and 3%, respectively [9,10]. Given an important fishing industry in the past, set-nets contributed millions US dollar to local income of Nha Trang city in 1980s and 1990s [10]. There were several set-nets in this city in 1995 [9,10], while a single operating set-net was chosen to present in this study. The set-net fishery has decreased in the last decades, the main reason being declining total catch and profit [5]. Although capture efficiency for set-nets are often low, and the set-nets fishery contributes a negligible number to total catch of Nha Trang city currently [3,4], its products are high value and good quality due to less interaction with fishing gear [10]. In addition, traditional set-net fishery is encouraged to remain by local government in order to support the marine tourist industry [5].

Spanish mackerel are a high migration species belonging to the family *Scombridae*. The species have been found in the Indo-West Pacific from South Africa and the Red Sea east to Australia, Fiji, China, Japan, and Mediterranean Sea [11]. As Spanish mackerel mature and increase in size, they migrate from the coastal water where abundant coral reef has in early life toward the deeper areas when become the maturity [12]. As a temperature hypersensitivity species, their living temperature ranges from 13°C to 29°C, with the depth ranging between 10 and 169 m, and salinities in the range 23%-35% [11,13]. The life cycle is up to 20 years in duration, and natural mortality rate is estimated at 0.27 per year [12]. Prey of Spanish mackerel consists of a*nchovies Anchoviella, clupeids Sardinella, slipmouths Leiognathus, penaeoid shrimps Penaeus* and *squid Todarodes pacificus* [11-13].

With global climate change, the sea surface temperature (SST) in South China Sea has been increased in average of 0.014°C annually [14]. This SST increase has produced both directly negative effects, as well as potential risks on marine fisheries, in particularly inshore and pelagic fisheries [14]. These impacts include larval, growing, maturity, distribution, and migration [15,16], resulting in declining landings of mackerel in the year with high SST [17,18].

As a major composition of set-net fishery, the purpose of this study is to investigate the effect of SST change on catch rate of set-net fishery targeting mackerel in Bich Dam village, Nha Trang city, Vietnam.

Materials and Methods

Research site

The observed set-net has belonged to the Fishing Cooperative Bich Hai located at Bich Dam village, Nha Trang City, Khanh Hoa province, Vietnam (Figure 1). The set-net has been set at position between 1209 '5''N- 12011'34''N and 109019'49''E- 109021'19''E. The fixed depth of the set-net ranges from 5 m to 30 m. The bottom substrate is mud-sand and sand. Average longshore current is from 20.7 cm/sec to 22.7

cm/sec in the northeast-east and southwest-west (25°C-205°C) directions, mixed tide area with 3 m tidal range, SST between 26°C and 30°C, salinity ranging from 23 ppt to 25 ppt, and sea water transparency at 5 m-12 m [19].

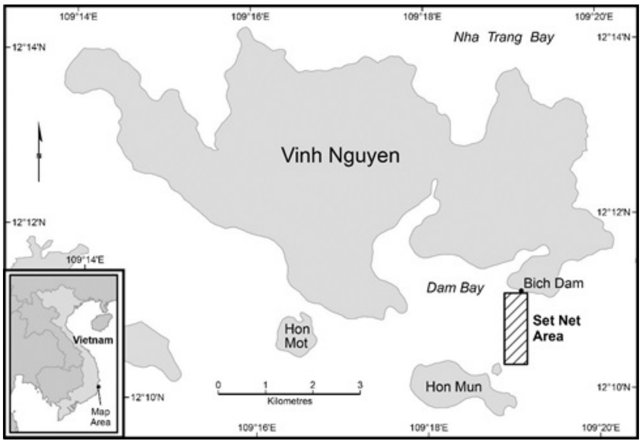

Figure 1: Map of set-net located in Bich Dam village, Nha Trang city, Khanh Hoa province, Vietnam.

