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EVALUATION OF THE HIGH SEAS FISHERY OF PELAGIC FISHES IN THE GALAPAGOS MARINE RESERVE

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Evaluation of the high seas fishery of pelagic fishes in the Galapagos Marine Reserve

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In the Galapagos Marine Reserve (GMR), there is an artisanal high seas fishery that targets pelagic fish including yellowfin tuna or albacore (*Thunnus albacares*), swordfish (*Xiphias gladius*), wahoo (*Acanthocybium solandri*), escolar (*Lepidocybium flavobrunneum*), blue marlin (*Makaira mazara*), and mahi-mahi (*Coryphaena hippurus*).

High seas fishing began in Galapagos in the 1930s, with foreign industrial fishing boats that employed longlines and purse seines. Subsequently Ecuadorian industrial fishing boats also began fishing in Galapagos (Reck, 1983). Since the creation of the GMR in 1998, only artisanal fishermen are permitted in Galapagos, while industrial fishing is banned (Castrejon, 2011).

Current regulations permit two types of boats for high seas fishing: 1) large fishing boats or artisanal fishing boats up to 18 m in length and 50 tons of gross tonnage; and 2) smaller fishing boats up to 12.5 m long. Permitted fishing gear includes: trolling with handline with lure or bait; fishing rod with or without a reel, and handline. High seas fishing is not regulated by any other management measures, such as total allowable catch, minimum or maximum size of catch, or spatial or temporal closures.

Most studies of fishing of pelagic species are assessments of fishing methods. The use of the longline in the GMR was evaluated in 2001 (Revelo *et al.*, 2005) and 2003 (Murillo *et al.*, 2004). An assessment of the oceanic handline was completed in 2006 (Tejada, 2006) and of fish aggregating devices (FADs; also known as plantados) in 2009 (Castrejon, 2009). More recently, in 2013, the modified oceanic handline method, which is similar to offshore longlining, was evaluated (Reyes *et al.*, 2014). Peñaherrera (2007) analyzed temporal and spatial assemblages of fish in the GMR, including the yellowfin tuna and wahoo. Castrejon (2011) compiled information on yellowfin tuna catches in the GMR from 1997 to 2003.

This assessment of the high seas fishery is intended to initiate regular evaluations of performance indicators established in the Fishing Chapter of the *Management Plan for the Protected Areas of Galapagos for Good Living* (DPNG, 2014).

Methods

We evaluated the following indicators of the high seas fishery in the GMR during 2012 and 2013: catch, fishing effort, catch per unit effort (CPUE), and value of the fishery.

Active fishing effort was measured based on the number of fishermen and vessels active each year. Although the Galapagos National Park Directorate's (GNPD) information system only identifies one fisherman per Monitoring Certificate or fishing trip, we assumed by direct observation that each fishing trip involved two fishermen. Passive fishing effort was obtained as a percentage of fishermen and vessels listed in the fishing register of the GNPD that had no activity in high seas fishing each year.

Catch was calculated in kilograms per species, month, and year. CPUE was defined as the catch in kilograms for each day of a trip and was calculated by species, month, and year. Positive or negative trends in monthly CPUE were detected using linear regression analysis.

Based on prices and volumes of the catch, we estimated the value of each species and the overall high seas fishery. Kruskal-Wallis statistical tests were used to determine differences in prices for 2012 and 2013.

Results

We reviewed 1382 monitoring certificates, 717 in 2012 and 665 in 2013, which indicated that more fishermen and boats participated in the 2012 season (Table 1).

Table 1. Active and registered fishing effort in the GMR in 2012 and 2013.

Year	Active fishermen	Active boats	Registered fishermen	Registered boats	Active fishermen	Active boats
2012	388	124	1084	416	35.8%	29.8%
2013	308	94	1124	416	27.4%	22.6%

The composition of the catch included yellowfin tuna (73.8%), followed by swordfish (15.3%), wahoo (6.5%), and escolar (4.1%), and much smaller numbers of mahi-mahi (0.27%) and sailfish (0.05%; Figure 1). This order of importance remained approximately the same in 2012 and 2013, except that in 2012 more escolar than wahoo were caught. The catch in 2012 was 244 TM and in 2013, 276 TM, giving a total of 520 TM (Table 2).

