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Relative abundance of yellowfin tuna for the purse seine and handline fisheries operating in the Philippines Moro Gulf (Region 12) and High Seas Pocket #1[1]

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Abstract

Port sampling data were used to estimate effort, catch, CPUE, standardized CPUE, and species composition from the purse seine fishery operating in the southern Philippines (Region 12, SOCCSKSARGEN) and High Seas Pocket #1 and the handline fishery operating in Region 12. A quarterly standardized CPUE index was produced for the purse seine (2005 to 2016) and handline (2004 to 2016) fishery for use in the 2017 WCPFC yellowfin tuna assessment. Standardized CPUE was estimated using Generalized Linear Models (GLMs) and removing effects due to vessel and area (fishing ground). The index for the 2014 assessment used a GLM that predicted monthly CPUE with year, month, and vessel effects. The current index predicted quarterly CPUE with a *YR:QTR*, *Area* (fishing ground) and *Vessel* effects. A combined *YR:QTR* effect was estimated to be consistent with other fishery CPUE standardization methods used in the assessment. There were 12 *Area* designations in the database; however, *Area* was relatively non-informative in the model as fishing trips were dominated by a few areas.

1 Introduction

Six tuna species dominate Philippine tuna landings, i.e. skipjack tuna (*Katsuwonus pelamis*), yellowfin tuna (*Thunnus albacares*), bigeye tuna (*T. obesus*), eastern little tuna (*Euthynnus affinis*), frigate tuna (*Auxis thazard*), and bullet tuna (*A. rochei*). The most common gears used by the commercial sector for catching these tuna species are purse seines and ringnets, while the municipal fishers use hook-and-line or handline. All these gears are operated jointly with fish aggregating devices (FAD), known as *payao* in the Philippines. Skipjack and yellowfin are found throughout the year in all Philippine waters but are abundant in Moro Gulf, Sulu Sea, and Sulawesi Sea off Mindanao Island. Large landings of these species occur in General Santos City where six out of eight tuna canneries are located.

The objective of this study was to use port sampling data to estimate effort, catch, CPUE, standardized CPUE for yellowfin tuna in the purse seine fishery operating in the southern Philippines (Region 12, SOCCSKSARGEN) and High Seas Pocket #1 and handline fishery operating in Region 12.

2 Methods

National Stock Assessment Program (NSAP) protocols, sampling coverage rates, raising factors for catch and effort, and quality control

Analyses on fishery performance and relative abundance were based upon NSAP data collected at the Fishport Complex in General Santos City. The Fishport is the major tuna landing site in Mindanao for handline, purse seine, and ringnet fisheries. The NSAP sampling was initiated in 1997, though sampling was sparse for several years. Analyses considered purse seine from 2005 to 2016 and handline from 2004 to 2016. With WPEA-OFMP funding, sampling of unloaded vessels to total vessels has especially improved since 2010. Port sampling data collection prior to 2013 followed a NSAP protocol where sampling was conducted every third day, regardless if the sampling day was on the weekend or a holiday. With Philippine purse seiners gaining access to High Seas Pocket #1 in 2013, the sampling protocol was altered to monitor up to 100% unloadings from vessel activity in High Seas Pocket #1 even if landings occur on a non-sampling day.

Sampling occurred where possible on all fishing boats (e.g. handline, purse seine, ringnet, gillnet) that unloaded their catch. Data were recorded on NSAP forms which include the following information based on each fishing trip:

A. Year
B. Month
C. Name of fishing ground
D. Region
E. Landing center
F. Date of sampling
G. Gear
H. Vessel name
I. No. of fishing days (time) of the actual fishing operation
J. Total catch by the vessel (no. of boxes/*bañeras* or weight)
K. Sample weight of the catch
L. Catch composition weight by species (scientific names)
M. Name and signature of the NSAP samplers/enumerators

Collected data are submitted monthly by the Project Leaders or Assistant Projects Leaders to the National Fisheries Research and Development Institute (NFRDI) office. Monthly port sampling reports are entered and managed in the NSAP Database System. Two types of data were extracted from the NSAP Database (version 5.1): 1) sampling of each vessel, hereafter referred to as 'trip sample,' and 2) raised estimates for each month for trips, effort (days), and catch by species, hereafter referred to as 'raised monthly estimates'.

