RESEARCH ARTICLE

Underreporting of Tuna Catch: Implications to Technical Efficiency of Handline Fishing Vessels in General Santos City, Philippines

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Abstract

With the increasing demand for tuna products and dwindling marine resources, there is a need to promote sustainability measures. By far, illegal, unreported, and unregulated (IUU) fishing is one of the most damaging problems in the fishing industry because it directly affects fisheries stocks. In this study, we identified the level of IUU fishing, particularly underreporting of tuna catch, in the Philippines. Moreover, we also identified the drivers of IUU fishing and the implications of IUU activities to the technical efficiency (TE) performance of fishing vessels. We collected the samples in General Santos City, the tuna capital of the Philippines. There were two data sets gathered in this study: an annual panel data (2012–2014) of reported inputs and catch level of 216 registered fishing vessels at the Fish Port Authority and primary data (2014) involving 40 handline tuna fishers. The latter data, assumed to be closer to the "true" level of inputs and catches, were compared per vessel to the former data set. It revealed a widespread underreporting of catches by 51%–100%. Underreporting is more prevalent among vessels of smaller size. Using stochastic frontier analysis, the TE scores of the tuna fishing vessels were overestimated to 0.80 (2012), 0.70 (2013), and 0.72 (2014) using the panel data while the primary data (2014) set suggested a lower TE score of 0.66. This implies that the actual efficiency performance of the handline tuna fishers could be lower by 6% if reporting were true and correct. Hence, we recommend increasing penalties for IUU fishing, increasing frequency of monitoring activities such as the Fisheries Observer Program, and promoting an enabling environment for small-scale fishers.

Keywords: fisheries • Philippines • small-scale fishers • stochastic frontier analysis

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Underreporting of Tuna Catch: Implications to Technical Efficiency of Handline Fishing Vessels in General Santos City, Philippines

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Introduction

Fisheries are a stable source of food around the globe and play a crucial role in food security in developing and developed countries. According to the Food and Agriculture Organization of the United Nations (2016), the global aquatic food production has been increasing over the years, reaching 167.2 million metric tons (MT) in 2014, with 93.4 million MT (56%) contribution from capture fisheries and the remaining 73.8 million MT (44%) from aquaculture. The current level of captured fisheries production is way above the maximum potential fish production of 80 million MT (FAO 2010). As a result, the global trend of world marine stocks since 1974 shows an increasing share of overfished species from roughly 10% to 30% of the total stocks (FAO 2016). This continued pressure on marine resources is a consequence of increased fish demand due to increasing human population (Merino et al. 2012).

The sustainability of the world fisheries remains an immense challenge to the entire sector. Among the many problems faced by global fisheries, illegal, unreported, and unregulated (IUU) fishing is considered as one of the major threats to marine ecosystems (FAO 2014). What constitutes IUU fishing is a range of unconventional and unsustainable fishing activities, from fishing without permission from the state to misreporting of catch data to the authorities and fishing in a manner not consistent with the conservation and management measures of the fisheries organizations (FAO 2001). Competing for dwindling marine resources, IUU fishing has become more prevalent during the late twentieth century and currently has become an economic, legal, and political problem in marine fisheries (Baird 2004). Moreover, IUU fishing has also become an international problem (Schmidt 2004). An estimated 11 to 26 million MT, which is equivalent to US$ 10 to 23 billion annually, was lost due to IUU activities (FAO 2014).

The Philippines is among the top 12 major producers in the world, contributing a total of 2.14 million MT in 2014 (FAO 2016). The Philippine fisheries provide food for over 90 million Filipinos with per capita consumption of 38 kg per year and a source of livelihood for 1.4 million fishers (Perez et al. 2012). Also, the Philippines contribute to the world consumption of aquatic food, particularly tuna products, in the three largest export markets: the United States, the European Union, and Japan (Garrett and Brown 2009). Despite this global performance, IUU activities are widespread in the country, resulting in a trade sanction warning from the European Union (European Commission 2014).

In the Philippines, IUU activities include unauthorized fishing by both Filipino and foreign fishing vessels, unsustainable fishing practices, unregulated fishing by unregistered fishing vessels, and unreported fishing (Palma 2008). Tuna vessels are identified to be among those involved in IUU fishing (Barut and Garvilles 2013). The most common IUU problem in the Philippines is the underreporting of marine catch (Pramod et al. 2008). Unlicensed commercial fishing vessels and incorrect registration as municipal fishing boats are the usual cases of IUU fishing (Alesna et al. 2004; Pomeroy and Pido 1995). The catching of juvenile tuna has also been reported to be rampant in the Western and Central Pacific Ocean, which includes the Philippines (Bailey et al. 2013). All of these activities resulted in the lack of adequate data to estimate the catch levels, which could serve as a good basis for policy formulation (Palomares et al. 2014).

The Philippines, as one of the biggest exporters of tuna products, has to actively respond to IUU fishing in order to maintain its global reputation. The tuna capital of the Philippines,