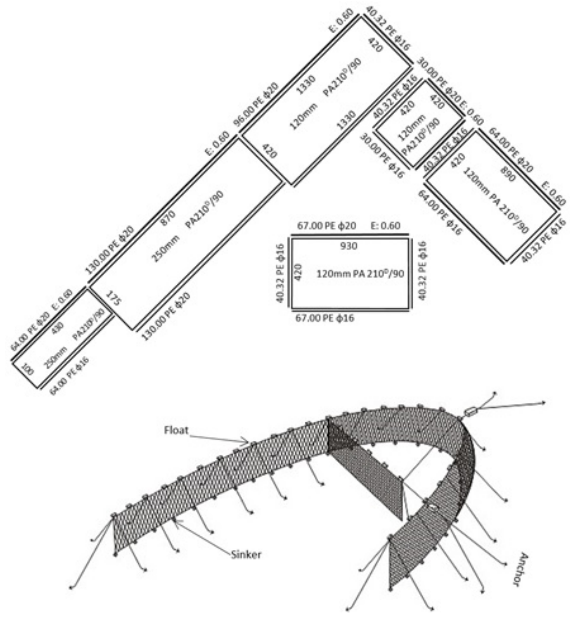

Figure 2: Set-net plan in Fishing Cooperative Bich Hai, Bich Dam village, Nha Trang city, Khanh Hoa province, Vietnam.

Set-net

Figure 2 illustrates the Bich Hai set-net at Bich Dam, Nha Trang city where we collected data of catch. The set-net mechanism is fixed by anchors, and floated by the globular Polyvinyl chloride (PVC) floats. The net is set once during the fishing season. The set-net consists of two components including leaders and playground with a special maze entrance. The leader net is extended from shoreline and fixed across the movement direction of fish schools. The leader net is 500 m long and the height equal to the depth of the fishing ground gradually increases from the shoreline. The net is made of nylon multifilament of 210D/90 with mesh size of 250 mm. The playground directly connects leader, which consists of an entry. The special structure of the entry is complicated to reduce the escape of fish from the playground. The mesh size of the playground net is smaller than that of the leader net, which varies from 90 mm to 120 mm. Finally, a lift net is used to harvest fish kept in playground. The net made of nylon multifilament of 210D/9-210D/21 with mesh size of 30 mm. Set-net was only operated in the evening, and standing by during the daytime.

Data collection

A daily catch data were taken from a mandatory fishing logbook of set net fishery at the Fishing Cooperative Bich Hai in the period between 2005 and 2016. Moon phases were obtained from the U.S. Naval Observatory website as cited by [20]. The four principal moon phases are considered including new moon which is from 1st to 8th of the lunar day, first quarter which is from 9th to 15th of the lunar day, full moon which is from 16th to 22nd of the lunar day, and third quarter which is from 23rd to 30th of the lunar day. Data of SST was obtained from Vietnam National Centre for Hydrometeorological Forecasting (NCHMF). The SST collection stations were located at the Nha Trang bay.

Statistical analysis

Catch comparison between years, months and moon phases, as well as average weight comparison was based on One-way ANOVA via "aov" function with RStudio. Pairwise post hoc analyses were performed using Tukey's HSD. Year, month, and weight were considered by continuous variable, while moon phase was a categorical variable. A Regression General Linear Model was used to determine the relationship between the catch yield and temperature. A general trend of average weight of mackerel, changing of SST was also based on a Regression General Linear Model. For using the ANOVA and Regression General Linear Model we explored and found that assumptions were met with regard to homogeneity of variance, normal distribution of errors, independence of errors, and errors sum to zero. General linear models (GLM) based on the Bayesian Model Average multiple regressions were conducted to estimate the effects of year, month, moon phase, and temperature factors on the catch. The most appropriate model was chosen based on the lowest BIC and highest posterior probability. Analyses were performed with RStudio for Windows. All analyses were calculated at a confidence level of p-value<0.05.