Raised estimates are based on the sampling coverage which is defined as the coverage of unloaded vessels on days that were sampled (i.e. the proportion of sampled vessels' unloaded catch to the total unloaded catch for days that were sampled) and the coverage of the sampling days in the month. Annual coverage prior to 2010 was 13% for the handline fishery and improved to 32% during 2010 to 2016. Annual coverage was 6% for the purse seine fishery prior to 2010. Coverage improved to 11% in the purse seine fishery during 2010 to 2012 and increased again to 45% during 2013 to 2016 because more unloadings were monitored. Vessel name entries in the NSAP database were particularly problematic due to multiple spellings for a unique vessel. Quality control for purse seine vessels consisted of consolidating obvious multiple spellings to a single vessel assignment, which resulted in the 357 purse seine vessels.

Statistical methods to estimate species relative abundance

Trip sample data were used to estimate fishing effort and catch of individual species. Statistical methods were used to estimate 'relative abundance' or 'standardized CPUE' by removing effects due to vessel and fishing area. Generalized Linear Models (GLMs) were used to estimate relative abundance. The GLM predicts mean catch (μ_i) using three categorical variables with a log link as follows:

$$\log(\mu_i) = YR:QTR_i + Area_i + Vessel_i + \log(Effort_i)$$

where *YR:QTR* is the mean local abundance or year and quarter effect, *Area* is the area effect, *Vessel* is the vessel effect (vessel name), and offset *Effort* is the number of days of the fishing trip. Since a species may have instances of zero catch per quarter, a GLM with a negative binomial distribution was used to accommodate zero observations. The GLMs were fit in R (R Development Core Team, 2016, version 3.3.0 for Linux) with a MASS library. GLMs were initially fit with the *YR:QTR* effect and then with sequential addition of other explanatory variables. Model selection was based on the Akaike Information Criterion (AIC). Relative abundance of each species was calculated from the GLM results using the 'predict.glm' routine by exponentiating *YR:QTR* while constraining other effects (*Area* and *Vessel*) to a single value. The GLM trends are normalized to facilitate comparison, such that the mean of the entire series is a value of 1.0.

The standardized CPUE for the Philippines purse seine fishery (Bigelow et al. 2014) used in the 2014 assessment (Davies et al. 2014) used a GLM that had separate *YR* and *Month* effects:

$$\log(\mu_i) = Year_i + Month_i + Area_i + Vessel_i + \log(Effort_i)$$

The *YR* and *Month* effects were predicted, and these effects were averaged for each quarter to correspond to the temporal resolution of the 2014 assessment (Davies et al. 2014). The current use of a combined *YR:QTR* effect was estimated to be consistent with other fishery CPUE standardization methods used in the 2017 assessment (Tremblay-Boyer et al. 2017).

3 Results and Conclusions

Handline fishery trends – effort and catch

Yellowfin tuna comprised ~82.8% of the handline catch during 2004 to 2016 (Table 1) and typically varies between 80 to 90% annually (NFRDI/BFAR 2012). The remainder of the catch is composed of blue marlin (*Makaira mazara*, ~11.2%), bigeye tuna (~3.4%), albacore (*Thunnus alalunga,* ~1.3%) and other species of ~1% (Table 1). Monthly trends in effort, catch, nominal CPUE, and relative abundance for the handline fleet based in General Santos City are illustrated in Figures 1–3. There are no estimates for months when sampling did not occur; therefore, gaps exist in the effort, catch, nominal CPUE, and relative abundance time-series. Handline effort averaged ~10,700 boat days per month and generally ranged from 5,000 to 15,000 days (Figure 1). Effort during 2006 to mid-2009 was higher than from mid-2009 until the end of 2013. Handline effort averaged 18 boat days per trip, although there has been an increase over time due to vessels traveling farther away from port in an attempt to obtain higher catch rates and/or the use of larger vessels that can remain at sea for longer durations. Handline catch of yellowfin tuna averaged ~750 mt per month during 2004–2016 with low catches in years 2010, 2012, and 2015 (Figure 2).

Handline species trends – nominal CPUE and relative abundance

Monthly yellowfin tuna nominal CPUE for the handline fleet averaged 88 kgs per boat day and fluctuated from 30 to 170 kgs per boat day (Figure 3). The CPUE increased from 2004 to 2007, declined precipitously from 2008 until the end of 2009, rebounded strongly in 2010, and was relatively stable from 2011 to 2016.

