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Notes on Yellowfin/Bigeye Tuna Ratio and Size Distribution in the Maldivian Tuna Fishery

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Abstract

The main target of livebait tuna pole-and-line fishery of the Maldives is surface-schooling skipjack (*Katsuwonus pelamis*). A small proportion of juvenile yellowfin tuna (*Thunnus albacares*) is also caught with skipjack. Presence of juvenile bigeye tuna (*T. obesus*) in the yellowfin component was first noticed in 1986. Review of data up to 1990 showed that proportion of bigeye in the *Thunnus* component was higher in the south than in the north. A small-scale tuna tagging experiment during mid-1990s allowed reasonable amount of sampling to provide estimates of bigeye in pole-and-line yellowfin component to be 15% in the south (1° 55'N – 0° 25'S) and 1.3% in the north (7°00'N- 4°50'N). Here we attempt to revise this information on bigeye composition and their size distribution from tag release data of the IOTC Regional Tuna Tagging Project. Estimates indicate bigeye composition in *Thunnus* catch was 4% in the north (north of 2°N), where as in the south it was 22%. Overall composition of the bigeye tuna in the pole-and-line/handline yellowfin component was estimated at 9%. Bigeye tuna were larger than yellowfin tuna in the overall data set (43 cm vs. 41 cm). These new estimates may be used to correct for bigeye and yellowfin tuna catch as reported in the nominal data from the Maldives.

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Introduction

The Maldives pole-and-line fishery targets surface swimming tunas. The main target is skipjack tuna, *Katsuwonus pelamis*, but a small proportion (~15%) of juvenile *Thunnus* sp are also caught along with skipjack. In the past it was assumed that *Thunnus* component was only yellowfin tuna (*T. albacares*). However, it is now well know that *Thunnus* fraction also comprises a proportion of bigeye (*T. obesus*) as well.

Bigeye and yellowfin tuna are difficult to identify when they are young or boat-worn and so traditionally Maldivian tuna statistics does not identify bigeye as a separate species in domestic catches. Anderson (1986) was the first to note the presence of bigeye in pole- and line catch. Subsequently Hafiz and Anderson (1988) and Yesaki and Waheed (1991) also showed the bigeye tuna made a small fraction of the *Thunnus* catch in the domestic catches.

Following review of the information available up to 1991 Anderson and Hafiz (1991) concluded the presence of bigeye in the yellowfin component was higher in the south than in the north. Based on all the sampling data from earlier work covering 1985 through 1995 Anderson (1996) concluded that composition of bigeye tuna was 15% in the south (1° 55'N – 0° 25'S) and 1.3% in the north (7° 00'N- 4°50'N). From their aggregated sample of *Thunnus* (n= 14,672, size range; 23-147 cm FL) the composition of bigeye (n=680) in the domestic fishery was estimated at 4.6%. This overall proportion has been used by the IOTC to estimate of the composition of bigeye in the yellowfin catch reports of Maldives.

Following MSC Certification of Maldives skipjack pole-and-line fishery, there has been push to improve the data collection and reporting. Logbooks have been introduced in 2010 and revised in 2012 and for the first time bigeye tuna are being recorded separated both in the handline and pole-and-line fishery. While there are ongoing efforts at improving collection of nominal catch and effort data and size sampling there still needs to revisit those estimates of Anderson (1996) in the light of the recent changes in the fishery.

The area of operation of the pole-and-line and handline fishery has expanded covering up to 60-70 miles from atoll reef. Widespread use of the anchored FADs in the fishery is now norm. The number of active FADs maintained around the archipelago increased from around 30 in the 1980s to about 50 from during the 2000 (Sharma et al. 2014). Since then the number of aFADs have remained around 50 indicating higher proportion of tunas would be caught around FADs compared in the past (Kolody et al. 2010). It is generally known that proportion juveniles caught around FADs are higher and their sizes smaller compared with free schools (IOTC-SC16 2013). Given that fishing around FADs have increased in the Maldives, it is likely that estimates made by Anderson (1986) may need revision.

A new tuna fishery has also developed in the Maldives targeting surface swimming large yellowfin. The fishing is carried out using handline with livebait. Adam and Jauharee (2009) notes that more than 90% of the catch comes from the dolphin associated schools. In the earlier period reporting has been poor and whatever reporting available appears to have been mixed in the pole-and-line catch. It is now known that fishery also catches small proportion of bigeye tuna as indicated by a small fraction of bigeye reported form the handline fishery for the 2013.