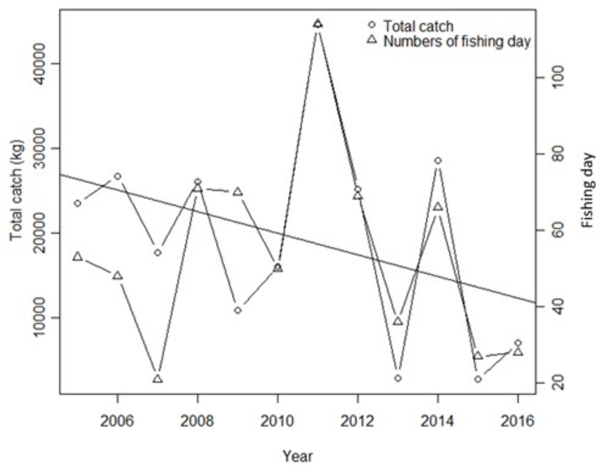

Figure 3: Total catch and numbers of fishing day during years of between 2005 and 2016. Black straight line represents the trend of total catch yield of set-net. Slope of decrease is minus 1276 kg per year (p-value<0.001).

Results

A total of 653 operating days and catch of set-net from 2005 to 2016 is illustrated in Figure 3. The total catch peaked at 44,672 kg in 2011 and then decreased 6,998 kg in 2016, while a general trend of total catch was significantly reduced during this time series (F-value=5.356; p-value<0.001). The numbers of fishing days varied between 21 days (i.e. in 2007) and 114 days (i.e. in 2011), and were proportional with total catch yield in each year. Mean catch per operating day that was defined as the Catch Per Unit Effort (CPUE) of Spanish mackerel harvested between 2005 and 2016 showed a fluctuation, which was highest value in 2007, with 842.38 (± 225.52) kg per operation, and lowest value in 2013, with only 79.42 (± 10.12) kg per operation (Figure 4).

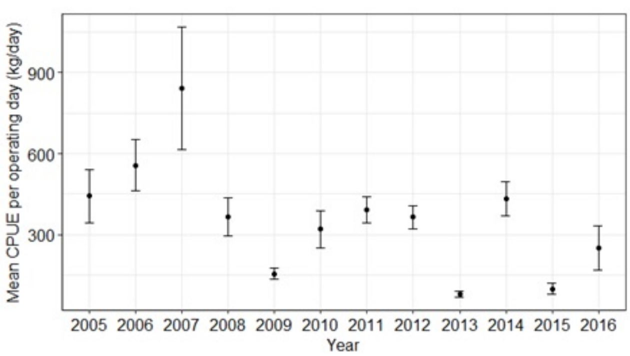

Figure 4: Mean CPUE per operating day in the twelve year period. The black dots are mean value. Bars are errors.

Although set-nets in Nha Trang bay operated between February and September, average catch in April and May was significant higher than other months across 12-years (p-value<0.001), with average catch reached approximately 7,813 kg in April and 5,227 kg in May, while less than 2,000 kg for remains (Figure 5).

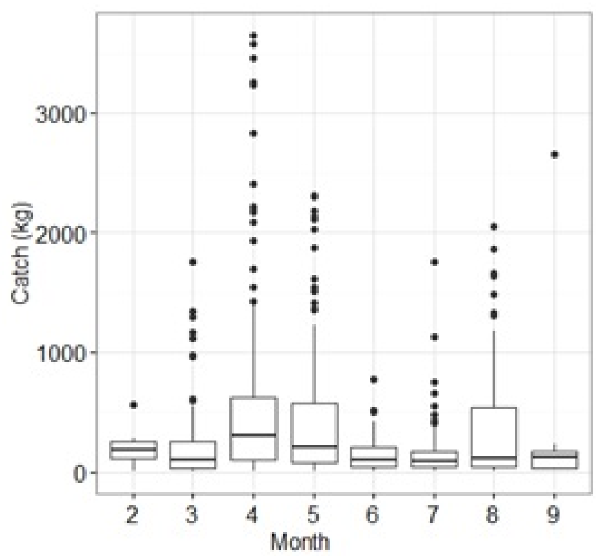

Figure 5: Boxplots of catch yield in different months across twelve year period. The band in the box is the median value. The bottom of the box is the lower quartiles, and the top of the box is the upper quartiles. The ends of whiskers are the 1.5 interquartile ranges. The high maximum points are outliers.

