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Relative abundance of skipjack and yellowfin in the Moro Gulf (Philippine Region 12)[1]

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Relative abundance of skipjack and yellowfin tuna in the Moro Gulf (Philippine Region 12)

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Introduction

There are six tuna species that 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 and Zamboanga City where eight tuna canneries are located.

Estimating tuna fisheries catch in the Philippines has been historically difficult due to the country having large and diverse fisheries that operate at thousands of domestic landing sites as well as purse seine fisheries that operate on the high seas and foreign EEZs. These large and diverse fisheries pose particular challenges for accurate data collection. Since 1987, the official fishery statistics for the Philippines have been compiled by the Bureau of Agricultural Statistics (BAS). Estimates are based on probability (stratified random sampling by data collectors) and non-probability (interviews by regular BAS staff) surveys, supplemented by secondary data from administrative sources such as landings sites and ports. Annual Fisheries Statistics for commercial, municipal, inland and aquaculture sectors are published for three year time frames, most recently for 2008–2011 inclusive (BAS 2011), and include volume and value of production by province and by region, information on fish prices and foreign trade statistics. Tuna fisheries data are collected by Bureau of Fisheries and Aquatic Resources (BFAR) and within BFAR; the National Stock Assessment Program (NSAP) collects data on species composition, length frequency, vessel catch and effort data from key tuna landing ports around the country. Increased port sampling coverage has occurred through support from the West Pacific East Asia Oceanic Fisheries Management Project (WPEA-OFMP) which started in 2010.

From 2008 to 2012, the total tuna catch by Philippine vessels (handline, purse seine, ringnet and municipal fisheries) in the Convention Area averaged 275,603 mt (Philippines 2013) and represented ~11% of the entire catch in the WCPF Convention Area. Catch by Philippine vessels was highest at 360,187 mt in 2008 and declined precipitously to 192,956 mt in 2011. The composition of oceanic tuna species by weight has remained fairly stable and averaged 62.6% skipjack, 35.0% yellowfin and 2.4% bigeye from 2008–2012. Within the WCPF Convention Area, Philippine flagged purse seine and ringnet vessels have operated within the Philippines EEZ, international waters typically referred to as High Seas pocket #1 and the EEZs of PNG and recently in the Solomon Islands under access arrangements. There has been a shift in the production by fishery sector from 2008 to 2012 as the Philippine bilateral purse seine fleet increased their catch from 16% to 27% of the total with corresponding declines in the domestic purse seine fleet from 61% to 16% and municipal fisheries from 36% to 21%.

The objective of this study was to utilize NSAP data to estimate relative abundance or standardized CPUE for tuna species in Region 12 (SOCCSKSARGEN) in southern Mindanao for use in the 2014 WCPFC skipjack and yellowfin assessments. This study produced monthly relative abundance indices for yellowfin tuna in the handline fishery and skipjack and yellowfin tuna in the purse seine fishery. A technical report will be produced that contains a larger scope of additional species and inclusion of the ringnet fishery. Bigeye tuna indices were not incorporated into the WCPFC assessment, as they are non-informative due to relatively low catch levels in the Philippines. Unlike many other purse seine fisheries, bigeye tuna identification problems are negligible in the Philippines due to the reliability of the BFAR NSAP catch composition data from port sampling

National Stock Assessment Program protocols, sampling coverage rates, 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. Port sampling data collection follows the NSAP protocol where sampling is conducted every third day regardless if the sampling day is on the weekend or a holiday. 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 available 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 a ‘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.

The NSAP sampling was initiated in 1997, though sampling was sparse for several years. Analyses considered handline from 2004–2012 and purse seine and ringnet from 2005–2012. With WPEA-OFMP funding, sampling of unloaded vessels to total vessels has especially improved during 2010–2012. Overall coverage prior to 2010 was 13%, 6% and 3% in the handline, purse seine and ringnet fishery, respectively. Overall coverage improved to 30%, 11% and 8% in these fisheries during 2010–2012.

Vessel name entries in the NSAP database were particularly problematic due to multiple spellings for a unique vessel. No quality control was attempted for the handline fishery. Quality control for purse seine and ringnet vessels consisted of consolidating obvious multiple spellings to a single vessel assignment, which consequently reduced the number of purse seine vessels in the database from 113 to 77. An attempt was made to assign a Gross Tonnage (GT) to each vessel from the BFAR licensing database in order to characterize fishing efficiency; however there were problems in linking vessel names between databases.

Statistical methods to estimate species relative abundance

Trip sample data were used to estimate fishing effort and catch of individual species. Catch rate or nominal catch per unit effort (CPUE) is the catch divided by fishing effort and relates to fishing performance of a vessel. Since nominal CPUE is estimated as kilograms per fishing day, the interpretation of CPUE can be confounded by several factors such as vessel efficiency, seasonality, fishing areas within Region 12, and the availability of fish in Region 12 that may be affected by fishery depletion from other fisheries in the Western Pacific or affected by the environment (El Niño/La Niña) etc.

