Dominion Consulting

An economic appraisal of the smart tuna hook system

Final report to the Ahi Enterprises Pty Ltd

By Dominion Consulting Pty Ltd

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Dominion Consulting was formed in 1997 and specialises in fishery economics, management and training for the marine resources sector.

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Executive Summary

The Smart Tuna Hook (STH) system is a seabird bycatch mitigation measure that has been devised to reduce the incidental capture and impacts on seabirds when longline fishing. This document examines the economics associated with using the smart tuna hook and how it may affect fishing productivity.

The trials in the South African pelagic long line fishery (SAPLLF) are evaluated through the economics of production as has been applied in fishery economics in several comparable situations. This framework enables two treatments, a constant typical of that used within the South African Longline Fishery (SAPLLF) and then sets using the Smart tuna hook, to be compared in actual commercial fishing conditions.

The method uses the relationship between fishing effort and the output catch, to compare the technologies. The data available means that from the hooks set more than one fish species is produced, which requires a multispecies approach to be considered in assessing the trials, incorporating the available data on species weights and prices.

The available data is estimated by the economic regression model which is applied to the relatively small data set available from the trials. In the analysis we find that when using catch numbers, catch weights and catch total values, there does not appear to be any significant differences between the treatments.

The results indicate that across the comparable longline fishing sets there was no evidence that the use of the STH either significantly increased, or significantly decreased, fish catch or the catch value. We accept these results which ideally should be confirmed by a much larger industry wide trial.

The study of bird mitigating efficacy estimated the STH led to the reduction of the bycatch of seabirds by between 81.8% and 91.4% (Baker and Candy 2014). The overall trial results indicate an economic relationship between the incremental cost of each STH set (A$300 per thousand hooks) and the benefits gained through decreasing the seabird bycatch. The SAPLLF has an annual bycatch limit per vessel of 25 birds which imputes an economic cost on bird fatalities. Seabird bycatch is often avoided by a range of setting measures (e.g. bird scaring lines weighted branch lines and night setting of longlines) and by fishing in areas of the fishery with low seabird abundance.

The degree of bird impact reduction from the STH as seen in this comparison with a standard longline fishing gear used in the SAPLLF indicates the potential of this device to reduce bird catch. Its application with other mitigations measures, makes the STH an attractive solution to this bycatch issue. The technical advantages brought by the STH to bird bycatch reduction can enable vessels to operate with greater flexibility in a fishery where bycatch reduction is a requirement of operation and the expenditure on the STH can help fishers to maintain fishing access by minimizing bird bycatch to regulated levels.

1. Introduction

This report is an economic analysis of the smart tuna hook proof of concept trial in a commercial long line fishery. The smart tuna hook (STH) shield is fitted to individual hooks on traditional branch lines attached to long line fishing gear, in order to reduce the likelihood of seabirds becoming hooked whilst predating on bait used in the deployment and laying of the fishing line. The smart tuna hook product is envisaged as reducing the impact of long line fishing on sea bird populations, which are known to be detrimentally impacted by traditional setting of baited longlines.

In the first instance the smart tuna hook system comprises the smart tuna hook (a modified standard Japanese or circle style hook) which enables a shield to be attached to cover the tip of the baited hook. Its additional size and weight assists the bait to sink more rapidly than a traditional baited hook making the interaction between fishing gear and seabirds less likely. The smart tuna hook has a dissolving component that will lead to the shield automatically detaching after a short period of time, hence presenting the bait to fish. The smart tuna hook enables more baited hooks to be available to fish by the increased sink rate that takes the baits away before birds can easily access them as opposed to traditional setting technology where some baits are removed by predation leaving less baited hooks in the water to attract fish. It is possible the use of the smart tuna hook system may increase the total catch from a typical set of hooks due to presenting more baited hooks to the target fish species. This is an example of several issues that can be addressed by a trial of empirical data in a commercial fishery.

The fishery selected for the trial is the South African pelagic long line fishery, based in Capetown, South Africa. The vessels in this fishery are typical small near-shore long liners. In 2005 the fishery had 50 long term fishing rights issued (DAFF 2013).