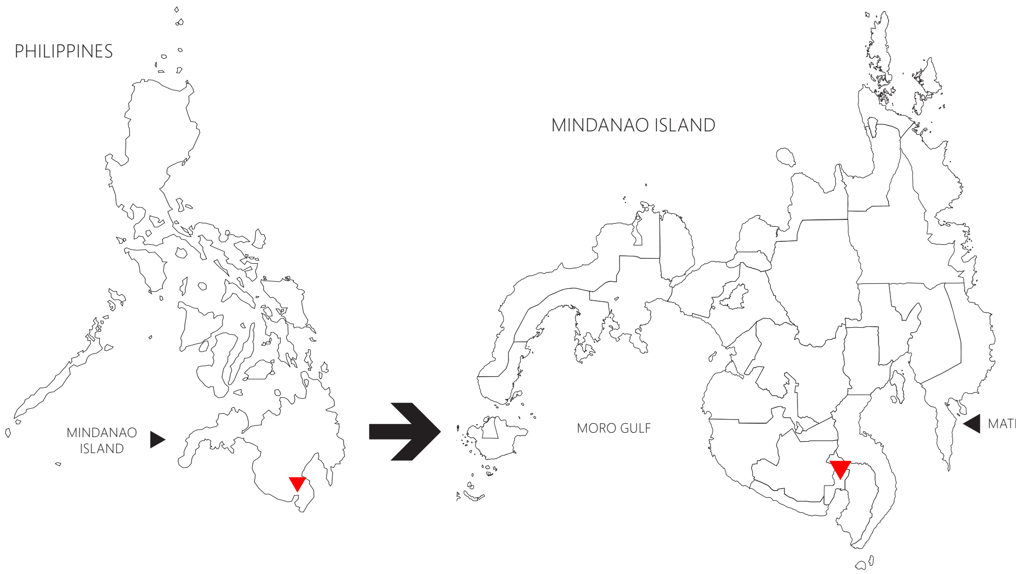

FIGURE 1 Location of General Santos City in Mindanao, Southern Philippines

General Santos City (Figure 1), houses the major tuna landing area: the General Santos Fish Port Complex (GSFPC). The highest catch over the last twelve years was recorded in 2014, reaching 193,867 MT; but 53% of this catch were frozen tuna imports, 77% of which from foreign and 23% from Manila suppliers (Espejo 2015b). It should be noted also that most of these catch landings are sourced from distant waters like the Celebes Sea, the Indonesian borders, the Pacific, and near Papua New Guinea (Macusi et al. 2015). On the other hand, tuna catches from Mindanao covering Regions 9 to 13 and the Autonomous Region for Muslim Mindanao (ARMM) revealed a decreasing trend over the last fifty years (Parducho and Palomares 2014). Three main gears are utilized in tuna fishing: purse seine, handline, and longline. Purse-seine fleets catch mostly skipjack used primarily for canning, handline vessels catch adult yellowfin used as high-grade sashimi, and longline fleets catch yellowfin and bigeye tuna fish in distant waters (Bailey et al. 2012). The handline industry in General Santos City was identified as an area of concern in terms of IUU fishing despite being known to be more sustainable compared to other fishing methods as it targets mature stocks of yellowfin tuna (West et al. 2011). According to West et al. (2011), there is inadequate information on the handline sector as well as regulations resulting to concerns in three areas—fisheries assessment, management, and compliance.

In this paper, we identify the level of IUU activities in the tuna industry, particularly underreporting of tuna catch, identify the drivers of IUU fishing, and estimate the effect of underreporting on the technical efficiency performance of the tuna handline vessels. Our approach in estimating underreporting was limited to the comparison of survey data from reported official data. Potential endogeneity issues could be present in the technical efficiency model. While still far from arriving at a robust estimate of the IUU activities, our effort provides an indication of the extent of underreporting of tuna catches in the Philippines and its implication to efficiency performance.

Methods

In marine economics, one of the most common approaches to efficiency modelling is the estimation of technical, allocative, and economic efficiency. Most researchers prefer this approach in modelling the efficiency performance of the fishing vessels (Jamnia et al. 2015; Solís et al. 2014;

Vázquez-Rowe and Tyedmers 2013). However, Tidd et al. (2016) cautioned that underreporting issues in the early years of the period 1994–2010 among Western Pacific purse-seine fleets could be the reason behind the productivity gains in the later years. Hence, this research posits that underreporting can affect the efficiency levels of the fishing vessels resulting in an overestimation of efficiency performance.

The stochastic frontier analysis (SFA) has been widely used in efficiency modelling. This approach has been applied in the context of marine fishing (Del Hoyo et al. 2004; Esmaeili 2006; Jamnia et al. 2015; Solís et al. 2014) and aquaculture farming (Bukenya et al. 2013; Iliyasu et al. 2016). SFA is preferred over the nonparametric data envelopment analysis because it can model the production function through Cobb-Douglas or Translog specification with sources of inefficiency (Coelli et al. 2005). In the Philippine fisheries literature, technical efficiency studies are limited to the aquaculture sector (Bimbao et al. 2000; Dey et al. 2000; Irz and Mckenzie 2003). To date, there are no studies on technical efficiency in the Philippine marine fisheries setting.

In our research, the dependent variable considered was the output of the fishing vessels and the independent variables were the inputs to production such as the gross registered tonnage (GRT) of the fishing vessels, the effort days of the fishermen at sea, the fuel consumption of the fishing vessel measured in liters, and the water consumption of the fishing vessel during the operation measured in cubic meters. The output variable total catch is expressed in metric tons (Del Hoyo et al. 2004; Esmaeili 2006). Moreover, variables such as the GRT (Del Hoyo et al. 2004), the effort days (Esmaeili 2006), and fuel consumption (Squires and Kirkley 1999) are all hypothesized to be positively affecting the output level of the fishing vessels. Water consumption, on the other hand, was identified as among the inputs of longline vessels (Sharma and Leung 1998). In this study, water was among the major inputs used by fishing vessels in General Santos City.