Statistical methods are used to estimate ‘relative abundance’ or ‘standardized CPUE’ by removing effects due to vessel, seasonality (i.e. month) and area. Generalized Linear Models (GLMs) were used to estimate relative abundance. The GLM predicts mean catch (μ_i) using four categorical variables with a log link as follows:

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

where *Year* is the mean local abundance or year effect, *Month* is the month effect, *Area* is the area effect, *Vessel* is the vessel effect (vessel name) and offset *Effort* is the number of days during fishing trip. Since some species may have instances of zero catch per month, a GLM with a negative binomial distribution was used to accommodate zero observations. The GLMs were fit in R (R Development Core Team, 2008, version 2.7.2 for Linux) with a MASS library. GLMs were initially fit with the *Year* effect and then with sequential addition of other explanatory variables. Model selection was based on the Bayesian Information Criteria (BIC, Schwarz 1978). Relative abundance of each species was calculated from the GLM results using the ‘predict.glm’ routine by exponentiating *Year* and *Month* effects 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. Trends in relative abundance were compared for each species by characterizing the percentage difference between the initial three years in the time-series with the last three years. For example, abundance was compared from 2010–2012 to 2004–2006 for the handline fishery and 2010–2012 to 2005–2007 for purse seine and ringnet fisheries.

Model results of the GLM analysis are provided in Appendix 1. Relative abundance trends were mostly based on the inclusion of *Year, Month* and *Vessel* effects. The inclusion of an *Area* effect did not constitute much explanatory power within the statistical analyzes because there was little contrast in the declaration of area fished thus *Area* as currently declared is not very informative. There were 14, 7 and 7 area designations in the database for the handline, purse seine and ringnet fisheries, respectively; however 93 to 98% of the trips were represented by three areas. Moro Gulf dominated the location of declared fishing trips (87% handline, 83% purse seine), followed by Moro Gulf/Centro (6% handline, 2% purse seine) and Mati (3% handline, 8% purse seine).

For the purse seine fishery, a subset of consistent vessels was used to illustrate CPUE in comparison with fleet-wide estimates. Vessels conducting 10 or more trips were considered consistent vessels.

Handline fishery trends – effort and yellowfin catch

Yellowfin tuna (*Thunnus albacares*) comprised ~82.9% of the handline catch from 2004–2012 and typically varies between 80 to 90% annually (NFRDI 2012). The remainder of the catch is composed of blue marlin (*Makaira mazara*, ~11.3%), bigeye tuna (*Thunnus obesus*, ~2.8%), albacore (*Thunnus alalunga*, ~1.7%) and other species of <1%. Monthly trends in effort, catch, nominal CPUE and relative abundance for the handline fleet based in General Santos City are illustrated in Figures 1–5. 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 ~9,000 boat days per month (Table 1) 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 2012. Handline effort averaged 23 boat days per trip, although there has been an increase over time due to vessels traveling further 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 ~820 mt per month from 2004–2012 with low catches in years 2005, 2009 and 2012 (Figure 2).

Handline species trends – yellowfin nominal CPUE and relative abundance

Monthly yellowfin tuna nominal CPUE for the handline fleet averaged 89 kgs per boat day and fluctuated from 36 to 171 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, followed by a decline in 2011 and a period of stability in 2012.

The GLM analysis considered four models based on effects of: 1) *Year* and *Month* (Figure 4 black line), 2) *Year*, *Month* and *Vessel* (Figure 4 blue line), 3) *Year*, *Month* and *Area* (Figure 4 red line) and 4) *Year*, *Month*, *Vessel* and *Area* (Figure 4 grey line). Results (Appendix 1) and diagnostics indicated that models based on *Year*, *Month* and *Vessel* and *Year*, *Month*, *Vessel* and *Area* were statistically preferred. The trends were similar for both models from 2004 to 2011 and only diverged in 2012.

Inspection of the *Area* declaration indicated that Moro Gulf was declared from 2004 to 2011, but in 2012 there was a shift in declaration to Moro Gulf/Centro. Considering that the *Area* effect in 2012 reflects different recording and not an actual spatial shift in area fished, the trend based on *Year*, *Month* and *Vessel* (Figure 4 blue line) is considered the most representative to illustrate relative abundance for yellowfin tuna.

In comparison between nominal CPUE and relative abundance (Figure 5), the relative abundance trend has less variability and generally follows the trend in nominal CPUE except in 2010 and 2011 where relative abundance is more pessimistic. While the GLMs included a *Vessel* effect, in reality the relative abundance trend may be biased because the analysis doesn't adequately quantify efficiency for each handline vessel. Consider that nominal CPUE increased for both yellowfin tuna (Figure 3) from 2004 to the end of 2008. The increase in CPUE 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 declines in 2008 and 2009 are not well understood, but may be related to a cessation in fishing access in Indonesia after July 2005 and/or environmental affects and further investigation is required.

The GLM handline results for *Year* effects are illustrated in Table 2. In characterizing the initial three years in the time-series (2004–2006) with the last three years (2010–2012), there was little difference (+1.0%) in relative abundance for yellowfin tuna. It should be noted that the estimated increases are largely contingent on assuming that the GLMs have adequately estimated effective handline effort. If vessel efficiency has increased with time and not quantified by the GLMs as postulated due to increased *pakura* usage especially after 2005, then the percentage increases are biased upwards and will be too optimistic.