The GLM analysis considered four models based on effects of: 1) *YR:QTR* (Figure 3 black line), 2) *YR:QTR* and *Vessel* (Figure 3 blue line), 3) *YR:QTR* and *Area* (Figure 3 red line), and 4) *YR:QTR, Vessel,* and *Area* (Figure 3 grey line). Results and diagnostics indicated that models based on *YR:QTR* and *Vessel* and *YR:QTR*, *Vessel*, and *Area* were statistically preferred. Relative trends were similar for all models, with *YR:QTR* and *Area* having the most optimistic trend. Inspection of the *Area* declaration indicated that Moro Gulf was declared for ~79% of the fishing areas from 2004 to 2016; therefore, the area effect is not too informative as an explanatory effect in the model. The trend based on *YR:QTR* and *Vessel* is considered the most representative to illustrate relative abundance of yellowfin tuna for the handline.

In the comparison between nominal yellowfin CPUE and relative abundance, the relative abundance trend has less variability and generally follows the trend in nominal CPUE. While the GLMs included a *Vessel* effect, in reality the relative abundance trend may be biased because the analysis does not adequately quantify efficiency for each handline vessel. The nominal increase in CPUE for yellowfin tuna (Figure 3) from 2004 to the end of 2008 may be related to increased vessel efficiency, such as handline vessels having an increasing number of *pakura* or small pump boats which were introduced in 2005. Thus the increasing CPUE and relative abundance may in reality relate to vessels with more *pakura* catching more fish per boat day.

The standardized CPUE trend from the 2014 and 2017 assessments is illustrated in Figure 5. The trajectory among trends is similar, though the 2014 trend has different covariates related to time (*Year* and *Month*; *YR:QTR*) estimated by the GLMs.

Purse seine fishery trends – effort, catch and nominal CPUE

Yellowfin tuna comprised 15.8% of the purse seine catch from 2005 to 2016. The remainder of the catch was composed of skipjack tuna (57.9%), mackerel scad (*Decapterus macarellus*, 9.0%), bullet tuna (*Auxis rochei*, 8.9%), frigate tuna (*Auxis thazard*, 4.4%), bigeye tuna (1.6%), and other species representing < 1% of the catch (Table 4). Monthly trends in raised effort and catch and nominal CPUE for the purse seine fleet based in General Santos City are illustrated in Figures 6–8.

Purse seine effort averaged ~ 518 boat days per month (Table 2) and generally ranged from 100 to 1,500 days (Figure 6). Effort during 2005 to 2009 was slightly higher than effort in 2010 to 2012. There has been an increase in purse seine effort from 2013 to 2016 due to re-opening of High Seas Pocket #1 for a limited number of Philippine flagged purse seine vessels.

Purse seine catch of yellowfin tuna averaged ~ 573 mt per month, and from 2010 to 2012, there was a decline in purse seine catches of yellowfin tuna (Figure 7). Yellowfin nominal CPUE in the purse seine fishery averaged 1.18 mt per day and was low during 2010 and 2011 (Figure 8).

Purse seine fishery trends – standardized CPUE

Model results of the GLM analysis are provided in Table 5. The highest explanatory ability and lowest AIC were for GLMs with the inclusion of *YR:QTR*, *Area*, and *Vessel* effects. There were 12 *Area* designations in the database; however, *Area* was relatively non-informative in the model as the trips were dominated by three areas. Standardized CPUE trends for the four models are illustrated in Figure 9. Trends were consistent among the models from 2005 to 2014, and nominal CPUE diverged from the other three models in 2014 and was more optimistic.

A model based on *YR:QTR* and *Vessel* effects was chosen as the model for inclusion in the 2017 yellowfin tuna assessment (Tremblay-Boyer et al. 2017). The model based on *YR:QTR*, *Area*, and *Vessel* had a slightly higher explanatory ability; however, there is an imbalance in the *Area* covariate as one area (International Waters) was not declared in the database prior to 2012, but was fished thereafter.

The standardized CPUE trend from the 2014 and 2017 assessments is illustrated in Figure 10. The trajectory among trends is similar, though the 2014 trend has different covariates related to time (*Year* and *Month*; *YR:QTR*) estimated by the GLMs.