We hypothesize three primary sources of efficiency performance in this study: first, the technical control measure such as closed areas and closed seasons, which is proxied by berthing days (Srinath and Pillai 2006); second, the fishing ground represented through distance using ordinal data is a potential source of inefficiency (Sesabo and Tol 2007); third, fishing season represented by the month and year of fishing can also explain the sources of inefficiency (Kirkley et al. 1998). All of the potential determinants of inefficiency are hypothesized to either result to a positive or negative coefficient. In our study, the sources of technical inefficiency include the berthing days of the fishing vessels, the area of the fishing ground, the harbor where the fishing vessels land their catch, and the corresponding quarters of the year of the catch landing. The description of the output, inputs, and sources of inefficiency variables are shown in Table 1.

We analyzed two data sets in this study: first, panel data of 216 registered fishing vessels from the years 2012, 2013, and 2014 (PFDA 2015), and second, a cross-section data of 2014 primary survey involving 40 handline tuna fishing vessels. The total sample represents 9% of the 451 total registered vessel having less than 250 GRT (BFAR and WCPFC 2012). The Cobb-Douglas specification (Equation 1) and Translog specification (Equation 2) with sources of inefficiency (Equation 3) were considered in modelling the production frontier (Esmaeili 2006; Iliyasu et al. 2016; Sesabo and Tol 2007; Sharma and Leung 1998).

$$\ln Output_{it} = \beta_0 + \beta_1 \ln GRT_{it} + \beta_2 \ln Eff_{it} + \beta_3 \ln Fuel_{it} + \beta_4 \ln Water_{it} + (v_{it} - \mu_{it}) \quad (1)$$

$$\begin{aligned} \ln Output_{it} = {} & \beta_0 + \beta_1 \ln GRT_{it} + \beta_2 \ln Eff_{it} + \beta_3 \ln Fuel_{it} + \beta_4 \ln Water_{it} \\ & + \beta_5 \ln GRT_{it}^2 + \beta_6 \ln Eff_{it}^2 + \beta_7 \ln Fuel_{it}^2 \\ & + \beta_8 \ln Water_{it}^2 + \beta_9 \ln GRT_{it} \ln Eff_{it} \\ & + \beta_{10} \ln GRT_{it} \ln Fuel_{it} \\ & + \beta_{11} \ln GRT_{it} \ln Water_{it} \\ & + \beta_{12} \ln Eff_{it} \ln Fuel_{it} \\ & + \beta_{13} \ln Eff_{it} \ln Water_{it} \\ & + \beta_{14} \ln Fuel_{it} \ln Water_{it} \\ & + (v_{it} - \mu_{it}) \end{aligned} \quad (2)$$

TABLE 1 Description of the output, inputs and sources of inefficiency variables

Short name	Variable name	Description
OUTPUT		
Volume	Volume	Total catch in metric tons in 2012, 2013, and 2014
INPUTS		
GRT	Gross registered tonnage	Tonnage size of the fishing vessel
Eff	Effort days	Total number of days spent for searching and fishing in 2012, 2013, and 2014
Fuel	Fuel consumption	Total number of liters of fuel spent for searching and fishing in 2012, 2013, and 2014
Water	Water consumption	Total number of cubic meters of water spent for searching and fishing in 2012, 2013, and 2014
SOURCES OF TECHNICAL INEFFICIENCY		
Berthing	Berthing days	Total number of berthing or mooring days in 2012, 2013, and 2014
Moro	Fishing ground: Moro Gulf	Takes the value of 0.01 to 1 if vessel fishes in Moro Gulf depending on output level; 0 otherwise
Sulawesi	Fishing ground: Sulawesi	Takes the value of 0.01 to 1 if vessel fishes in Sulawesi depending on output level; 0 otherwise
Sarangani	Fishing ground: Sarangani	Takes the value of 0.01 to 1 if vessel fishes in Sarangani depending on output level; 0 otherwise
Pacific	Fishing ground: Pacific Ocean	Takes the value of 0.01 if the vessel fishes in Pacific Ocean depending on output level; 0 otherwise
Sulu	Fishing ground: Sulu Sea	Takes the value of 0.01 to 1 if vessel fishes in Sulu Sea depending on output level; 0 otherwise
HSP	Fishing ground: High Seas Pocket 1	Takes the value of 0.01 to 1 if vessel fishes in High Seas Pocket 1 depending on output level; 0 otherwise
PNG	Fishing ground: Papua New Guinea	Takes the value of 0.01 to 1 if vessel fishes in Papua New Guinea depending on output level; 0 otherwise
Palawan	Fishing ground: Palawan	Takes the value of 0.01 to 1 if vessel fishes in Palawan depending on output level; 0 otherwise
Manila	Fishing ground: Manila	Takes the value of 0.01 to 1 if vessel fishes in Manila depending on output level; 0 otherwise
Centro	Fishing ground: Centro	Takes the value of 0.01 to 1 if vessel fishes in Centro depending on output level; 0 otherwise
Indonesia	Fishing ground: Indonesia	Takes the value of 0.01 to 1 if vessel fishes in Indonesia depending on output level; 0 otherwise
Mati	Fishing ground: Mati	Takes the value of 0.01 to 1 if vessel fishes in Mati depending on output level; 0 otherwise
Tawi-Tawi	Fishing ground: Tawi-Tawi	Takes the value of 0.01 to 1 if vessel fishes in Tawi-Tawi depending on output level; 0 otherwise
Celebes	Fishing ground: Celebes Sea	Takes the value of 0.01 to 1 if vessel fishes in Celebes Sea depending on output level; 0 otherwise
H1	Harbor 1	Harbor 1 depending on the share of output level; 0 otherwise
H2	Harbor 2	Harbor 2 depending on the share of output level; 0 otherwise
H3	Harbor 3	Harbor 3 depending on the share of output level; 0 otherwise
Q1	Fishing period: 1st quarter of 2012, 2013, and 2014	Takes the value of 0.01 to 1 if vessel fishes in the 1st quarter depending on the share of output level; 0 otherwise
Q2	Fishing period: 2nd quarter of 2012, 2013, and 2014	Takes the value of 0.01 to 1 if vessel fishes in the 2nd quarter depending on the share of output level; 0 otherwise
Q3	Fishing period: 3rd quarter of 2012, 2013, and 2014	Takes the value of 0.01 to 1 if vessel fishes in the 3rd quarter depending on the share of output level; 0 otherwise
Q4	Fishing period: 4th quarter of 2012, 2013, and 2014	Takes the value of 0.01 to 1 if vessel fishes in the 4th quarter depending on the share of output level; 0 otherwise