The catch observed for the different moon phases are shown in Table 1. New moon period harvested the highest catch, peaking at 68,291 kg corresponding to 29.46%, followed by last quarter of moon phase, accounting for 66,379 kg corresponding to 28.63%, and 57,816 kg for the first quarter, accounting for 24.94%, and finally the full moon, with only 39,359 kg corresponding to 16.98%. Post-hoc comparisons revealed a significant difference between the last quarter and full moon (t-value=221.76; p-value=0.001) as well as a significant difference between new moon and full moon (t-value=180.99; p-value=0.009).

Moon phases	Number of fishing day	Total catch (kg)	Percentage (%)

New moon	165	68,290.97	29.46
First quarter	173	57,816.37	24.94
Full moon	169	39,358.59	16.97
Last quarter	146	66,378.55	28.63
Moon phase comparison	t-value	95% CI	p-value
Full moon vs first quarter	-101.31	-248.29 to 45.67	0.286
Last quarter vs first quarter	120.45	-32.28 to 273.17	0.177
New moon vs first quarter	79.69	-68.19 to 273.17	0.507
Last quarter vs full moon	221.76	68.21 to 375.31	0.001
New moon vs full moon	180.99	32.26 to 329.72	0.009
New moon vs last quarter	-40.76	-195.17 to 113.65	0.904

Table 1: Mean catch of mackerel for the different moon phases, including their pairwise post hoc comparison using Tukey's HSD. SE is standard error of the mean and CI is confident interval. New moon is from 1st to 8th of the lunar day; First quarter is from 9th to 15th of the lunar day; Full moon is from 16th to 22nd of the lunar day; and third quarter is from 23rd to 30th of the lunar day.

Figure 6 illustrates the mean weight for mackerel caught during the 12 year-period. Based on the one-way ANOVA revealed that the mean weight of mackerel significantly varied between the years (F-value=6.367, p-value<0.001). However, a general trend of average weight changing between 2005 and 2016 shows a decrease according to the equation: Average Weight=157.05644–0.07695 *Year with statistically significant (p-value<0.001) for all parameters.

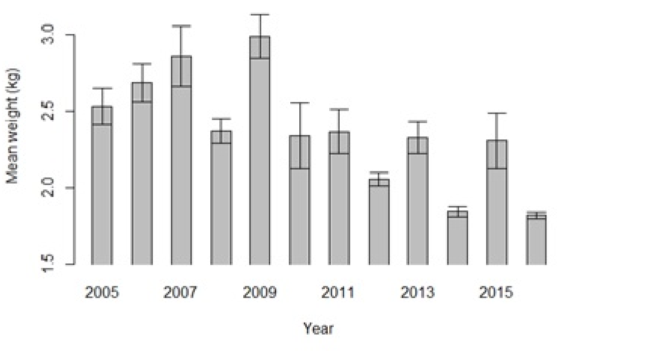

Figure 6: Mean weight of mackerel captured during each of the 12-years. Bars are standard errors.

Mean SST in Nha Trang bay including the set-net located is illustrated in Figure 7. Results from general linear regression analysis showed that SST significantly increased between 2005 and 2016, with a positive value of slope of 0.052°C per year (p-value<0.001). Analysis results also revealed the first quarter of 12 year-period showing a greatest temperature change, with value of 0.074°C per year for slope (p-value<0.001), followed by second quarter, fourth quarter, and third quarter, with both positive slope of 0.065, 0.039, and 0.029, respectively, (p-value<0.001 for all parameters). The relationship between catch yield and SST is showed in Figure 8. The negative slope indicates the catch significantly decreased with increasing temperature.