Purse seine fishery trends – effort and catch

Skipjack tuna (*Katsuwonus pelamis*) comprised the majority (~55.6%) of the purse seine catch from 2005–2012. The remainder of the catch was composed of yellowfin tuna (~15%), bullet tuna (*Auxis rochei*, 11.3%), mackerel scad (*Decapterus macarellus*, 9.4%) frigate tuna (*Auxis thazard*, 4.5%), bigeye tuna (1.8%), eastern little tuna (*Euthynnus affinis*, 1.1%) and other species of 1.4%. Monthly trends in effort, catch, nominal CPUE and relative abundance for the purse seine fleet based in General Santos City are illustrated in Figures 6–14. Purse seine effort averaged ~400 boat days per month (Table 1) and generally ranged from 100 to 1,500 days (Figure 6). Effort during 2005 to 2009 was slightly higher than in all years and effort from 2010 to 2012 has been relatively stable. Purse seine catch of skipjack and yellowfin averaged ~2,255 and ~634 mt per month, respectively. From 2005 to 2012, there was a decline in purse seine catches of skipjack (Figure 8) and yellowfin (Figure 9).

Purse species trends – nominal CPUE and relative abundance

Monthly nominal CPUE for all species in the purse seine fishery averaged 8.6 mt per boat day. Nominal CPUE was ~10 mt per boat day from 2005 until the end of 2008, declined precipitously from 2009 until the end of 2011 and rebounded in 2012 to ~7 mt per boat day (Figure 10). In general, nominal CPUE for the subset of consistent vessels was similar to all vessels. Large fluctuations in nominal CPUE for all species largely reflect catch rates of skipjack in the purse fishery. Monthly skipjack tuna CPUE averaged 5.1 mt per boat day and fluctuated from 0.5 to 13.8 mt per boat day (Figure 11). Nominal CPUE was ~6 mt per boat day from 2005 until the end of 2008, declined precipitously from 2009 to very low levels in 2011 and rebounded in 2012.

The GLM analysis considered four models for each species and the preferred model was similar to the handline fishery with effects of *Year*, *Month* and *Vessel*. Model results for all vessels are illustrated as the explanatory power was higher than analyzes using consistent vessels. In a comparison of nominal CPUE and relative abundance (Figure 12), the relative abundance trend for skipjack tuna had less variability and generally follows the trend in nominal CPUE except in 2004 where relative abundance was more pessimistic and in 2011–2012 where relative abundance was more optimistic.

Monthly yellowfin tuna CPUE averaged 1.26 mt per boat day and fluctuated from 0.15 to 4.1 mt per boat day (Figure 13). Nominal CPUE for yellowfin followed the skipjack trend with a period of stability from 2006 until the end of 2008, declined precipitously from 2009 to a low in 2011 and rebounded in 2012. The trends in nominal CPUE and relative abundance were similar (Figure 14).

The GLM purse seine results for *Year* effects are illustrated in Table 3. In comparing the initial three years in the time-series (2005–2006) with the last three years (2010–2012), there were decreases of 19.2% for skipjack and 40.1% for yellowfin.

Data Recommendations

1) Better coordination with BFAR licensing section to: i) have an improved quality control of vessel names in the NSAP database, ii) be able to construct a master list of vessel names from the licensing database participating in the purse seine, ringnet and handline fisheries in order to avoid multiple spellings for a unique vessel, and iii) easily obtain vessel attributes such as length, Gross Tonnage and operational attributes.
2) Revision of Port sampling form(s) (e.g. NSAP form(s)) to include the number of *pakura* or small pump boats used per handline vessel. The number of *pakura* is required to better quantify fishing effort in the handline fishery.
3) Area designations could be improved in the NSAP data by considering smaller spatial areas.

References

BAS. 2011. Fisheries Statistics of the Philippines. 2008-2011. Volume 19. Fisheries Statistics Division, BAS, Dept. of Agriculture, Quezon City, Philippines. 404p.

NFRDI. 2012. Philippines tuna fisheries profile. Bureau of Fisheries and Aquatic Resources National Fisheries Research and Development Institute Republic of the Philippines and Western and Central Pacific Fisheries Commission. 84p.

Philippines 2013. Annual report to the Commission, Part 1: Information on fisheries, research, and statistics, WCPFC-SC9-2013/CCM–19, Pohnpei, Federated States of Micronesia, 6–14 August 2013.

R Development Core Team (2008). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. ISBN 3-900051-07-0, URL http://www.R-project.org.

Table 1. Mean operational and catch characteristics for handline (5,523 trips) and purse seine (594 trips) fisheries operating Region 12 based on BFAR NFRDI monitoring.

	Handline (2004–2012)	**Purse seine (2005–2012)**
Number of trips per month	417	111
Number of days per month	9,027	400
Days per trip	22.9	3.8
Catch (mt) per month	1,013	4,235
Catch (kgs) per day	107.8	8,632
Gross tonnage (GT)		108.1 (33 vessels)

Table 2. Year effects (relative abundance) for species in the handline fishery in Region 12 based on standardized CPUE analysis. The mean is 1.0, thus values <1.0 indicate lower abundance in a particular years while values >1.0 indicate higher abundance. A value of 1.01 for yellowfin in 2004 would indicate a 1% increase in abundance for 2004 as compared to the average from 2004 to 2012. The percentage increase from 2010–2012 is compared to 2004–2006 based on the year and month effects from the standardized CPUE analysis.