$$
\begin{aligned}
\mu_{it} = {} & z_0 + z_1 Berthing_{it} + z_2 Moro_{it} \\
& + z_3 Sulawesi_{it} + z_4 Sarangani_{it} \\
& + z_5 Pacific_{it} + z_6 Sulu_{it} + z_7 HSP_{it} \\
& + z_8 PNG_{it} + z_9 Palawan_{it} \\
& + z_{10} Manila_{it} + z_{11} Centro_{it} \\
& + z_{12} Indonesia_{it} + z_{13} Mati_{it} \\
& + z_{14} Tawi\text{-}Tawi_{it} + z_{15} Celebes_{it} \\
& + z_{16} H1_{it} + z_{17} H2_{it} + z_{18} H3_{it} + z_{19} Q1_{it} \\
& + z_{20} Q2_{it} + z_{21} Q3_{it} + z_{22} Q4_{it} \\
& + w_{it}
\end{aligned} \quad (3)
$$

NOTE: In all equations, i represents the vessel observation, t represents the time observation, β represents the coefficient of the input parameters, z represents the coefficient of the inefficiency parameters, and μ_{it} represents the inefficiency level of vessel i at time t.

We used the likelihood ratio test in hypothesis testing to identify which among the models best fit the data (Coelli et al. 2005). Also, we utilized the mixed chi-squared distribution to obtain the critical values for hypothesis testing (Kodde and Palm 1986). We show the comparison of the summary statistics of the two data sets in Table 2. In this study, we used the software FRONTIER 4.1 since it can accommodate an unbalanced panel data (Coelli 1996).

Results and Discussion

Level of IUU Fishing

The commercial tuna fishing sector can be divided into three types of operation: the small scale (3.1–20.0 GRT), which utilizes passive or active gears; medium scale (20.1–150.0 GRT), which utilizes active gears; and large scale (>150 GRT), which also utilizes active gears (Vera et al. 2007). Most of the fishing vessels with GRT equal to or lesser than 3 normally fish in municipal waters, and the rest of the large fishing vessels fish in commercial fishing grounds (Vera and Hipolito 2006). Among the commercial tuna-fishing vessels, the handline sector (mostly small scale) is of interest in this study.

Handline tuna vessels are the primary producer of grade A tuna for export to other countries as either fresh, frozen, or processed products. These small-scale fishing vessels manage to maintain the quality of the fresh yellowfin tuna due to minimal effort days at sea, which usually span three to ten days (BFAR and WCPFC 2012). An estimated 3000 to 4000 handline fishing vessels operate in the waters of the Philippines, Indonesia, Palau, the High Seas, and Papua New Guinea (Vera and Hipolito 2006). However, most of these fishing vessels are unregistered or erroneously registered as municipal vessels to minimize the registration cost (Alesna et al. 2004; Vera and Hipolito 2006). Since 2008, the Bureau of Fisheries and Aquatic Resources (BFAR) of the Department of Agriculture started a system wherein the inputs for fishing, including effort days and the total catch, are recorded in logsheets for the purse seine and ringnet vessels. The bureau also started requiring canning factories to report their monthly unloading data to BFAR (Barut and Garvilles 2014). From these logsheets (official report), we compared the response of 40 handline tuna fishing vessels in terms of the level of inputs and outputs. The comparison is only applicable to small-scale vessels, with 65% of the sample having less than 5 GRT, 21% with 5–10 GRT, and the remaining 14% with more than 10 GRT.

There was widespread underreporting of catch level among the small-scale handline tuna vessels. Out of the 40 vessels, only 3 respondents (7.5%) disclosed near the accurate level of catch (0%–50% deviation) as recorded by the Philippine Fisheries Development Authority (PFDA) during the last time they landed in the fish port. The remaining 37 respondents (92.5%) underreported their latest catch. Of these 37 respondents, 16 (40%) underreported at 51%–100%, 9 (22.5%) at 101%–150%, 7 (17.5%) at 151%–200% , and the remaining 5 (12.5%) at over 200%. This implies that for every 1000 kg reported, there is 501 to 1000 kg that is unreported (i.e., 51%–100% level of underreporting).

Moreover, the level of underreporting increases as the size of the vessel decreases (Table 3). Vessels having 0%–50% lower level of reported catch had an average of 23.17 GRT, those with 51%–100% lower level of reported catch had an average of 10.11 GRT, those with 101%–150% lower level of reported catch had an average of 9.06 GRT, those with 151%–200% lower level of reported catch had an average of 7.03 GRT, and those with more than 200% lower level of reported catch had an average of 4.06 GRT. Hence, there is a high rate of underreporting in vessels of smaller size. However, this could be due to the fact that vessels operating in the municipal waters are not

TABLE 2 Summary statistics of output, inputs, and sources of inefficiency variables