The Indian Ocean Regional Tuna Tagging Programme (RTTP) provided data to revisit the estimates of bigeye proportions made by Anderson (1996). The data also to allows estimating size composition around FADs and free schools. The objective of this paper is to analyze the tag release data with a view to revises estimates of composition and size of bigeye and yellowfin tuna in the domestic catches.

Data and Methods

Data used in the analyses was tag release data form the Maldivian fishery during IOTC-supported tagging cruises of Regional Tuna Tagging Project (Hallier and Million 2012[2], Adam et al. 2012[3]). Tag releases occurred during 2004, 2007 and later during 2008-2009. Tags were released from regular pole-and-line and handline vessel by trained MRC officials and later jointly by the MRC and IOTC officials. Initially tagging was done on regular fishing trips on opportunistic basis. During the latter half of 2008 and 2009 all tagging was undertaken from charted fishing vessels.

The following assumptions were made in the analysis of data:

1. Tagging cruises were no different in any way (targeting and use of gear) than normal livebait pole-and-line fishing trips.
2. Presence of tagging teams on fishing vessels did not unduly change the fishing operations in any way or manner.
3. Selection of fish by the tagging team was random without bias and so the observed proportions in the release data reflect the composition in the catch.
4. Tagging teams correctly identified all releases and recorded positions accurately.
5. Tagging teams correctly identified yellowfin and bigeye tuna during tagging operations.
6. Lengths of tuna were measured on measuring boards or on a specially prepared canvas-bed that allow taking straight lengths. All lengths were fork lengths measured to the full centimeter below.

Since tagging exercise does not unduly induce bias in the fishing practice or pattern of operation it was assumed the catches of skipjack and *Thunnus* represent the composition in normal fishing events reported to the Ministry. Figure 2 shows the released data by species and the locations of anchored fish aggregating devices (aFADs) at the time of tagging.

Literature is not clear on cut-off distance from FADs to determine 'fad schools' and 'fad-free schools' and so an arbitrary cut off distance of 5 miles and 10 miles have been used in filtering the data. Since the FADs in the Maldives are all anchored FADs and therefore knowing the position of the FADs and release points exact distance of release can be calculated.

For purposes of making distinction between north and south, releases made from Thaa Atoll and north was considered north and remaining was considered to be south. This is to make analyses consistent with the cut-off boundary used by Anderson (1986).

Results

A total of 23 cruises were made releasing a total of 5,844 *Thunnus* of which 534 were positively identified and released as bigeye tuna (Table 1). Most of the cruises were made in the north (83% of the cruises) and 4 cruises were made in the south (7% of the total). The

[2] Presentation at the IOTC Tagging Symposium - http://www.iotc.org/documents/02-indian-ocean-tuna-tagging-programme
[3] Presentation at the IOTC Tagging Symposium - http://www.iotc.org/documents/06-exploratory-analysis-maldives-tagging-data-released-during-rttp-2004-2009

total number of release in the north was 4,150 (71% of the total) where as in the south it was 1,694 (29%). Releases occurred during most months of year (except June, July, Sept and November) covering the entire fishing season.

Overall the proportion of bigeye tuna was 9.1% of the *Thunnus* component. The composition of bigeye in the north was 4.0% while in the south was 21.8%

Figure 1 shows the proportion of tags released by distance to closest aFAD. More than 90% of the tags were made within 20 miles distance from aFADs, although few were released as far as 40 miles and beyond from the closet aFAD.

Table 4 gives the number of release by species separated by 5 miles distance or more from aFADs and 10 miles distance or more from aFADs. Total number of *Thunnus* occurred at 5-miles radius cut-off was not much different at closer to aFAD or beyond (2916 vs 2928) showing the proportion does not change much at the cut-off distance. However, the proportion of *Thunnus* changed quite markedly at the 10-mile cut-off (3728 vs. 2116) showing less bigeye tuna were present further away than they were closer to aFADs. It should be noted that in the both cases the proportion of bigeye tuna were greater closer to the FADs than away from the FADs, 12.41% vs. 5.87% and 12.33% vs 3.50%.