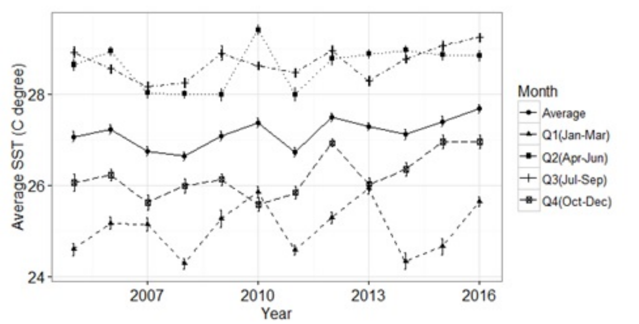

Figure 7: Mean SST in Nha Trang bay for different seasons from 2005 to 2016. Bars are standard errors. Q1, Q2, Q3, and Q4 is quarter 1, 2, 3, and 4 of year, respectively.

Although there are four appropriate models to describe catch yield by using Bayesian Model Average multiple regression, the most parsimonious model included only parameters for moon phases, year and SST (based on lowest BIC and highest posterior probability) (Table 2). The probability of the regression coefficient being different from zero for the month factor was very low, only 11.8%, compared to 94.3%, 60% and 59.7%% for the year, temperature, and moon phase factors, respectively (Table 3). A negative coefficient for year and temperature for all models indicate a lower catch yield was observed with each year and increasing temperature. The predicted value of the most parsimonious model showed a good fit versus the observed value less than 2000 kg (Figure 9). An uniform distribution was found in the plot of the deviance residual versus the linear predictor of the model. This plot also showed the symmetric evidence of the deviance residual.

Model	Equation	R^2	BIC	Posterior probability
1	CY=47628.43+48.76*MP -22.96*Yr -44.1*T	0.039	-6.233	0.311
2	CY=45415.62-21.79*Yr -44.19*T	0.028	-5.481	0.214
3	CY=47844.53+48.86*MP -23.68*Yr	0.027	-5.091	0.176
4	CY=45627.45 -22.52*Yr	0.017	-4.389	0.124
5	CY=46660.38-27.52M+50.87MP -23.03*Yr	0.034	-3.15	0.067

Table 2: Bayesian Model Average multiple regression describing catch yield (CY) for different variables. (M) is month; (MP) is moon phase; (Yr) is year; and (T) is SST.

Discussion

In this study we found that the total landing of Spanish mackerel dramatically decreases from approximately 23,457 kg in 2005 to only 6,998 kg in 2016, while SST in Nha Trang bay increases at the same time. There was a significant negative correlation between the catch and SST. In addition, the highest monthly catch of set-net fishery is concentrated in April and May which reaches 68% of total landing. However, SST, moon phase and year are the significant factors contributing to the Spanish mackerel catch of set-net fishery. Landing statistics reveal that, like other pelagic species Spanish mackerel often aggregate at the deeper positions at night during the full moon days, while they move toward the surface and school for feeding in the no moon days [21,22]. Although Spanish mackerel was harvested by set-net in the wide range of temperature, 93% catch was distributed between 26°C and 30°C (Figure 8). This is consistent with published literatures that this species was found at the temperature from 14°C to 31°C [5,9,11,13]. Set-net fishery used to be an important industry in Nha Trang city, Vietnam [9,10]. In recent years, with the advent of findings that the fishery resources are dwindling for many reasons. Harvesting performance declines led to most set-nets ceasing to operate [5]. However, anglers, fisheries managers and other stakeholders have started to recognize the importance of the role of set-net fishery contributing to sustainable development of local fisheries and economic development. Therefore, a substantial number of studies have been conducted during the last years on its capture and improvement of fishing efficiency of this fishery as contributing to sustainable coastal fisheries development and management [5]. Set-net fishery is not only developing in Vietnam, but also effectively harvesting in other countries, such as Thailand, Taiwan, and Japan, which is considered one of the major fishing industries in these countries [6,8,14,23,24]. For example, set-nets contributed 14% of the total marine fishing yield in Japan in 2009 [6].