Variable	Panel data (n = 296)				Cross-section data (n = 34)			
	Mean	Standard deviation	Min	Max	Mean	Standard deviation	Min	Max
Period	2.25	0.68	1.00	3.00	1.00	0.00	1.00	1.00
lnVol	1.22	0.73	–1.00	5.30	2.93	0.53	1.70	3.90
lnGRT	1.18	0.49	0.43	3.13	0.56	0.41	–0.30	1.18
lnEff	2.39	0.24	0.85	2.56	1.24	0.18	0.85	1.48
lnFuel	0.24	0.56	–1.30	1.70	–0.01	0.42	–1.05	0.60
lnWater	1.31	0.52	0.00	2.69	0.05	0.36	–0.74	0.62
Berthing	37.08	34.28	1.00	209.00	7.97	10.62	1.00	45.00
Moro	0.90	0.22	0.00	1.00	0.06	0.24	0.00	1.00
Sulu	0.04	0.13	0.00	1.00	-	-	-	-
Sarangani	0.02	0.05	0.00	0.41	-	-	-	-
Pacific	0.02	0.08	0.00	1.00	-	-	-	-
Sulu	0.01	0.07	0.00	1.00	-	-	-	-
HSP	0.01	0.09	0.00	1.00	-	-	-	-
PNG	0.01	0.08	0.00	1.00	-	-	-	-
Palawan	0.00	0.06	0.00	1.00	-	-	-	-
Manila	0.00	0.06	0.00	1.00	-	-	-	-
Centro	0.00	0.01	0.00	0.11	0.38	0.49	0.00	1.00
Indonesia	-	-	-	-	0.41	0.50	0.00	1.00
Mati	-	-	-	-	0.06	0.24	0.00	1.00
Tawi-Tawi	-	-	-	-	0.06	0.24	0.00	1.00
Celebes	-	-	-	-	0.03	0.17	0.00	1.00
H1	0.70	0.40	0.00	1.00	-	-	-	-
H2	0.20	0.33	0.00	1.00	-	-	-	-
H3	0.10	0.29	0.00	1.00	-	-	-	-
Q1	0.22	0.24	0.00	1.00	-	-	-	-
Q2	0.25	0.22	0.00	1.00	-	-	-	-
Q3	0.26	0.22	0.00	1.00	-	-	-	-
Q4	0.27	0.25	0.00	1.00	-	-	-	-

TABLE 3 Summary statistics of output, inputs, and sources of inefficiency variables

Level of underreporting (%)	Percentage to total sample	Gross registered tonnage		
		Average	Minimum	Maximum
0–50	7.50	23.17	1.50	65.00
51–100	40.00	10.11	0.50	51.00
101–150	22.50	9.06	2.00	19.00
151–200	17.50	7.03	2.00	15.00
Above 200	12.50	4.06	2.00	15.00

required to report their catches to BFAR or other recording agencies.

Drivers of IUU Fishing

The drivers of IUU fishing can be both internal and external. The decision-making process of the fishermen could be a factor of the socio-demographic profile, the profit-sharing scheme involved, and the relationship between the fishermen and the vessel owner. The effectiveness of the policies and regulations are considered external factors affecting IUU activities.

Tuna fishermen are mainly from small-scale fishing communities surrounding the coasts of General Santos City. According to Allen and Gough (2006), more than 60% of the Filipino crew members grew up in a fishing or farming area, and most of them reported only finishing high school with a few completing associate or trade school degrees related to maritime studies. Results of our interviews show that the fishermen had accumulated 21.47 years of experience in marine fishing as they started to fish as early as 20.55 years old. The respondents, who are boat captains, had an average age of 42.02 years old. According to Peji (2014), most of the fishermen in General Santos City are middle-aged and in their prime and most productive years, supporting a family of four to six members with their meager income. Moreover, an average fisherman earns a living of PhP 25,426 (1992) annually, with 27% of them having motorized boats (Barut et al. 2003). The extra income from IUU fishing could help provide for the needs of the small-scale handline tuna fishers' families.

The profit sharing in tuna fishing is another driver to IUU fishing. The profit-sharing system of the owner and operators of the fishermen exist in two forms: *lilima* sharing system and *sukod* sharing system (BFAR and WCPFC 2012). In the *lilima* sharing system, 20% share from the actual gross sale goes to the fishermen and the remaining 80% goes to the owner of the fishing vessel. In some instance, the boat captains are also the boat owners. In the *sukod* sharing system, the operator has an almost equal share of the net sales like the owner. Here, the operator, who could also be the boat captain, is considered as a partner of the vessel owner, which means that the operator is also responsible for the cost of each fishing trip (BFAR and WCPFC 2012). Since there are fishing seasons wherein the fishermen have no catch and incur losses, owners (sometimes aided by financiers) experience financial setbacks. There are vessel owners and/or financiers who are very strict toward their operators regarding the minimum level of tuna catch when the fishing vessel lands in the fish port. Also, according to Peji (2014), a feudal relationship exists between operators and financiers. Since these owners and/or financiers spend a large sum of money for each fishing trip, they get suspicious of their operators when little or no tuna are caught during the trip. According to anecdotal evidence, operators sometimes take advantage of a large catch by selling a portion of their catch to other buyers before docking in the fish port. Also, official reports are underreported to reduce taxes (Vera and Hipolito 2007). This contributes to the underreporting of tuna catch.

The unregulated fishing effort is one of the causes of the declining productivity of the fishing industry (Carreon 2004). While licensing has the potential to minimize IUU activities, the deficient monitoring, control, and surveillance over the registered fishing vessels contribute to the fishers' decision to engage in IUU activities (Alesna et al. 2004). Monitoring and surveillance are already implemented by BFAR and the local government units (LGUs) in coordination with the private sector (BFAR and WCPFC 2012). Recently, the Indonesian government conducted a crackdown against Filipino fishing vessels as they are no longer allowed to operate in Indonesia's exclusive economic zone (EEZ) (Espejo 2015a). Because of this adverse policy change, Filipino vessels, including handline vessels, are heavily affected.