A two sample t-test for comparing two mean sizes of yellowfin and bigeye were done for data from cruises 902, 903 and 904 which has reasonable number of bigeye tuna. Results showed it was not possible to differentiate the mean size in the sample in the individual cruise data, but when the samples were combined the means were significantly different (Table 2). The mean size of yellowfin was 40.52 cm and mean size of bigeye was 42.58 cm.

Roughly the same results were obtained for samples aggregated at two cut-off distances; sizes of bigeye were large at close to the FADs than away from FADs (Table 3).

Discussions

Estimates of bigeye represented in the *Thunnus* catch were higher in this study compared with the earlier ones. Overall composition of bigeye was almost 2 times more (4.6% vs 9.1) in this study compared with earlier with similar magnitude of difference between north and south (1.3% vs 15% against 4.0% vs 21.8%).

Such increased proportions of bigeye may be explained by a real increase in availability (or catchability) due to changes in fishing practices or due to a biased selection of bigeye for tagging. Support for the first possibility is due to observation of increase and sustained use of aFADs in the Maldives. In 80s and 90s aFADs were also in use, but their numbers and effort (resources expended) at replacing lost ones were lower. Form around early to mid-2000s the Ministry of Fisheries and Agriculture decided that number of aFADs will be increased up to around 50 and considerable resources were available and spent for timely replacement of the lost ones. As a result the number active aFADs available to fish were much more at the time of RTTP compared with the earlier (Sharma et al. 2014). It is widely known that in the Indian Ocean, newly recruited bigeye tuna are primarily caught by the purse seine fishery on floating objects or dFADs (IOTC-SC-2013). Therefore it reasonable to assume that there is a real increase in availability bigeye to surface gears used in the Maldives around the aFADs.

Alternatively it is also possible there exists a real positive bias in the data due non-random selection of fish during the tagging operations. In the earlier tagging experiments release of positively identified bigeye were few and it was believed that taggers were not experienced enough to quickly identify bigeye in tagging conditions. Therefore extra effort was made to ensure bigeye tuna were identified correctly during releases. Two of the authors (ARJ and MA) actually took part in IO-RTTP tagging experiments. Their confirmation is that it would unlikely as the fish presented to the tagging teams were random and entirely dependent on what was hooked on the poles and passed for taggers. Therefore a real increase in availability of bigeye to surface gears would the preferred explanation of the differences in the result.

The choice cut-off limits to define what is FAD-associated and free schools are arbitrary. The definition used here is either within the sphere of 5 nautical miles or 10 nautical miles from the aFADs. Literature is not clear on the range of association around FADs (or floating objects). ISSF's definition of FAD free (or free-schools) is 1 mile radius from the FADs (or logs) which they consider to be conservative (Restrepo & Dagorn, 2012[4]). However, it is well known that tuna and other bycatch species are 'attracted' to FADs or floating objects from distances greater than 5 miles radius (Klieber and Hampton, 1994). That there is strong association of bigeye between aFADs is shown by the high concentration of bigeye close to aFADs and also at some distance away from the aFADs (Figure 5). Maldivian fishermen's view of FAD-associated schools certainly goes beyond the 1-mile radius defined by the ISSF. Whilst ISSF's definition of 'FAD associated' and 'free schools' may be motivated by the desire to circumvent association of bycatch around FAD or log-associated schools, it may not be applicable context of aFAD association in Maldives's setup. Clear definition of FAD-associated fish will be important, as IOTC requires data to be separated by aFAD and free schools.

It is not clear why bigeye tuna are larger in the south than in the north. Anderson (1996), referring to samples of composition of bigeye in Sri Lanka and in various location of Maldives suggests there is a cline in bigeye tuna abundance, increasing from north to south. In his article on North-South variations in the distribution of the fishes in the Maldives (Anderson, 1992) suggest that the channel between Laamu Atoll and Gaafu Alifu (about 2°N) marks a significant boundary where many species of fish change variations in their abundance. It is assumed that this channel also marks something of a boundary for bigeye tuna.

Further and more detailed analysis of composition and size from purse seine catches western Indian Ocean and from Sri Lankan fisheries may be useful to further understand the latitudinal distribution of bigeye and their size compositions associated with bigeye tuna.

The findings from this analysis re-confirm that abundance bigeye tuna are much higher in the south than in the north. The analysis also gives revised estimates of the proportion of the bigeye tuna in the Maldivian tuna fishery that will be useful for updating the bigeye and yellowfin tuna catches from nominal data.