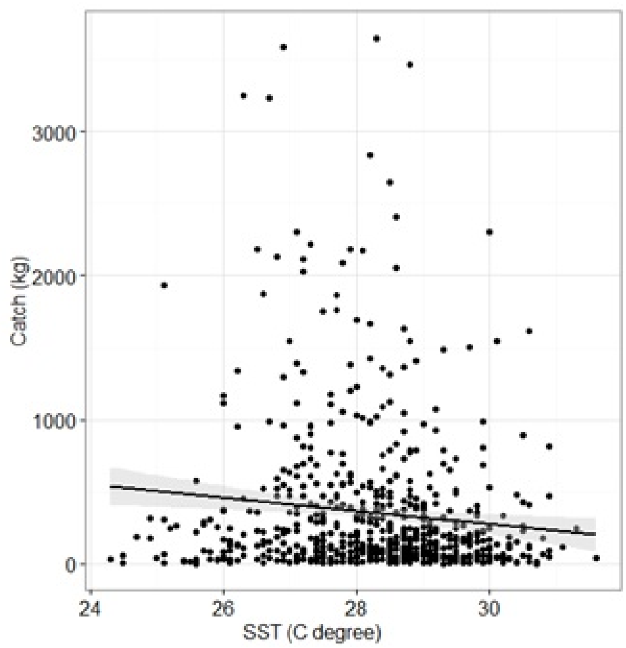

Figure 8: Scatter plot of relationship between catch yield and sea surface temperature for time series of 12-years. A solid line is the regression line. Light black area is the 95% confidence interval. The linear regression model for this relation is Catch=45627.45–22.52*(SST). All parameters are statistically significant (p-value<0.001). Correlation coefficient between the catch and SST was minus 0.11 (p-value=0.004).

Parameter	Regression coefficient probability being different from zero (%)	Expected value	Standard deviation
Intercept	100	44122.84	16921.62
Yr	94.3	-21.428	8.47
T	60	-26.447	24.97
MP	59.7	29.171	27.8

M	11.8	-2.933	9.38

Table 3: Estimated coefficients.

The variation of SST at Nha Trang bay was strongly influenced by ENSO operation in this region. For example, the years of 2006, 2010, 2012 and 2016 were the higher SST corresponding to the El Niño years, while the lower SST years of 2007, 2011 and 2014 corresponded with La Niña [25]. SST played a negative effect on the catch of mackerel in our study, which is consistent with previous studies. For example [14] pointed out that mackerel, bigeye scad, chicken grunt and largehead hairtail showed negative correlation with SST. Evidence suggests that the observed catch of Spanish mackerel could be related to STT, but we do not know the mechanism behind this. Further research into whether SST and other oceanography characteristics affect their migration, schooling behaviour, predation risk, hatchery, reproduction, and grow is therefore recommended. It is also unclear whether changing SST affects abundance and distribution of mackerel's prey (e.g. anchovy, shrimp and squid) that lead to declining of mackerel resource. In this study we could not consider the effect of other fishery activities (e.g. gill net, perse seine) catching same species on set-nets performance, because it might have interactions with the set-net catch. We recognize this was a limitation of our research. We therefore suggest further research investigating the stock assessment and migration of Spanish mackerel in this region.

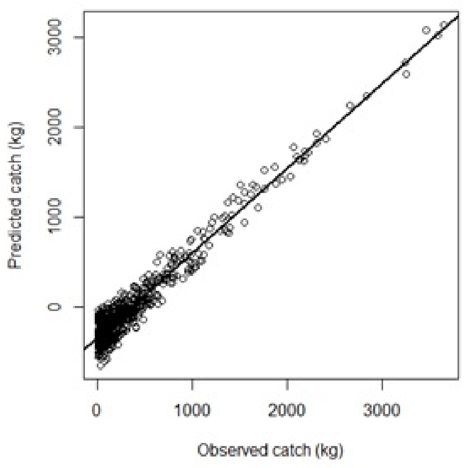

Figure 9: Predicted catch (kg) plotted against observed catch (kg) for linear regression model. Black straight line designates equal values.

Encouraging set-net technology, which is an environmentally friendly fishing method, is necessary to conserve the coastal fishery resources for the benefit of future generations. In addition, collaborating amongst stakeholders (i.e. fishers and tourist companies) is encouraged in order to improve the income of fishers through providing the recreation fishery as being a new tourist product for the tourist industry.

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