Implications of IUU Fishing to Technical Efficiency

The two data sets used in our study differ in terms of the levels of inputs and catch. The panel data set has lower levels of catch compared to the cross-section data set, with the latter's level of catch assumed to be closer to the true value. In this case, the latter data set was used to interpret the factors affecting the efficiency performance, and the technical efficiency levels were compared across data sets. The deviation in the technical efficiency level could be attributed to underreporting of catch level (i.e., IUU activity).

We performed standard hypotheses testing to identify the (1) the absence of the constant term of the technical inefficiency model, (2) the absence of the technical inefficiency terms, and (3) the appropriate production function, i.e., whether the Cobb-Douglas or the Translog specification best fit the data (Coelli et al. 2005). As a result of the series of hypothesis testing, we found that the Cobb-Douglas with technical inefficiency constant term is the best model for the panel data while the Cobb-Douglas without technical inefficiency constant term is the best model for the cross-section data (Table 4). The technical efficiency models for both data sets are significant at 0.01 level of error (alpha).

According to the models (Table 5), the vessel size positively affected the productivity of the vessel. A 1% increase in the vessel size increases total catch by 0.56%, but not significantly if there is underreporting. In the panel data model, vessel size suggests a positive effect to tuna catch, which is consistent with the results of Del Hoyo et al. (2004). The fishing vessel size also determines the type of gears used, which affect the productivity. In particular, commercial vessels that use ringnet, trawl, bagnet, and purse seine have an average annual catch of 26,250 to 132,858 kg while municipal vessels that use drive-in net, fish corral, beach seine, and gillnet have an average catch of 938 to 78,157 kg (Trinidad et al. 1993). However, Pomeroy and Pido (1995) argued that the small and medium trawlers in the Philippines are categorized as unmotorized gillnetters under municipal registration, and this results to conflicts between small-scale traditional fishers and trawl fishers as they compete for limited coastal resources. Moreover, the limited capabilities of municipalities constrained the implementation of coastal fishery laws leading to further resource exploitation (Pomeroy and Pido 1995).

In terms of effort days at sea, a 1% increase in the number of days at sea decreases total catch by 1.18%; however, with underreporting, the effect was positive. The positive effect of effort days to tuna is consistent with the study of Esmaeili

TABLE 4 Hypotheses testing of the stochastic frontier models

Hypothesis	Log likelihood			Degrees of freedom (alpha)	Critical value	Decision
	Null (H_0)	Alternative (H_1)	Likelihood ratio statistics			
PANEL DATA						
H_0: $\delta_0 = 0$						
Cobb-Douglas	−147.23	−139.86	14.74	1 (0.01)	5.41	Reject H_0
Translog	−148.75	−146.40	4.7	1 (0.01)	5.41	Fail to reject H_0
H_0: $\gamma = 0$						
Cobb-Douglas	−174.19	−139.86	68.66	19 (0.01)	35.56	Reject H_0
Translog	−168.88	−148.75	40.26	18 (0.01)	34.17	Reject H_0
H_0: $\beta_5 + \ldots + \beta_{10} = 0$						
H_0: Cobb-Douglas vs H_1: Translog	−139.86	−148.75	−17.78	9 (0.01)	20.97	Fail to reject H_0
CROSS-SECTION DATA						
H_0: $\delta_0 = 0$						
Cobb-Douglas	0.13	−1.27	−2.79	1 (0.01)	5.41	Fail to reject H_0
Translog	−3.27	1.20	8.95	1 (0.01)	5.41	Reject H_0
H_0: $\gamma = 0$						
Cobb-Douglas	−15.24	0.13	30.74	7 (0.01)	17.76	Reject H_0
Translog	−10.21	1.20	22.82	7 (0.01)	17.76	Reject H_0
H_0: $\beta_5 + \ldots + \beta_{10} = 0$						
H_0: Cobb-Douglas vs H_1: Translog	0.13	1.20	2.14	11 (0.01)	24.05	Fail to reject H_0

TABLE 5 Technical efficiency performance of the tuna fishing vessels

Parameters	Panel data			Cross-section data		
	Coefficient	Standard error	T-ratio	Coefficient	Standard error	T-ratio
beta 0: Constant	–0.30	0.31	–0.98	4.62	0.43	10.63***
beta 1: GRT	0.67	0.06	12.17***	0.38	0.44	0.87
beta 2: Effort	0.28	0.11	2.48**	–1.18	0.23	–5.08***
beta 3: Fuel	0.15	0.06	2.50**	–0.44	0.25	–1.77*
beta 4: Water	0.29	0.06	4.84***	0.92	0.68	1.35
delta 0: Constant	–0.93	0.72	–1.29	-	-	-
delta 1: Berthing	–0.00	0.00	–1.45	0.00	0.03	–0.15
delta 2: Moro	1.07	0.55	1.96*	0.96	0.45	2.14**
delta 3: Sulawesi	0.79	0.70	1.13	-	-	-
delta 4: Sarangani	–0.44	1.24	–0.36	-	-	-
delta 5: Pacific	–2.36	0.92	–2.58**	-	-	-
delta 6: Sulu	1.26	0.67	1.87*	-	-	-
delta 7: HSP	–0.64	1.28	–0.50	-	-	-
delta 8: PNG	–2.24	0.67	–3.32***	-	-	-
delta 9: Palawan	–1.13	0.90	–1.26	-	-	-
delta 10: Manila	–1.13	0.90	–1.26	-	-	-
delta 11: Centro	1.49	2.16	0.69	0.60	0.26	2.35**
delta 12: Indonesia	-	-	-	–0.04	0.51	–0.07
delta 13: Mati	-	-	-	–2.97	1.12	–2.64**
delta 14: Tawi-Tawi	-	-	-	–1.85	1.05	–1.76
delta 15: Celebes	-	-	-	0.52	0.82	0.64
delta 16: H1	0.33	0.56	0.58	-	-	-
delta 17: H2	0.26	0.56	0.47	-	-	-
delta 18: H3	–1.52	0.81	–1.88*	-	-	-
delta 19: Q1	–0.13	0.56	–0.23	-	-	-
delta 20: Q2	0.12	0.57	0.21	-	-	-
delta 21: Q3	–0.30	0.63	–0.48	-	-	-
delta 22: Q4	0.07	0.56	0.13	-	-	-
sigma squared (σ^2)	0.23	0.03	8.04***	0.22	0.09	2.50**
gamma (γ)	0.64	0.09	6.90***	0.99	0.00	511.82***
log likelihood	–139.86			0.13		