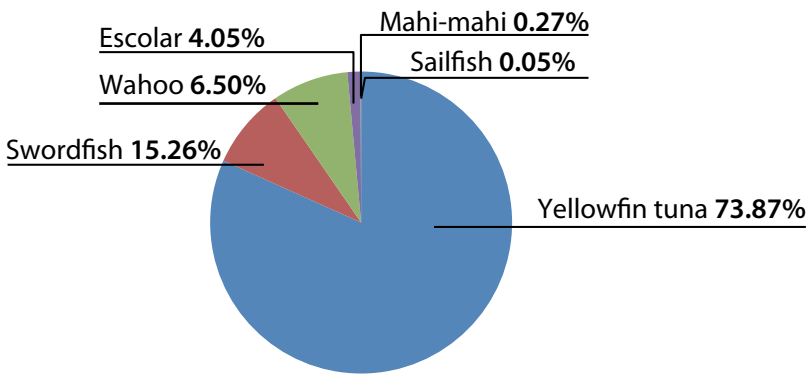

Figure 1. Composition of the high seas fishery catch in the GMR in 2012 and 2013.

Table 2. Volume of catch in metric tons for the high seas fishery in the GMR in 2012 and 2013.

Species	2012	2013	Total
Yellowfin tuna	163.7	220.7	384.4
Swordfish	5.3	21.1	79.4
Wahoo	9.4	24.5	33.8
Escolar	11.7	9.4	21.1
Mahi-mahi	0.9	0.5	1.4
Sailfish	0.0	0.2	0.2
Total	243.9	276.4	520.3

Overall, the average monthly catch was greater in 2013 than in 2012, with a monthly average for the two years of 21.7 MT (Table 3). Sailfish were only caught on one occasion in June 2013 (250 kg). The peak catches of yellowfin tuna were in February, May, and November 2012, and February, April, and November 2013 (Figure 2). Higher catches of swordfish occurred from February to May 2012, of wahoo in April 2013, and of escolar in March 2012.

Table 3. Monthly catch in metric tons by species for the high seas fishery in the GMR in 2012 and 2013.

Species	Average	Maximum	Minimum	Standard deviation
2012				
Yellowfin tuna	13.6	20.3	5.2	5.1
Swordfish	4.9	13.9	0.02	5.1
Wahoo	0.78	2.8	0.09	0.73
Escolar	1.0	4.4	0.0	1.6
Mahi-mahi	0.07	0.74	0.0	0.21
Total	**20.3**	**35.0**	**8.7**	**8.3**
2013				
Yellowfin tuna	18.4	31.1	10.6	5.6
Swordfish	1.8	6.1	0.30	1.8
Wahoo	2.0	11.3	0.09	3.2
Escolar	0.78	2.8	0.0	1.0
Mahi-mahi	0.04	0.11	0.0	0.04
Total	**23.0**	**37.2**	**15.5**	**7.4**
2012-2013				
Yellowfin tuna	16.0	31.1	5.2	5.8
Swordfish	3.3	13.9	0.02	4.0
Wahoo	1.4	11.3	0.09	2.4
Escolar	0.88	4.4	0.0	1.3
Mahi-mahi	0.06	0.74	0.0	0.15
Total	**21.7**	**37.2**	**8.7**	**7.8**