4 References

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Tremblay-Boyer, L, S. McKechnie, G. Pilling, and J. Hampton. 2017. Stock assessment of yellowfin tuna in the Western and Central Pacific Ocean. WCPFC-SC13-2017/SA-WP-XX, Rarotonga, Cook Islands 9-17 August 2017.

Table 1. Catch and species composition (%) estimated by NSAP for the handline fishery (2004 to 2016) in Region 12 (SOCCSKSARGEN) based on BFAR NFRDI monitoring.

Species	**Catch (mt)**	**Percent (%)**	**Monthly catch – mean (median)**
Yellowfin tuna (*Thunnus albacares*)	116,806.3	82.79%	768 (687)
Blue marlin (*Makaira mazara*)	15,835.3	11.22%	108 (84)
Bigeye tuna (*Thunnus obesus*)	4,769.7	3.38%	32(26)
Albacore (*Thunnus alalunga*)	1,896.8	1.34%	
Sailfish (*Istiophorus platypterus*)	696.2	0.49%	
Black marlin (*Makaira indica*)	656.7	0.47%	
Swordfish (*Xiphias gladius*)	333.0	0.24%	
Moonfish (*Lampris guttatus*)	62.8	0.04%	
Other	11.9	<0.01%	
Total	141,091.3	100%	

Table 2. Mean operational and catch characteristics for handline (9,727 trips) and purse seine (2,359 trips) fisheries operating in Region 12 (SOCCSKSARGEN) and High Seas Pocket #1 based on BFAR NFRDI monitoring.

	Handline (2004–2016)	**Purse seine (2005–2016)**
Number of trips per month	588	113
Number of days per month	10,735	518
Days per trip	21.9	4.1
Catch (mt) per month	928	3,621
Catch (kgs) per day per vessel	74.7	7,734

Table 3. Results for Generalized Linear Models (GLMs) applied to yellowfin tuna in the handline fishery (2004 to 2016) in Region 12 (SOCCSKSARGEN). The percent deviance explained is ((null deviance-residual deviance)/null deviance). Model selection was based on the Akaike Information Criteria (AIC).

GLM Model	Null deviance	Residual deviance	AIC	% deviance explained
YR:QTR	11,958	11,293	165,573	5.5
YR:QTR+ Vessel	24,040	10,819	164,972	55.0
YR:QTR+ Area	12,265	11,271	165,313	8.1
YR:QTR+ Area+Vessel	24,327	10,818	164,887	55.5

Table 4. Catch and species composition (%) estimated by NSAP for the purse seine fishery (2005 to 2016) in Region 12 (SOCCSKSARGEN) and High Seas Pocket #1 based on BFAR NFRDI monitoring.

Species	**Catch (mt)**	**Percent (%)**
Skipjack tuna (*Katsuwonus pelamis*)	326,114.4	57.9
Yellowfin tuna (*Thunnus albacares*)	88,990.9	15.8
Mackerel scad (*Decapterus macarellus*)	50,744.6	9.0
Bullet tuna (*Auxis rochei*)	49,943.4	8.9
Frigate tuna (*Auxis thazard*)	24,970.4	4.4
Bigeye tuna (*Thunnus obesus*)	9,097.8	1.6
Eastern little tuna (*Euthynnus affinis*)	5,029.9	0.9
Rainbow runner (*Elagatis bipinnulata*)	4,908.5	0.9
Mahimahi (*Coryphaena hippurus)*	1,183.0	0.2
Other	1,799.9	0.3
Total	562,782.8	100.0

Table 3. Results for Generalized Linear Models (GLMs) applied to yellowfin tuna in the purse seine fishery (2005 to 2016) in Region 12 (SOCCSKSARGEN) and High Seas Pocket #1. The percent deviance explained is ((null deviance-residual deviance)/null deviance). Model selection was based on the Akaike Information Criteria (AIC).

GLM Model	Null deviance	Residual deviance	AIC	% deviance explained
YR:QTR	3,004	2,758	45,748	8.2
YR:QTR+ Vessel	4,296	2,670	45,406	37.8
YR:QTR+ Area	3,434	2,724	45,373	20.6
YR:QTR+ Area+Vessel	4,393	2,660	45,368	39.3

Figure 1. Raised monthly effort in the Philippine Region 12 (SOCCSKSARGEN) handline fishery based on BFAR NFRDI monitoring.