Acknowledgements

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[4] http://iss-foundation.org/2012/04/19/defining-fad-free-tuna/

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Table 1: Summary of releases of *Thunnus* and number of bigeye tuna and their proportions.

Cruise	Time period	Region	Main Area of Release	Monsoon Season	Thunnus	no. BET	prop BET
401	May-04	North	SW of Ari Atoll	Interchange	13	0	0.00
402	Aug-04	North	NW of Ha Atoll	South West	72	0	0.00
403	Aug-04	North	NW of Ha Atoll	South West	165	0	0.00
404	Aug-04	North	NW of Ha Atoll	South West	236	0	0.00
405	Aug-04	North	NW and Wof HDh Atoll	South West	259	0	0.00
406	Aug-04	North	NW of Ha Atoll	South West	34		0.00
407	Aug-04	North	NW of HDh Atoll	South West	268	0	0.00
408	Aug-04	North	NW of HDh Atoll [?]	South West	144	0	0.00
409	Aug-04	North	NW of Ha Atoll	South West	5	0	0.00
410	Aug-04	North	NW of Ha. Atoll	South West	16	0	0.00
411	Aug-04	North	NW of Ha Atoll	South West	25	0	0.00
412	Aug-04	North	E of North Malé Atoll	South West	20	0	0.00
701	Aug-07	North	E of North Malé Atoll	South West	21	0	0.00
702	Oct-07	North	W of Sh. Atoll	South West	63	0	0.00
801	Jan-08	North	East of Sh. Atoll	North East	474	40	0.08
802	Feb-08	North	E of North Malé Atoll	North East	87	0	0.00
804	Dec-08	North	East and West of Thiladhunmathi Atoll	North East	1847	19	0.01
901	Jan-09	North	East of North Malé Atoll	North East	16	2	0.13
904	Apr-09	North	East and West of South Double Chain	North East	385	103	0.27
					4150	164	0.04
703	Oct-07	South	West of Huvadhoo Atoll	South West	109	0	0.00
803	Mar-08	South	Centre of Huvadhoo Channel	North East	95	0	0.00
902	Feb-09	South	East and South of Gaafu Alifu Atoll	North East	268	83	0.31
903	Mar-09	South	West & South of Huvadhoo Atolll + SW of Addu	North East	1222	287	0.23
					1694	370	0.22