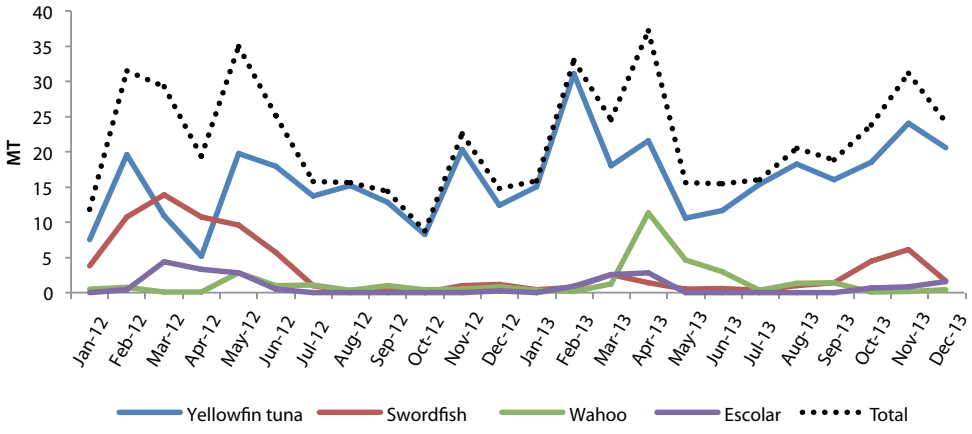

Figure 2. Monthly catch in metric tons for the main species in the high sea fishery in the GMR in 2012 and 2013.

A total of 1382 fishing days were recorded, 717 in 2012 and 665 in 2013. Total average CPUE was 170.5 kg per day of fishing (Table 4). The order of importance of the monthly average CPUE by species was the same as the catch composition. Linear regressions indicated a positive trend of monthly CPUE for yellowfin tuna and a negative trend for swordfish (Figure 3).

When completing the CPUE analysis, 44 monitoring certificates for yellowfin tuna, swordfish, and mahi-mahi, and one certificate for wahoo and escolar were not included as they did not have departure and arrival dates. The sailfish was not considered for the analysis by species as there was only a single catch.

Table 4. CPUE (kg/day fishing trip) of species in the high seas fishery in the GMR in 2012 and 2013.

Species	2012	2013	Average 2012-13
Yellowfin tuna	3.9	4.4	4.1
Swordfish	4.0	4.9	4.6
Wahoo	4.5	3.9	4.3
Escolar			1.8
Mahi-mahi			0.9
Sailfish			1.1

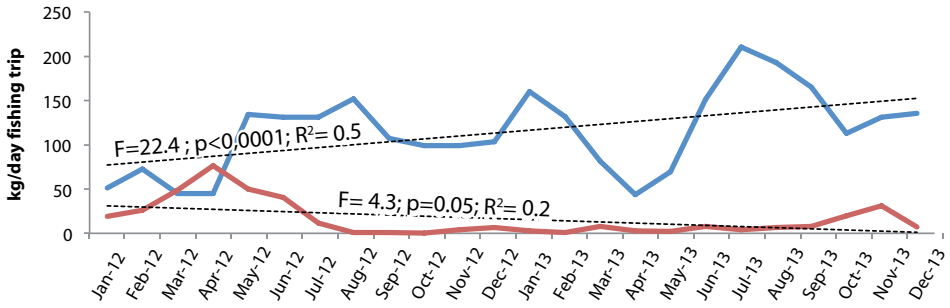

Figure 3. CPUE (kg/day fishing trip) and monthly trend for yellowfin tuna and swordfish in 2012 and 2013. The statistical results of each regression are shown..

Although there were price fluctuations for the main species (Figure 4), swordfish had the highest average price, followed by wahoo, yellowfin tuna, escolar, mahi-mahi, and sailfish (Table 5). There was no statistical difference between the average prices in 2012 and 2013 for yellowfin tuna, swordfish, and wahoo.

Table 5. Average prices in US$/kg of the species caught in the high seas fishery in the GMR in 2012 and 2013.

Species	2012	2013	Average 2012-13
Yellowfin tuna*	$ 3.9	$ 4.4	$ 4.1
Swordfish*	$ 4.0	$ 4.9	$ 4.6
Wahoo*	$ 4.5	$ 3.9	$ 4.3
Escolar*			$ 1.8
Mahi-mahi**			$ 0.9
Sailfish**			$ 1.1

* Average prices in COPROPAG (Artisanal Fisheries Production Cooperative of Galapagos). Escolar had very few data per year; only the total average price is shown.
** Reference prices at the dock in Puerto Ayora during 2013.