NOTES: two-tailed, DF = 273 and 22, respectively
*** Statistically significant at 1% level; ** Statistically significant at 5% level; * Statistically significant at 10% level

(2006). This implies that accounting for the actual effort days at sea, there was a decreasing effect to catch productivity. According to Gutierez (2014), handline fishermen need to travel to farther fishing grounds and stay longer days in those fishing grounds in order to catch tuna. They fish tuna as far as the High Seas Pocket 1 of the Pacific Ocean (Barut and Garvilles 2014). The High Seas Pocket 1 is a shared region bounded by Indonesia and Papua New Guinea (south), Palau (west), and Micronesia (north and east) (WCPFC 2012). Small fishing vessels usually increase fuel or crewdays to maintain the same level of fishing effort (Padilla and Trinidad 1995). However, Carreon (2004) suggested that the effort days of fishermen should be minimized since it contributes to higher cost but does not improve the productivity of the vessel. The ideal effort days is less than ten days in order to preserve the freshness of the yellowfin tuna (BFAR and WCPFC 2012). In order to lessen the fishing effort of the fishermen, they use fish-aggregating devices or *payao*s; however, it has led to overfishing not only of adult tuna species but juvenile tuna as well (Babaran 2006).

In terms of fuel usage, a 1% increase in the variable decreases total catch by 0.44%; however, with underreporting, the effect was positive. The positive effect of fuel consumption to tuna catch is similar to the results obtained by Squires and Kirkley (1999). Similarly, the actual level of fuel use showed a negative effect to catch productivity. High fuel consumption was an effect of the longer effort days (Carreon 2004; Padilla and Trinidad 1995) and farther distance (Barut and Garvilles 2014). Unlike in the past, fisher vessel's fuel consumption is no longer subsidized by the Philippine government (Bailey et al. 2012). In Indonesia, 50% of the fishing vessel's fuel cost is subsidized by the government, resulting to very competitive tuna prices (Sumaila et al. 2014). Fuel subsidy, however, may pose direct challenges to the sustainability of the tuna resources.

We also considered the fishing ground as potential factor affecting technical efficiency performance, and three fishing grounds in Mindanao were significant in the model: first, the Moro Gulf, which is known for its abundance of yellowfin tuna and skipjack tuna all year round (Bigelow et al. 2014); second, Centro, which is often referred to as Moro Gulf / Centro in the literature (Bigelow et al. 2014); and lastly, the Mati City fishing ground, which is located near the Palau waters and is a good fishing ground for large bigeye tuna (Parducho and Palomares 2014). Our results show that fishing at the Moro Gulf and Centro is technically inefficient in both models while fishing at Mati seas suggests higher efficiency performance.

Overall, the average technical efficiency scores of tuna vessels were overestimated at 0.80 (2012), 0.70 (2013), and 0.72 (2014) using the panel data, but it was lower at 0.66 using the cross-section data (2014). Thus, there could be a 6% overestimation of efficiency performance due to the underreporting of tuna catch. This implies that the actual performance of the handline tuna fishing vessels could be lower if reports of the inputs and catch levels are accurate.

Hence, our study found that there was a widespread underreporting in the handline fishery sector in the Philippines estimated at 51%–100%. Secondly, underreporting is more prevalent among fishing vessels of smaller size. Lastly, the effect of underreporting to the technical efficiency performance of the fishing vessels resulted to an overestimation of efficiency by 6%. This poses some methodological issues in the technical efficiency studies using reported data from fisheries agencies.

Policy Implications

The legal measure to combat IUU fishing in the country has already been established. In 2013, the Philippine government issued the Executive Order 154 (EO 154), an adoption of a national plan of action to prevent, deter, and eliminate IUU fishing (Official Gazette 2013). This executive order provided a basis for the establishment of the Philippine Committee Against IUU Fishing, which was tasked to create regulations against IUU fishing activities, as well as institute measures for implementation. However, other than additional options on how fishermen may register their vessels, there were no further actions done in relation to EO 154 (Gutierez 2014).

Due to the Philippines' slow action against IUU fishing, the European Union (EU) issued a yellow card warning to the country in 2013, which could result to trade sanctions of Philippine exports if IUU remains unresolved in the next six months (European Commission 2014). In 2015, EO 154 was finally implemented through the release of implementing rules and regulations (Valencia 2015) and the yellow card warning from the EU was subsequently lifted (Binondo and Yan 2015). Better compliance to FAO 236 or Rules and Regulations Involved in Fish Aggregating Devices Closure Period and the Fisheries Observer Program has also been recommended (Ramiscal et al. 2013). The Observer Program requires the fishing vessels to carry BFAR personnel on board and allow them to gather or verify data and recommend improvements in relation to conservation and management measures. Also, incentive mechanisms for sustainable fishing such as the International Seafood Sustainability

Foundation ProActive Vessel Register, Marine Stewardship Council Certification, and the World Wildlife Fund for Nature's fishery improvement project model are now available for Filipino fishers (Tolentino-Zondervan et al. 2016).