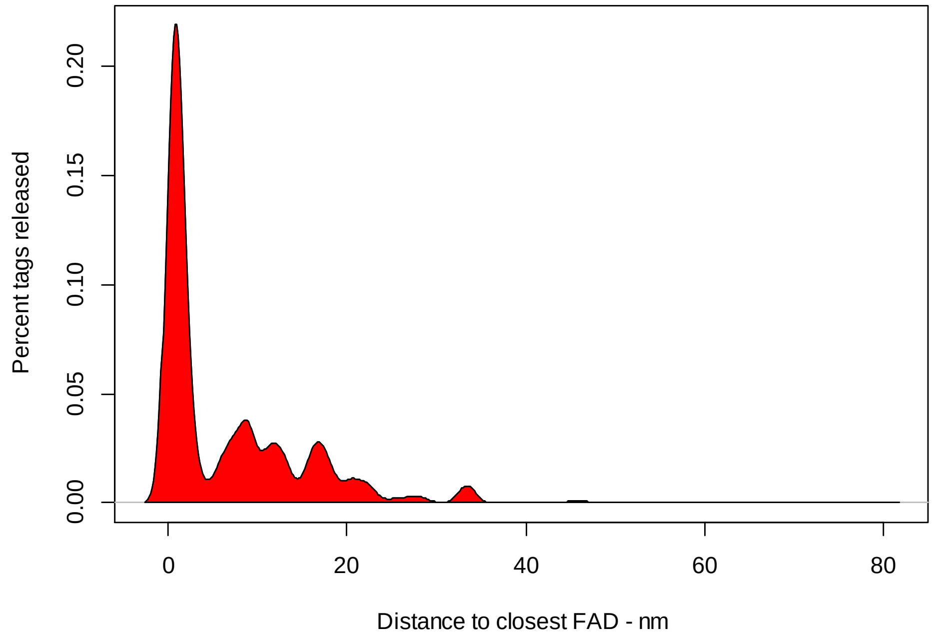

Figure 1: Proportion of the tag releases by distance from anchored FADs

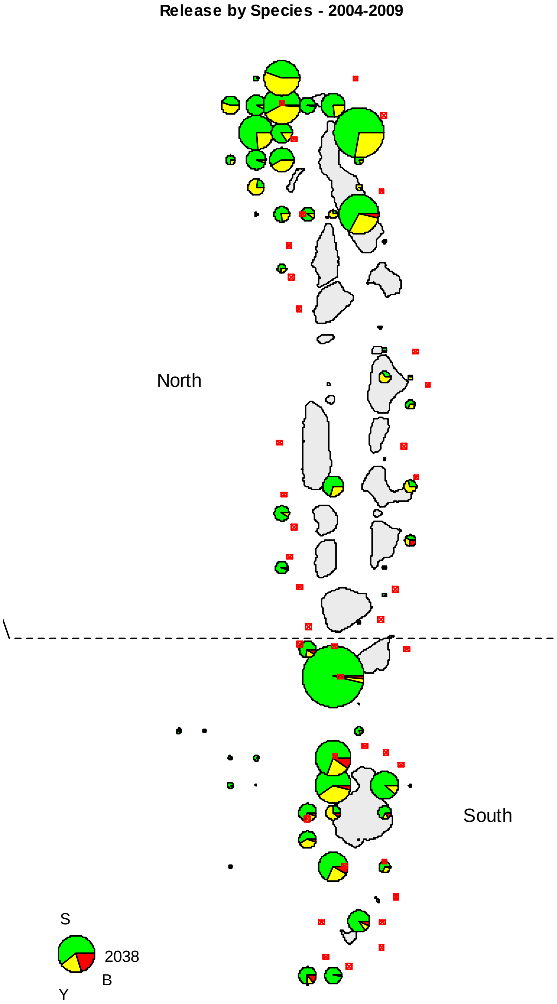

Figure 2: Position of release and aFADs present at the time of release (red squares)

Table 2: Welch Two Sample t-test for means size of the samples in cruises; (YFT/BET) 902 - 94/48; 903 - 934/287 and cruise 904 - 282/103.

Cruise	p-value	Mean (YFT) /Mean (BET)	Remarks
902	0.62380	51.51 / 52.42	From same population, p > 0.05
903	0.05137	39.14 / 40.48	From same population, p > 0.05
904	0.36350	43.88 / 45.08	From same population, p > 0.05
Combined	0.00018	40.57 / 42.58	From different populations, p < 0.05

Table 3: Mean size (and standard deviations) of the yellowfin and bigeye tuna from release made <5 miles and > 5miles and <10 miles and > 10 miles.

	< 5miles	> 5 miles	<10 miles	> 10 miles
Skipjack	37.5 [07.6]	42.3 [08.2]	38.5 [08.0]	42.3 [07.8]
Yellowfin	40.8 [07.3]	42.3 [04.7]	40.5 [11.3]	43.3 [06.4]
Bigeye	45.0 [12.7]	42.7 [14.3]	44.3 [12.3]	44.0 [18.4]

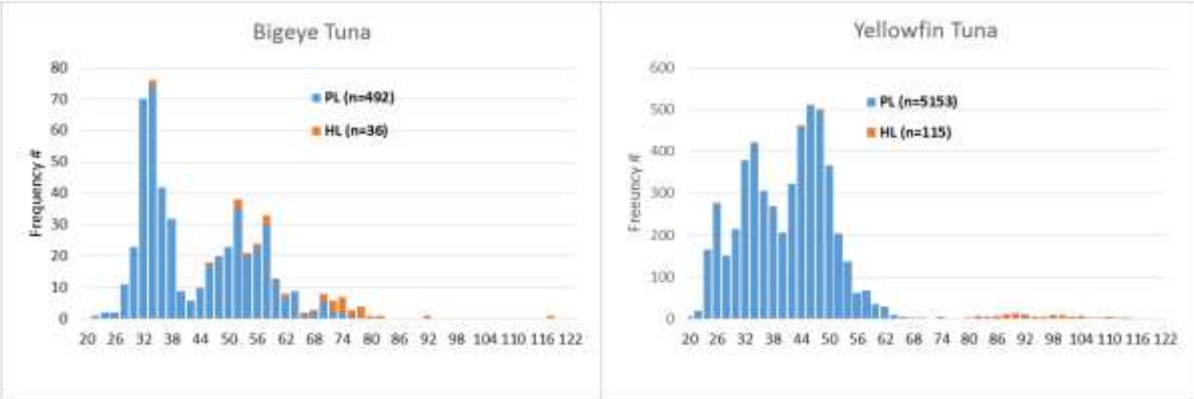

Figure 3: Size distribution of handline caught yellowfin and bigeye tuna during all tagging cruises cf. Table 1