The tuna longline gear and fishing method is described in this fishery by DAFF (2013) and Barry and Candy 2014:

“Pelagic longline fishing involves the use of a main line of up to 150 km in length from which as many as 3,000 shorter branch lines, each with a baited hook, are dangled in the water column. The mainline is kept afloat by a series of buoys attached at intervals. The gear is passive, in that it captures any fish that happen to take the bait. Longlines operate mostly at depths between 100 m and 150 m, but can be set as deep as 300 m when targeting bigeye. Squid bait is generally used to target swordfish, and fish bait (pilchard, mackerel, maasbanker) for tunas. The line is set at night when fish are closer to the surface to feed and to reduce seabird bycatch and the line is left for up to 8 hours to soak. Light sticks are used by the swordfish-directed fishery and these are attached to the branch lines. Since very high quality fish is needed for sashimi, most vessels are equipped with "flash freezers" to freeze the fish to -60°C almost immediately” (DAFF 2013).

Some details of the catch of tuna and associated pelagic species are reported in Figure 1.

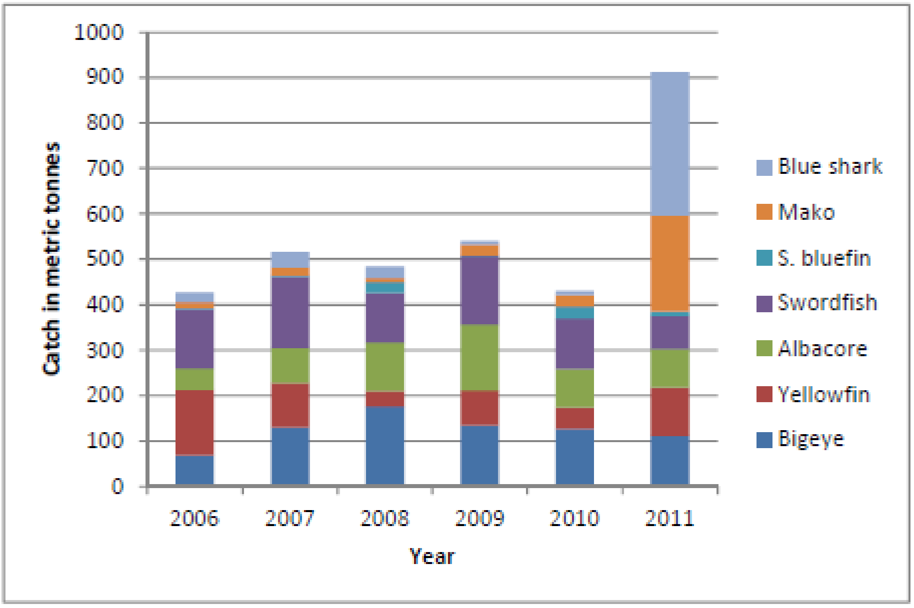

Figure 1: The retained catch of the tuna/swordfish longline fishery 2006-2011 (Source: DAFF 2013).

The total quantity exported per month are reported in Figure 2.