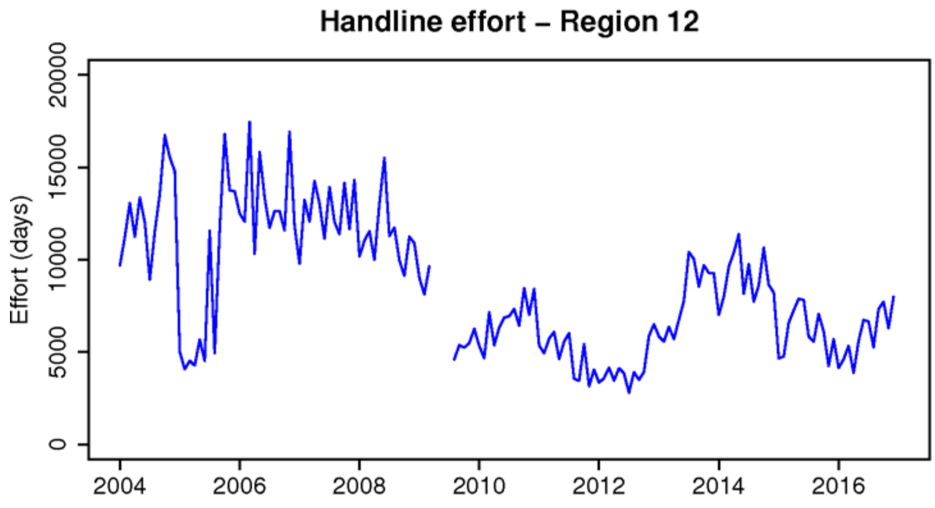

Figure 2. Raised monthly yellowfin tuna catch in the Philippine Region 12 (SOCCSKSARGEN) handline fishery based on BFAR NFRDI monitoring.

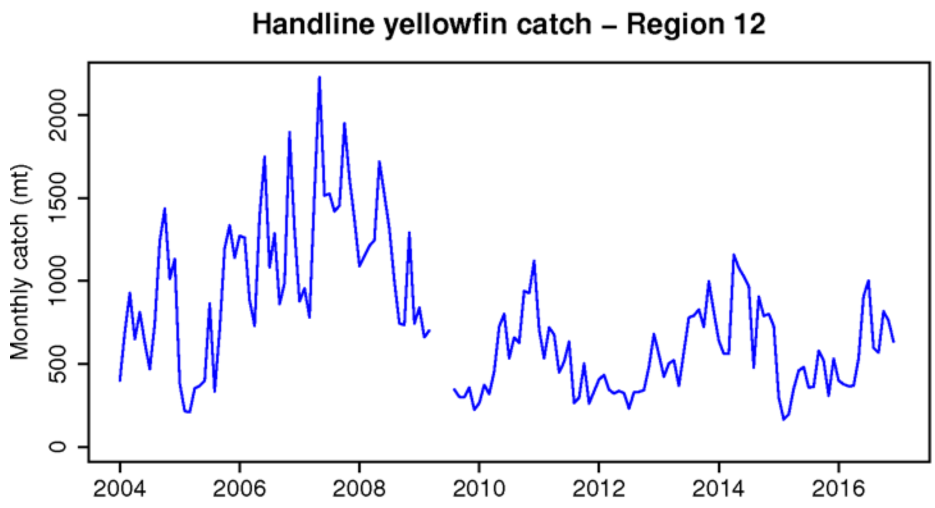

Figure 3. Nominal monthly yellowfin tuna CPUE in the Philippine Region 12 (SOCCSKSARGEN) handline fishery based on BFAR NFRDI monitoring.