	Year									**2010–2012 compared to 2004–2006**
Species	2004	2005	2006	2007	2008	2009	2010	2011	2012	
Yellowfin tuna	1.01	0.99	0.8	0.98	1.14	1.15	1.08	0.90	0.94	+1.0%

Table 3. Year effects (relative abundance) for species in the purse seine fishery in Region 12 based on standardized CPUE analysis. The mean is 1.0, thus values <1.0 indicate lower abundance in a particular years while values >1.0 indicate higher abundance. A value of 0.82 for skipjack in 2005 would indicate a 18% decrease in abundance for 2005 as compared to the average from 2005 to 2012. The percentage increase from 2010–2012 is compared to 2005–2007 based on the year and month effects from the standardized CPUE analysis.

	Year								**2010–2012 compared to 2005–2007**
Species	2005	2006	2007	2008	2009	2010	2011	2012	
Skipjack tuna	0.82	1.19	1.10	1.25	1.13	0.91	0.48	1.12	-19.2%
Yellowfin tuna	0.88	1.41	1.31	1.30	0.94	0.86	0.47	0.83	-40.1%

Appendix 1. Results for Generalized Linear Models (GLMs) applied to species in the handline, purse seine and ringnet fisheries. Model selection is based on the percent deviance explained ((null deviance-residual deviance)/null deviance) and Bayesian Information Criteria (BIC).

	Percent deviance explained with predictor variables			
Handline fishery, 5,523 trips	Year and month	Year, month and vessel	Year, month and area	Year, month, vessel and area
Yellowfin tuna	4.3%	58.6%	5.4%	58.9%
Purse seine fishery, 594 trips				
Skipjack tuna	14.4%	31.7%	15.8%	32.4%
Yellowfin tuna	16.4%	34.0%	18.0%	34.4%

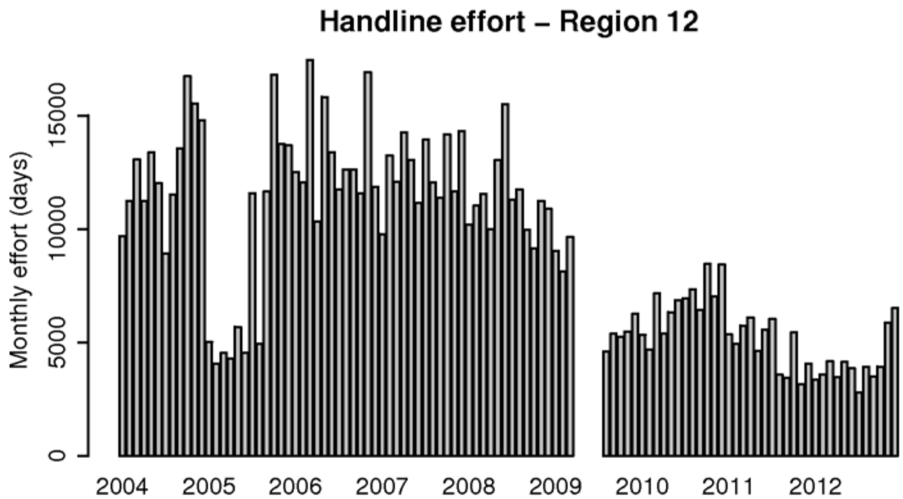

Figure 1. Monthly handline effort in the Philippine Region 12.

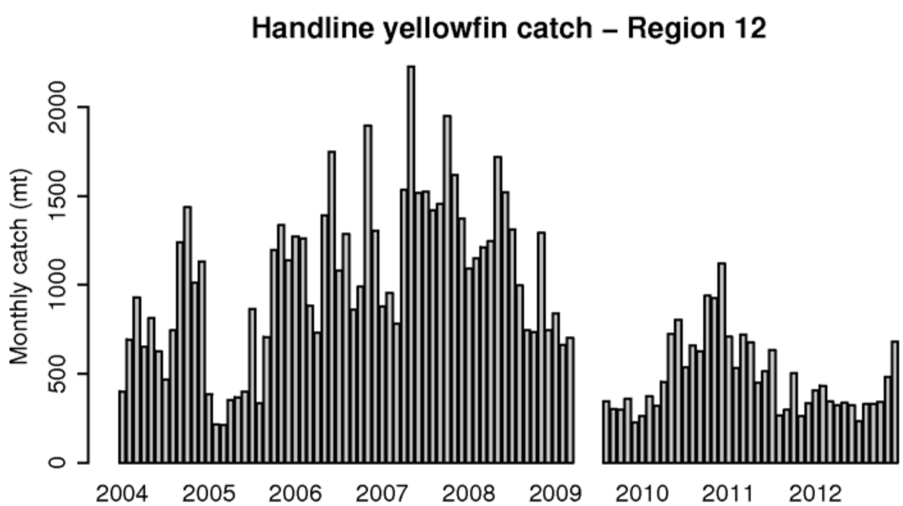

Figure 2. Monthly yellowfin tuna catch in the Philippine Region 12 handline fishery.