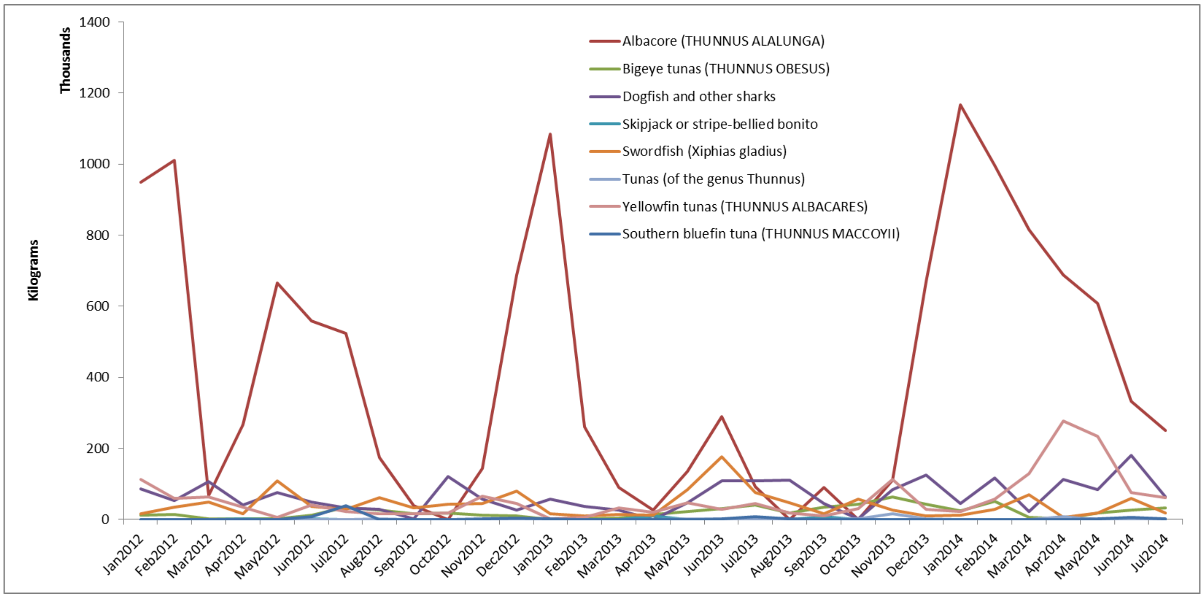

Figure 2: The total quantity exported per month in the Jan 2012—July 2014 period. (Source: DAFF)

The seasonal changes in the abundance of albacore are a feature of the fishery.

The catch rates of the different species are presented in Figure 3 below.

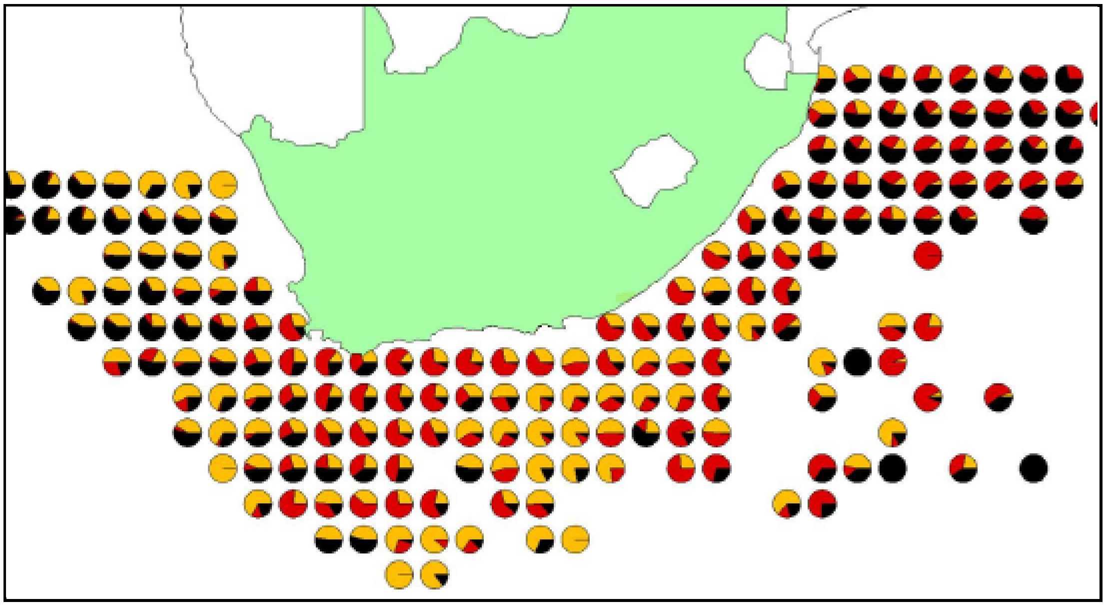

Figure 3: The average CPUE (kg per 1,000 hooks) of bigeye (orange), yellowfin (red) and swordfish (black) from 2006-2011 per 1 degree square in the South African pelagic longline fishery (Source: DAFF 2013).

The fishery is known for its seabird interactions and is suitable to trial the smart tuna hook and shield. DAFF (2013) state that:

"South Africa has been collecting data on seabird interaction with its longline fishery since 1998. South Africa's NPOA for seabirds and was published in 2008. The NPOA-SEABIRDS specifies a maximum mortality rate of 0.05 birds/1000 hooks, and lays out bycatch mitigation measures for use in longline fishing. South Africa has introduced a number of bird mitigation measures through permit conditions since the start of its fishery, including the compulsory flying of tori-lines, no daylight setting, and use of thawed bait to improve sink rates, in the tuna fishery. South Africa does not consider the use of line shooters or offal discard management to be useful in reducing seabird incidental mortality. Furthermore, South Africa has developed a management plan to reduce seabird by-catch in its longline fishery in 2008. This plan includes a seabird limit per vessel per year that was implemented in 2008. Once a vessel reaches 25 birds killed in a year, it must adopt additional mitigation measures, it has to fly a second tori line and it has to place additional weights on to each branchline. Since the implementation of seabird mitigation measures and the stringent monitoring thereof seabird mortality rates has reduced by more than an order of magnitude." (DAFF 2013).