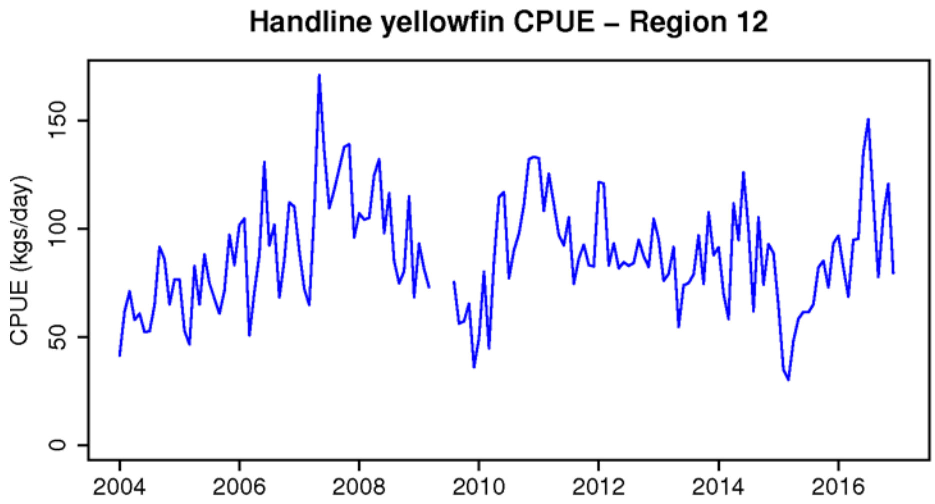

Figure 4. Quarterly relative abundance for yellowfin tuna in the Philippine Region 12 (SOCCSKSARGEN) handline fishery as determined by Generalized Linear Models (GLMs). Each series is normalized to a mean value of 1.0.

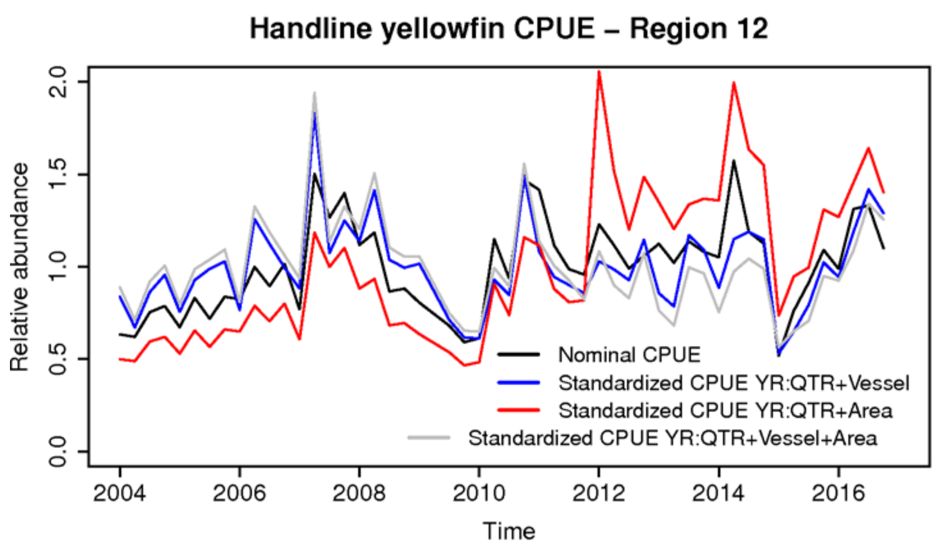

Figure 5. Comparison of Philippine relative abundance indices used in the 2014 and 2017 yellowfin tuna assessments for the western and central Pacific Ocean. Indices are for yellowfin tuna in the Philippine Region 12 (SOCCSKSARGEN) handline fishery as determined by Generalized Linear Models (GLMs). Each series is normalized to a mean value of 1.0.