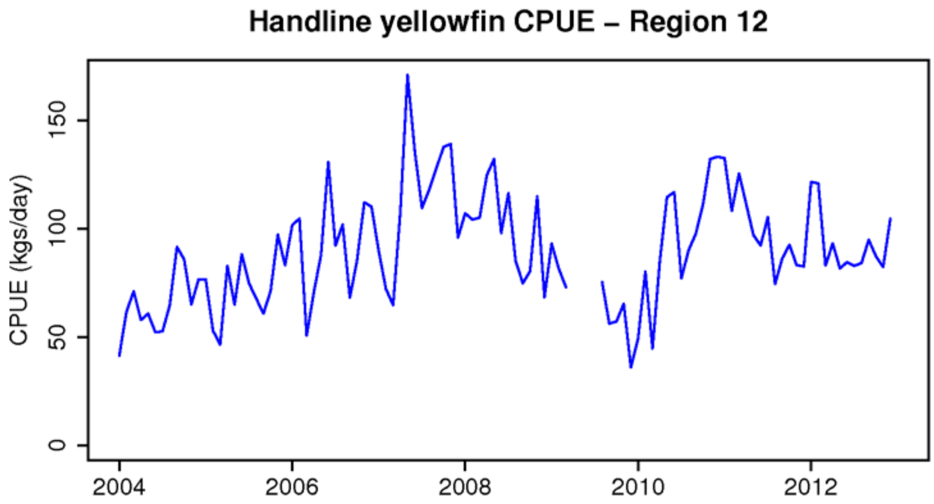

Figure 3. Monthly nominal CPUE (kgs/day) for yellowfin tuna in the Philippine Region 12 handline fishery.

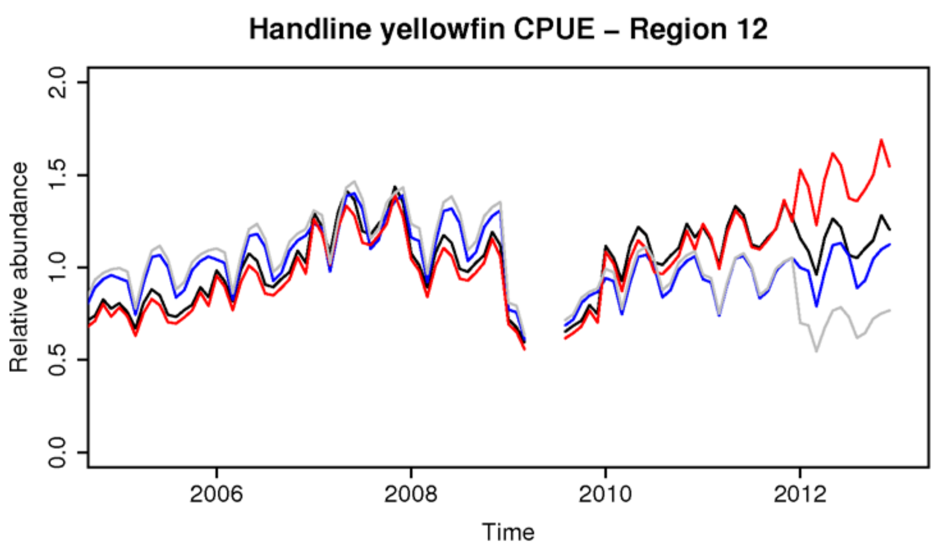

Figure 4. Monthly relative abundance for yellowfin tuna in the Philippine Region 12 handline fishery as determined by Generalized Linear Models (GLMs). Effects in GLMs are *Year* and *Month* (black line), *Year*, *Month* and *Vessel* (blue line), *Year*, *Month* and *Area* (red line) and *Year*, *Month*, *Vessel* and *Area* (grey line). Each series is normalized to a mean value of 1.0.

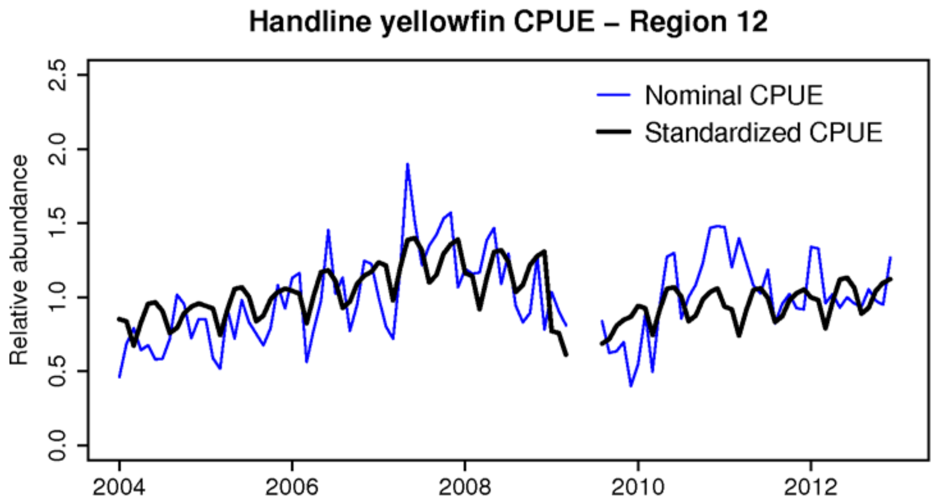

Figure 5. Comparison of monthly nominal CPUE and relative abundance for yellowfin tuna in the Philippine Region 12 handline fishery. Each series is normalized to a mean value of 1.0.