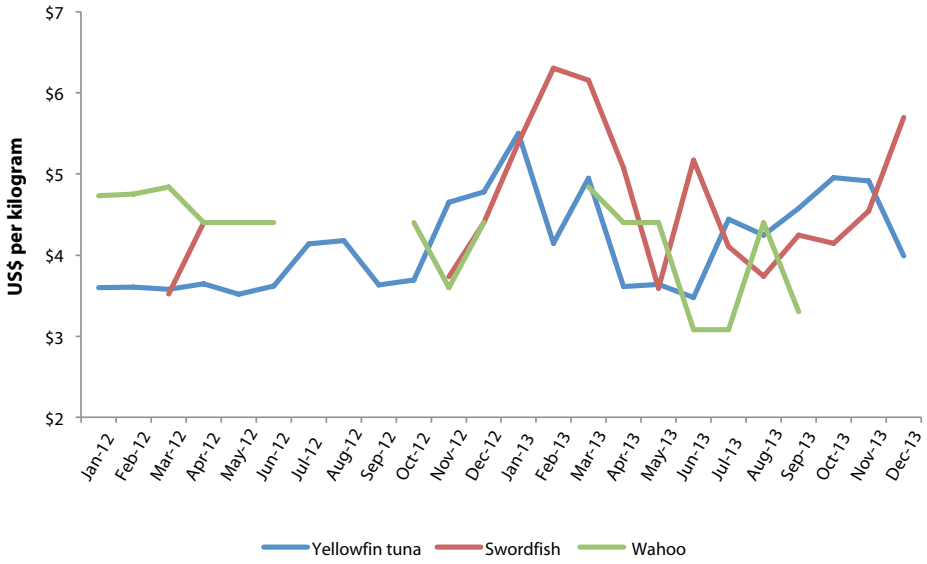

Figure 4. Average monthly prices for the main species of the high seas fishery in the GMR in 2012 and 2013.

Estimated gross income of the high seas fishery was US$958,419 for 2012 and US$1,180,320 for 2013 (Table 6). In 2013, there was an increase in income for yellowfin tuna and swordfish compared to 2012 (Figure 5).

Table 6. Estimated gross income (US$) from the high seas fishery in the GMR in 2012 and 2013.

Species	2012	2013	Total
Yellowfin tuna	636,375.1	964,483.8	1,600,858.9
Swordfish	233,231.8	102,421.7	335,653.5
Wahoo	42,130.3	96,123.2	138,253.5
Escolar	45,876.8	16,543.2	62,420.0
Mahi-mahi	804.9	462.8	1,267.7
Sailfish	0.0	285.0	285.0
Total	**958,418.8**	**1,180,319.7**	**2,138,738.5**

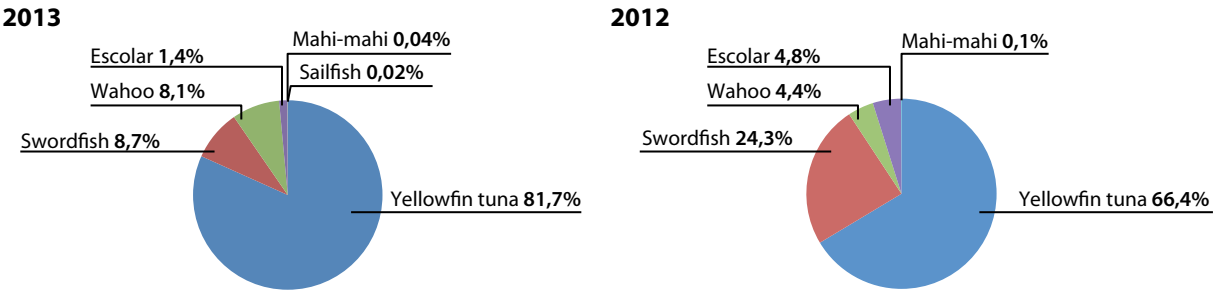

Figure 5. Distribution of gross income by species in the high sea fishery in the GMR in 2012 and 2013.

Discussion

This is the first long-term assessment of all species of economic importance in the high seas fishery in the GMR and includes performance indicators outlined in the Fishery Chapter. Indicators included: fishing effort, catch, CPUE, price, and economic value. However, more information is needed on other important indicators,

such as: average size, sex ratio, and distribution of gross income. Having data on all of these indicators would permit a better analysis of whether production changes in this fishery are due to population, fishing, and/or environmental changes.