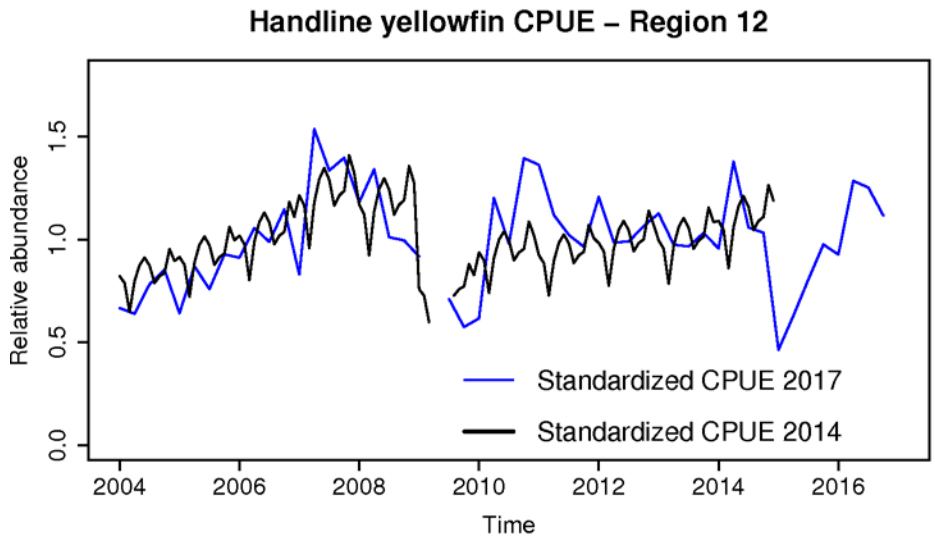

Figure 6. Raised monthly effort in the Philippine Region 12 (SOCCSKSARGEN) and High Seas Pocket #1 purse seine fishery based on BFAR NFRDI monitoring.

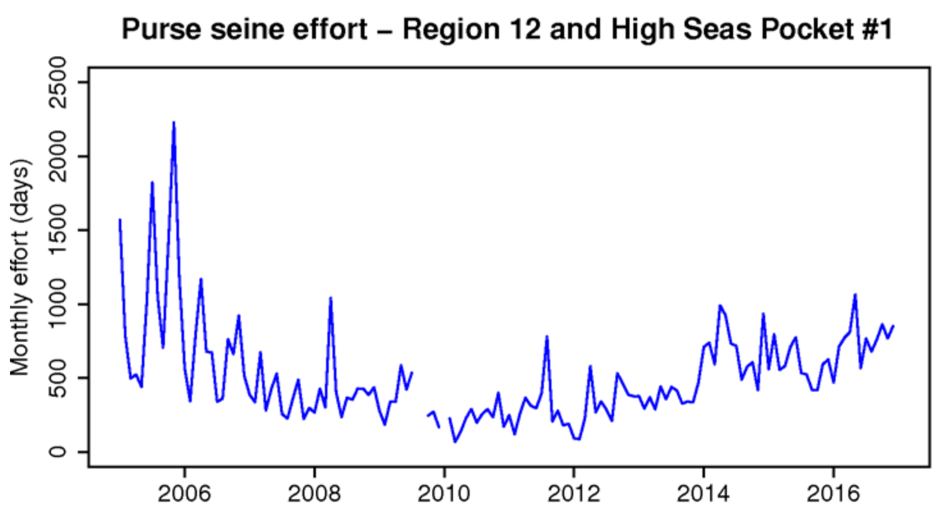

Figure 7. Raised monthly yellowfin tuna catch in the Philippine Region 12 (SOCCSKSARGEN) and High Seas Pocket #1 purse seine fishery based on BFAR NFRDI monitoring.

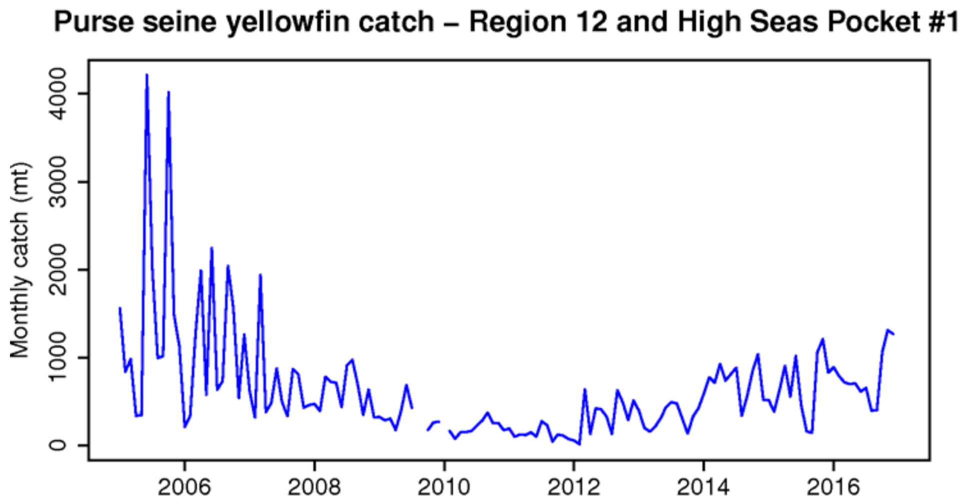

Figure 8. Nominal monthly yellowfin tuna CPUE in the Philippine Region 12 (SOCCSKSARGEN) and High Seas Pocket #1 purse seine fishery based on BFAR NFRDI monitoring.