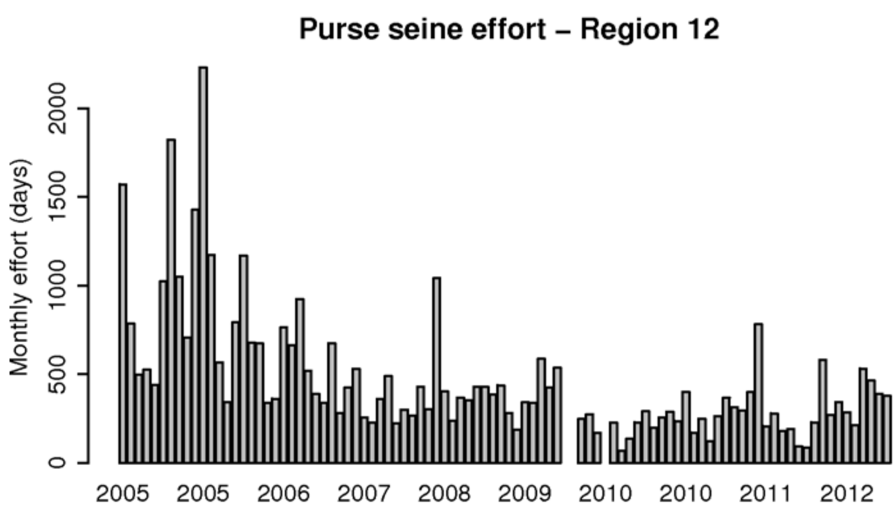

Figure 6. Monthly purse seine effort in the Philippine Region 12.

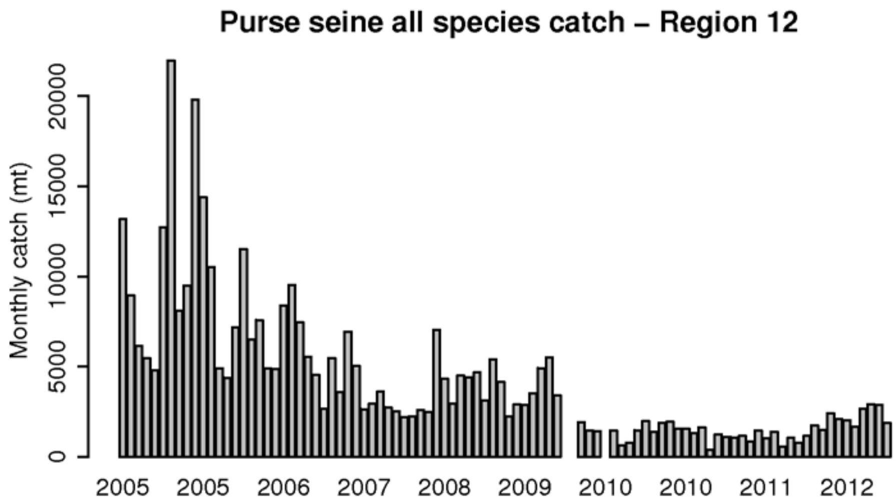

Figure 7. Monthly catch of all species in the Philippine Region 12 purse seine fishery.

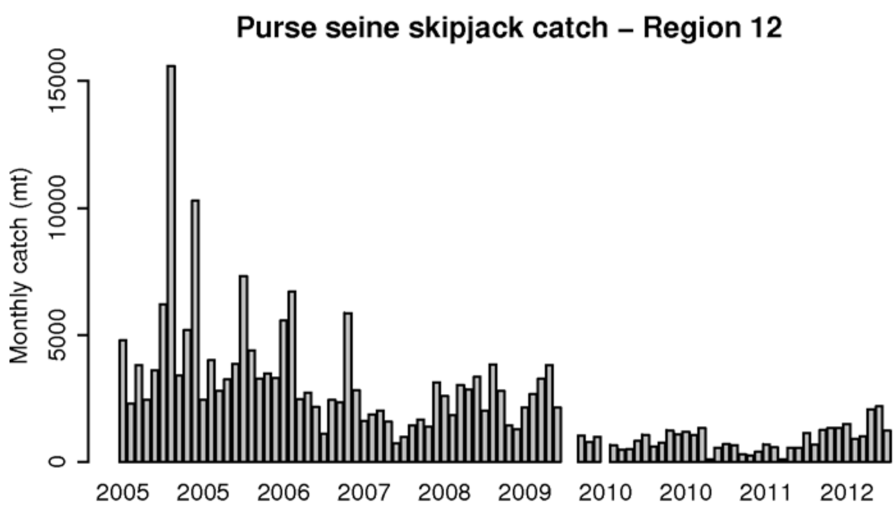

Figure 8. Monthly skipjack tuna catch in the Philippine Region 12 purse seine fishery.