The percentage of active effort in the high seas fishery in the GMR is low in relation to registered fishermen and boats. This is the same for the lobster fishery, where the percentage of active effort is approximately 40% (Ramírez *et al.*, 2013). This indicator reinforces the recommendation made on several occasions to update the GNPD fishing registry to include only those who are actively fishing (Ramírez *et al.*, 2013; Castrejon, 2011).

Catch volume and value are likely underestimated. There is an unknown level of landed catch that is not monitored by the GNPD, especially catch that is sold at local fishing docks, establishments, or markets. This unregistered volume remains unknown for all three ports.

Results indicate that yellowfin tuna is increasingly important for fishermen in the GMR. From 1997 to 2003, the maximum production of yellowfin tuna was a little more than 40 MT (Castrejon, 2011). The current catch is five times higher than during that period. Peñaherrera (2007) shows that in catches from 1998 to 2006, wahoo was equal to or more important than yellowfin tuna. Currently the yellowfin tuna catch far exceeds that of wahoo.

This analysis reveals a change in the dynamics of the high seas fishery in the GMR. In 2010, a new technique was documented to catch pelagic fish called the modified oceanic handline (MOHL). The MOHL was developed by combining several oceanic handlines, giving rise to a fishing method with features similar to mid-deep longlines (Reyes *et al.*, 2014). Unfortunately it was impossible to know which fishing method fishermen used, since it was often commented that many fishermen reported using one method when completing the Monitoring Certificate, when in reality they used another. However, it is likely that the use of MOHL is the reason for the change in species composition in the high seas fishery catch in the GMR. The MOHL is being evaluated through a pilot project carried out jointly by the Artisanal Fisheries Production Cooperative of Galapagos (COPROPAG – Spanish acronym) and the GNPD. The final decision regarding use of the MOHL, based on the results of the pilot project, has not yet been taken.

According to CIAT (2013), yellowfin tuna is fully exploited and swordfish under exploited in the Eastern Pacific. This suggests that trends in monthly CPUE of yellowfin tuna and swordfish are due more to fishing method utilized, than to resource abundance. Data from the MOHL pilot project also show a positive trend in CPUE of yellowfin tuna. For swordfish the trend was unclear as there were few records (GNPD data). However we must also consider the impact of the MOHL on the ecosystem, especially given that longlines have proven to have a negative impact on some of the most protected species on a global scale, such as sharks, sea turtles, and sea lions (Reyes *et al.*, 2014).

Despite no statistical differences in the prices of the main species of high seas fishing between 2012 and 2013, it is worth noting that since November 2012, prices have increased. This increase was due to COPROPAG taking control of marketing these resources in continental Ecuador. Prices fluctuated due to quality and size (for yellowfin tuna and swordfish), changes in the COPROPAG customer base, and changes in international price (Kléber López, manager of COPROPAG, pers. com.).

The economic value of the high seas fishery in 2012 was slightly less than that of the spiny lobster fishery, which was estimated to be US$1,086,408 (GNPD data) for the same year. If the catch and price of pelagic fish continue to increase, in a few years the high seas fishery will be the most important in the GMR.

Recommendations

Based on this evaluation of the high seas fishery in the GMR, we recommend that more information be collected, and existing information and management of fishing effort and marketing be improved. To do this, the following actions are recommended:

- Evaluate all performance indicators of the high seas fishery referred to in the Fishery Chapter. For this purpose it is suggested to:

  Update the GNPD fisheries information system to provide greater and easier access to information, such as mobilization of the fishery product, fishing methods, costs, etc.

  Obtain biological information of species caught onboard or at the docks.

- Update the GNPD Fishing Register based on active fishing effort and the exploitation status of each resource.

- Monitor 100% of landings, or failing that, estimate the volume of fish not registered by the GNPD.

- Continue to strengthen the marketing of quality products through fishing cooperatives. Marketing by the cooperatives was observed to increase the price of the products and, it is assumed, results in a more equitable distribution of income.

- Conduct periodical assessments of the high seas fishery, as is done with sea cucumbers and spiny lobsters.

Acknowledgements

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