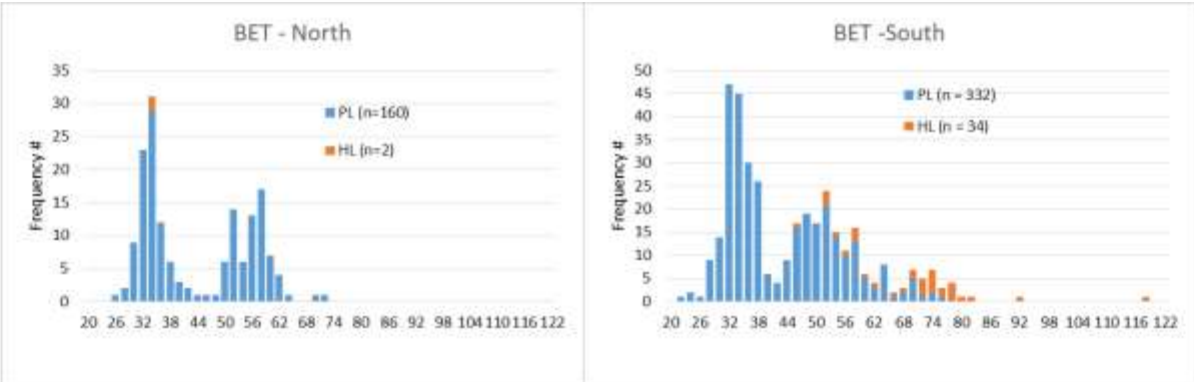

Figure 4: Size Distribution of bigeye tuna caught from HL and PL in the north and south

Table 4: Proportion of BET in *Thunnus* catch; 10 miles and 5 miles from aFADs in three data combinatins.

ALL	< 5miles	> 5 miles	< 10 miles	> 10 miles	Overall
# Skipjack	9698	6040	12056	3682	15738
# *Thunnus*	2916	2928	3728	2116	5844
# bigeye	362	172	460	74	534
% bigeye	12.41%	5.87%	12.33%	3.50%	9.13%

NORTH	< 5miles	> 5 miles	< 10 miles	> 10 miles	Overall
# Skipjack	7175	4354	8183	3346	11529
# *Thunnus*	2403	2107	2263	1887	4150
# bigeye	133	31	136	28	164
% bigeye	6.51%	1.47%	6.01%	1.48%	3.95%

SOUTH	< 5miles	> 5 miles	< 10 miles	> 10 miles	Overall
# Skipjack	2523	1686	3873	336	4209
# *Thunnus*	873	821	1465	229	1694
# bigeye	229	141	324	46	370
% bigeye	26.23%	17.17%	22.12%	20.09%	21.84%

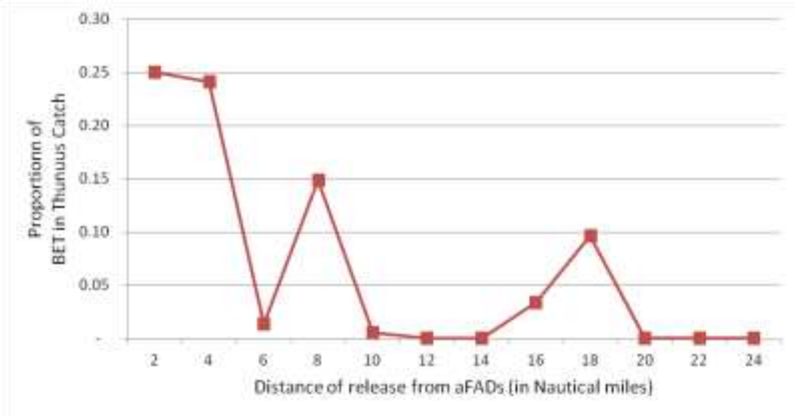

Figure 5: Proportion of BET in *Thunnus* catch with distance from the aFADs

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