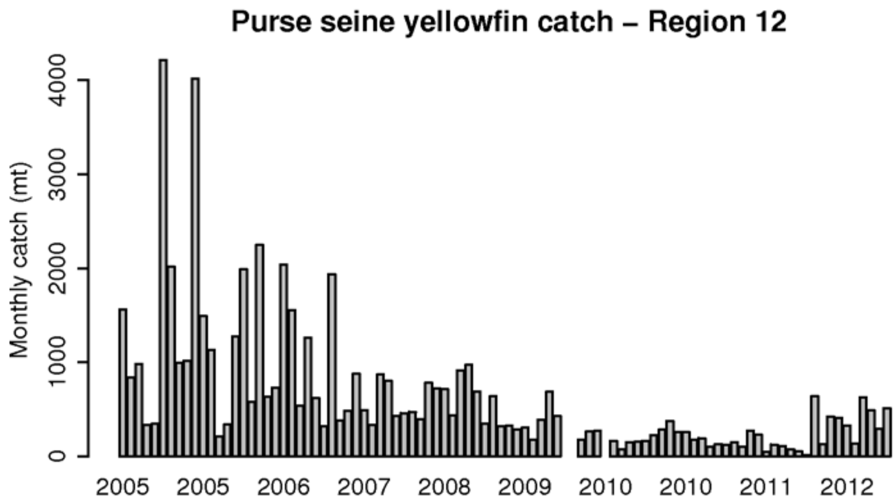

Figure 9. Monthly yellowfin tuna catch in the Philippine Region 12 purse seine fishery.

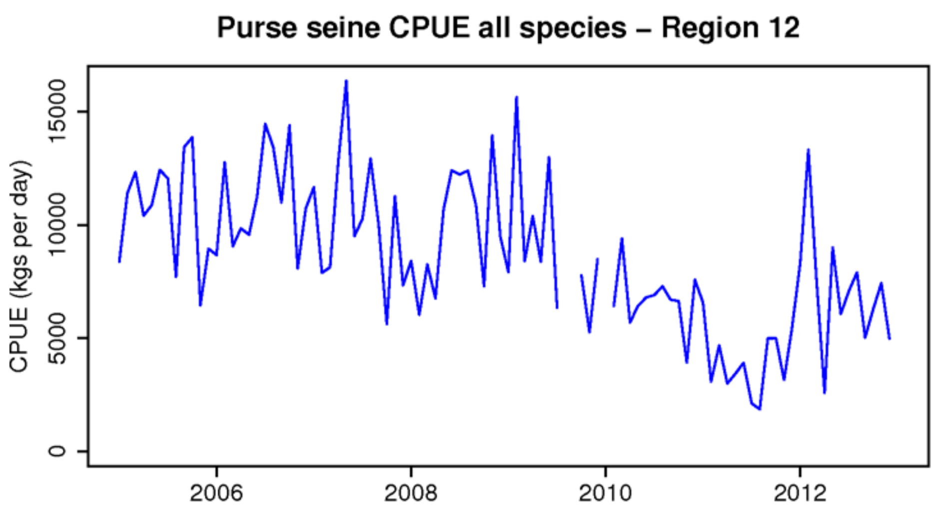

Figure 10. Monthly nominal CPUE (kgs/day) for all species in the Philippine Region 12 purse seine fishery.

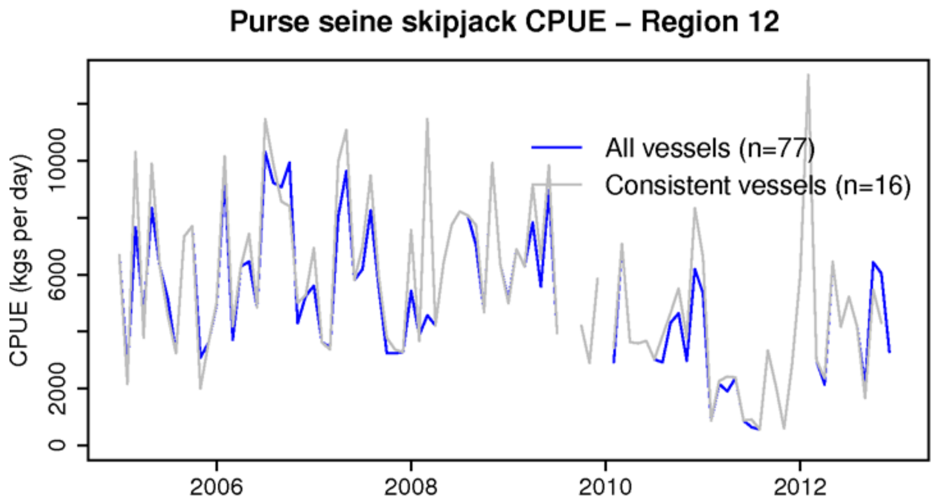

Figure 11. Monthly nominal CPUE (kgs/day) for skipjack tuna in the Philippine Region 12 purse seine fishery.