The trial is to be assessed by fishery scientists studying the difference between bycatch rates of seabirds using the smart tuna hook and the current study assesses the economic aspects of the trails of the smart tuna hook system.

The proposed Economic analysis

The economics of the smart tuna hook product is addressed through asking a range of questions:

1. What are the cost implications of operating the new Smart tuna hook system?;
2. What are the costs or benefits to vessel production when using the smart tuna hook product?;
3. Does the smart tuna hook product have any other costs or benefits in terms of fishing costs or fishing revenues?; and
4. An assessment of the overall costs and benefits of the Smart tuna hook product for a typical fishing operation.

The assessment will be undertaken with the data available to the study.

2. What are cost implications of operating the smart tuna hook system?

The tuna long line fishing process has a boat as the fishing platform and crew operate a drum holding the main fishing lines and manually set bait on hooks as the mainline is shot away. The long line fishing operation has several stages from preparation of equipment and provisions in port, travelling to the fishing grounds, searching for suitable setting locations, deploying fishing gear, retrieving fishing gear, processing catch and travelling back to port. The efficiency of doing these stages all contribute to the effectiveness and hence economics of the fishing operation. Each vessel in the fishery has initial capital costs and then their ongoing operating costs.

2.1 Capital costs of a typical long line vessel

The capital costs for the vessel and the long line fishing equipment can have both historic and current depreciated values. This information was not available for the trial vessel in the study due to confidentiality, but does not impact the economic appraisal as the capital costs are the same for both treatments applied in the trial.

2.2 Operating costs

These are either fixed costs, being paid irrespective of activity, or variable costs, which change with different activity levels. The amount of debt a fisher has is not generally taken into economic evaluations, which are done on an all equity basis. The study is interested in the costs and benefits of the smart tuna hook product on an existing fishing operation's costs and income.

Fixed costs- are costs such as an annual wharf fee, licenses, annual slippage, annual maintenance which are fixed in nature, not being related to fishing activity. The fixed costs will be regarded as constant in this evaluation they are equal for both treatments.

Variable costs- vary with levels of fishing activity as seen in fuel expenses. In a tuna longline fishery the following are typical trip operating costs (fuel, oil, bait, labour and fishing equipment- for example some of the branch lines and hooks would be replaced during fishing and so vary with operations).

2.3 The costs of the smart tuna hook system

The smart tuna hook system is applied at the hook level and has minimal capital costs. The change to smart tuna hook involves replacing each of the existing tuna hooks to a hook that is compatible with the smart shield. In this study the vessels were reluctant to change the hooks and used hooks that they believed were compatible with the shields. The typical cost of a small volume of hooks is A$0.50 each and each shield has a cost of A$0.30. Initial change over cost per thousand long line hooks would be A$800 (pers. comm. H. Jusseit).

The application of the smart tuna hook shield to the branch line hook can take place when baiting the hooks. The time to deploy the long line in trials has been the same as for the normal operations (pers. comm. H. Jusseit).

In summary, the incremental costs of using the smart tuna hook over traditional hooks that capture more birds, are mainly the incremental cost of each shield, which would be a recurrent variable cost of A$300 per thousand hooks set.

3. Assessing the impacts of smart tuna hook on industry production in the longline fishery

This study evaluates the economics of applying the Smart Tuna Hook system in commercial tuna longline fishing operations. This evaluation requires using techniques available in the fishery economic literature to evaluate this fishing method using the economics of production.

To apply the economic theory of production we require vessel data. This was made available from the trials of the smart tuna hook system in the South African Pelagic Longline fishery (SAPLLF). This data has been supplied by Latitude 42 and AHi Enterprises P/L from the trials using independent observers provided by CAPfish who collected the data.

3.1 Measuring the production impacts of smart tuna hook

The application of smart tuna hook shield to the branch line leads to hooks being set in a way that is identical to sets of non smart tuna hooks. Any differences in the impact of smart tuna hook on production of fish will be seen in the harvest obtained between the treatment (smart tuna hook) and the constant (the traditional hook set).