Aside from these initiatives, policies relevant to minimize IUU activities include imposing a quota, taxing fish catch or fish effort, closing areas to fishing, and imposing higher penalties for IUU activities. Imposing quotas, as experienced by the North-East Atlantic Fisheries Commission, can function as a redistribution scheme to manage the fishers' behavior; those abiding by the rules will receive higher quota levels while those breaking the rules will receive lower quota levels (Stokke 2009). Quotas were implemented in the North Atlantic Ocean to combat IUU through the regional enforcement by the International Commission for the Conservation of Atlantic Tunas (ICCAT) and the national enforcement of the member-states (Sumaila et al. 2006). The introduction of individual transferable quotas (ITQ), where an individual is given a right to catch a percentage of fish from the total allowable catch (TAC), was aimed to achieve economic efficiency in fishing but may lead to stock collapse with uncertain stock estimates due to IUU activities (Sumaila 2010).

One of the strategies to minimize IUU activities in the international market is through import taxes and placing tariffs, which makes the imported fish more expensive and thus reducing the profit for both fishers and importers (Sovacool and Siman-Sovacool 2008). Also, taxing fish effort would lead to fleet reduction, resulting to increased net benefits from the marine resources (Pauly et al. 2002). In the literature on IUU fishing, however, tax avoidance are possible by choosing a flag for convenience and non-compliance, which gives the vessel owner an economic advantage over those vessels following the rules (Miller and Sumaila 2014). Furthermore, middlemen in the fish trade in Mexico opt to remain underground and informal to continue patronizing the markets for IUU activities, which makes the fish cheaper because of low or non-reporting to avoid fiscal obligations (Pedroza 2013). In our study, we found similar motivations for local fishers to engage in IUU fishing.

Closing seas for a fishing season or specific fishing region are also among the strategies to reduce IUU activities in the Philippines. Seasonal closures were implemented in the Visayan Sea to encourage the spawning of fish (Ramos 2014) and the Sulu Sea and the Basilan Strait for sardine fishing (Pareño 2016). Also, seasonal closures for purse seine and ring netters to use fish-aggregating devices during the months of July to September were implemented (BFAR 2014). However, closures are only effective to some extent but cannot stop the depletion of resources, especially if the timing does not coincide with the spawning season of the fish (Yu and Yu 2008).

As the fisheries sector is transitioning towards an ecosystem-based management, it is important that IUU fishing is minimized if not totally eradicated (Pauly et al. 2002). At the current stage of the fisheries development, the benefits involved in IUU fishing outweighs the cost twenty-four times (Sumaila et al. 2006). The current penalty levels of most countries do not act as a deterrent to IUU activities (Le Gallic and Cox 2006). Aside from monetary penalty, Le Gallic and Cox (2006) identified vessel and catch confiscation and imprisonment as in the case of Indonesia as more effective measures. For the Philippines, it is practical to increase the penalties involved in IUU fishing and further improve the monitoring activities such as the Fisheries Observer Program.

Conclusion

The increasing demand for tuna exports put pressure on the sustainability of tuna fishing in the Philippines. Being one of the top exporters of tuna in the world, it is important that illegal, unreported, and unregulated (IUU) fishing be addressed to maintain the country's global reputation and contribute to the sustainability of tuna fishing. However, as the fishermen sail farther from the Philippine exclusive economic zone to catch tuna in distant waters, including the High Seas and the Indonesian and Papua New Guinea seas, monitoring IUU activities becomes a challenging task. Handline tuna fishing, although more sustainable in terms of fishing practice, is a source of concern in terms of IUU fishing.

Hence, we identified the level of IUU fishing in the country, particularly the underreporting of tuna catches. Also, we explored the drivers of IUU fishing and its implication to the efficiency of tuna vessels. We found widespread underreporting of tuna catches estimated at 51%–100% and prevalence of underreporting among vessels of smaller size. Influencing the handline fishers' decision to engage in IUU activities are the need to generate extra income to support household needs, the drive to get a higher share of the profit vis-à-vis operators and vessel owners, and the deficient monitoring, control, and surveillance of fishing vessels by responsible agencies. Our results also show that longer effort days and higher fuel consumption do not necessarily translate to technical efficiency. This implies that limiting the effort days at sea have a positive effect on the efficiency level of the fishing vessels. Moreover, the increasing number of fishing vessels operating in the Moro Gulf and Centro fishing grounds suggests lower efficiency performance while fishing in the less distant seas of Mati is an efficient alternative. More distant and open access resource could be enticing in terms of the volume of catch but could be inefficient as suggested by the models. The actual efficiency level of the tuna handline fishers could be lower if actual levels of inputs and catch are accounted for. Sustainable management of tuna starts from the appropriate inventory of fish stocks. Hence, if catch reports are more accurate, the management of the fisheries becomes more sustainable.

We recommend that penalties should be increased to discourage the fishermen from engaging in IUU activities. While we recognize the efforts of the country's fisheries bureau to eradicate IUU activities, monitoring activities such as the Fisheries Observer Program need to be more frequent. Since small-scale fishers are more likely to engage in IUU activities, we recommend improving the enabling environment for the small-scale handline fishers by providing training support for livelihood opportunities for the housewives to provide extra sources of income, safety nets to support the household's food security and income especially during off-fishing season, and empowerment of the community to sustainably manage marine resources.

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