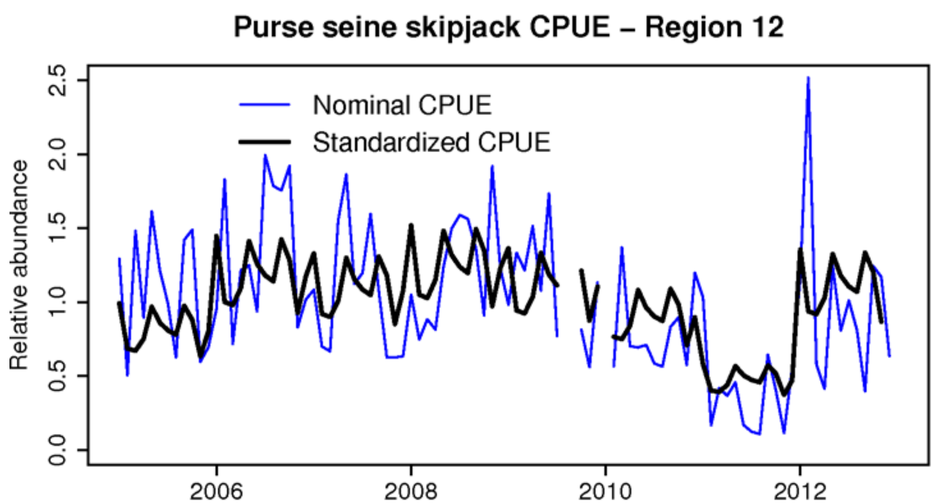

Figure 12. Comparison of monthly nominal CPUE and relative abundance for skipjack tuna in the Philippine Region 12 purse seine fishery. Each series is normalized to a mean value of 1.0.

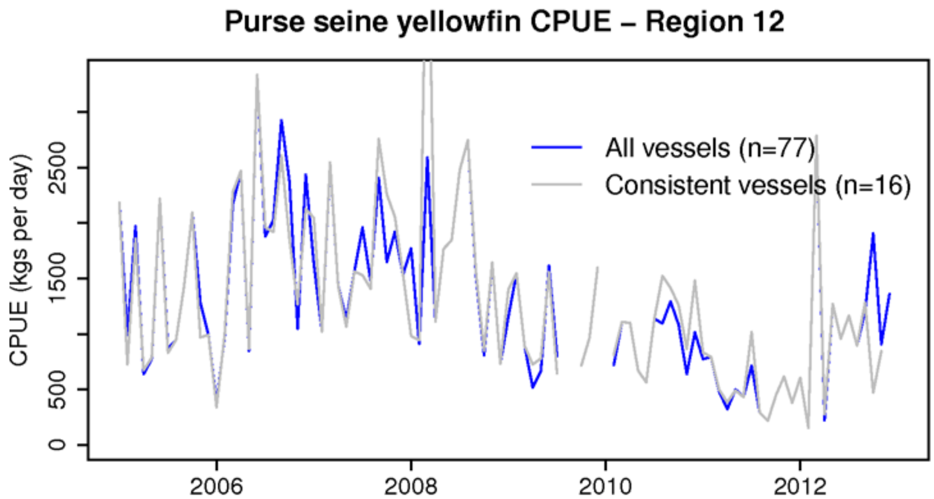

Figure 13. Monthly nominal CPUE (kgs/day) for yellowfin tuna in the Philippine Region 12 purse seine fishery.

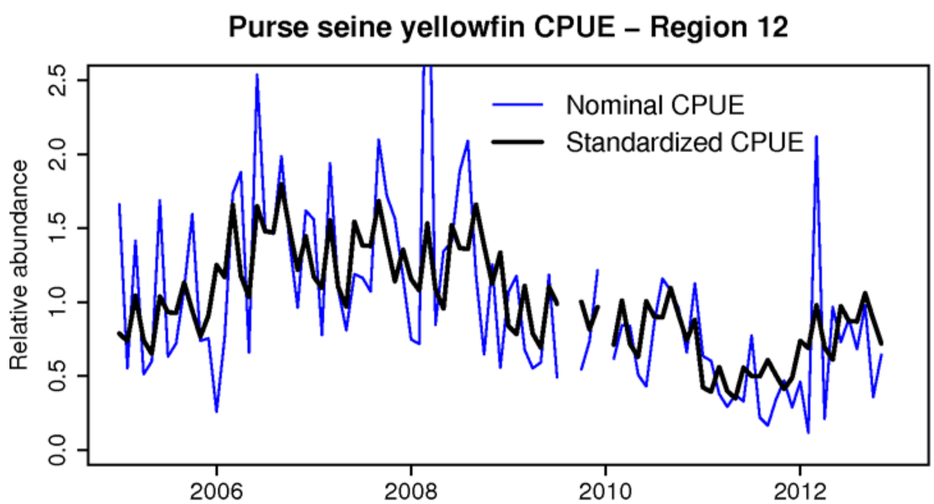

Figure 14. Comparison of monthly nominal CPUE and relative abundance for yellowfin tuna in the Philippine Region 12 purse seine fishery. Each series is normalized to a mean value of 1.0.