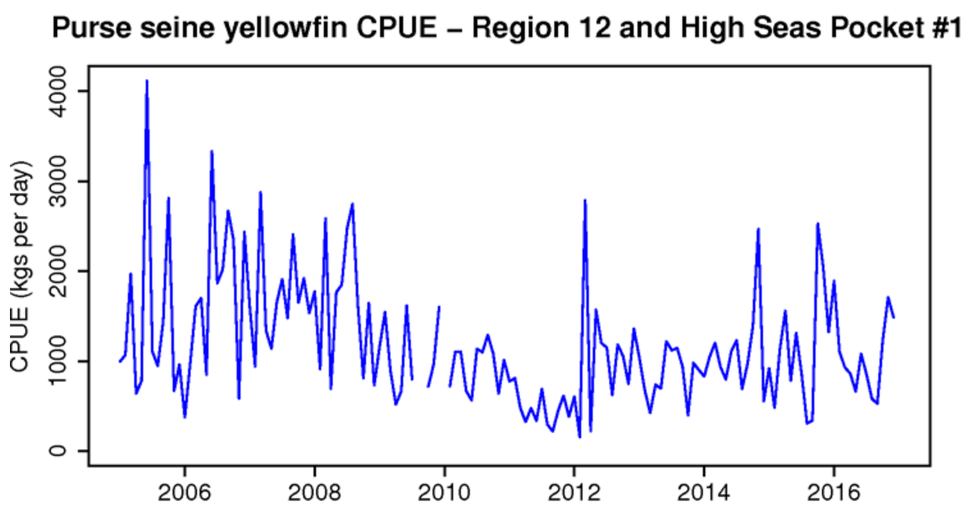

Figure 9. Quarterly relative abundance for yellowfin tuna in the Philippine Region 12 (SOCCSKSARGEN) and High Seas Pocket #1 purse seine fishery as determined by Generalized Linear Models (GLMs). Each series is normalized to a mean value of 1.0.

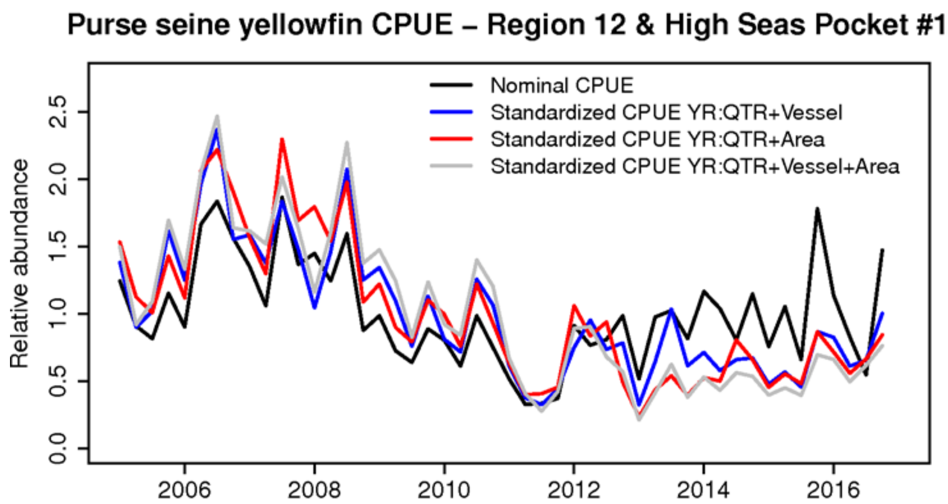

Figure 10. Comparison of Philippine relative abundance indices used in the 2014 and 2017 yellowfin tuna assessments for the western and central Pacific Ocean. Indices are for yellowfin tuna in the Philippine Region 12 (SOCCSKSARGEN) and High Seas Pocket #1 purse seine fishery as determined by Generalized Linear Models (GLMs). Each series is normalized to a mean value of 1.0.