From our understanding of the fishing process the smart tuna hook may enable more baited hooks to reach the required fishing depth and hence present more baited hooks to potential fish, than traditionally set hooks laid under intense seabird attack of baits as they sink. If this is the case, then *a priori* we may expect the smart tuna hook to have greater total catch from the same number of hooks set. This would require statistical estimation to prove it's significance or otherwise. The differences in catches between the ordinary hook sets and the sets which use the smart tuna hooks will be a test to detect any differences in fish productivity associated with this product.

There have been several previous economic analyses of vessel production in tuna longline fisheries. Campbell and McIlgorm (1994) estimated vessel specific production of tuna longline vessels in the tuna fisheries in northern and southern New South Wales. McIlgorm (1995) estimated the economic production of both the Japanese and Australian longline vessels in the East Coast Tuna Long line fishery.

3.2 Production theory

The basis of vessel level production analysis is the Cobb-Douglas production function which describes the harvesting of tuna by an individual vessel:

$$H= AE^{\alpha} X^{\beta}$$

Where H is daily harvest in metric tonnes, E is the amount of effort measured in in thousands of hooks fished and X is the stocks of tuna susceptible to the vessel's gear during the fishing. The term A is the catchability coefficient, representing fishing technology, and α and β are constants. A special form of the model in which $\alpha = \beta=1$ was adopted by Schaefer (1967) in the Eastern Pacific yellowfin tuna fishery and has been extensively used in bio-economic studies to relate harvest to fishing effort and stock (Strand et al. 1981; Bjorndal 1989).

The Cobb-Douglas production function cannot be directly estimated due to the absence of observations on the actual fish stock encountered by each vessel. This limits the estimation of the catchability coefficient A and constant β. Studies seek to include indirect measures of factors influencing catchability and stock levels and can be included by means of dummy variables. Using these measures with the observations on vessels catch and effort the constant, α in the equation can be estimated. The factors affecting the tuna stock encountered by each vessel, and the vessels catchability coefficient can be divided into categories of vessel characteristics, fishing practices and stock levels.

In the proposed estimation of the smart tuna hook sets, the vessel and stock are assumed to be the same for both treatments as the hook treatments are set adjacent to each other. The difference in fishing practices can then be evaluated by this methodology.

The model above is for one species. In many fisheries the fishing effort, which is an aggregate of all inputs going into the fishing process, leads to a range of different species being produced. The adding of different species by weight is potentially erroneous when fish have different prices. The model above can thus be adapted to replace harvest (a = all species) with the total revenue (TR) associated with each fishing set. The equation above becomes:

$$TR_a = A_a E^{\alpha} X_a^{\beta}$$

Where TR_a is daily harvest in dollars, E is the amount of effort measured in number of hooks fished and X_a are the stocks of tuna and other species susceptible to the vessel's gear during the fishing. The term A_a is the catchability coefficient across all species, representing fishing technology, and α and β are constants, the stock variable X_a, now being across all species.

3.3 Method

From the theory above the available catch and effort data can be analysed to determine the impact of the smart tuna hook on fishing. The laying of hooks with and without the smart tuna hook will provide a test for the impacts of the smart tuna hook on the fishing production process.

In the fishing trials, the vessel lays hooks with and without the smart tuna hook in the same set in alternating sequence. For example 100 hooks of the constant and then 100 as the treatment. Thus the available stock is assumed to be equal for both treatments. Differences in vessel production can then be related to the vessel differences or fishing practices (i.e. Smart tuna hook versus no smart tuna hook). The theory would predict that any differences in harvest from the same fishing effort, measured in numbers of hooks, would reflect the differences between the constant and the treatment, and will be seen in the catchability coefficient.

It is proposed to estimate the production relationship across all species by regression techniques. We can apply a binary dummy variable to the catch and effort relationship to test for relative changes in fish catchability that may be attributable to the smart tuna hook. This will initially be a physical analysis, as harvest is measured in (a) numbers of fish or (b) in kilograms. However the longline fishing vessel effort catches several different species and these may be impacted differently by smart tuna hook requiring a multispecies analysis that considers mixed value outputs. This requires changing the catch to total revenue across all species to include the values of the different species values.

Data

The multispecies nature of the tuna long line fishery causes some issues in relating output (catch of several species) to the input (effort). For the aggregate variable, fishing effort, which in this case is measured in hooks set per day, there can be a range of species caught. These include:

- Yellowfin tuna;
- Albacore;
- Bigeye tuna;
- Southern Bluefin tuna;
- Swordfish; and

- other by-catch species, such as Blue shark.

The supply equations can be specified as either physical catch or by the total revenue:

(1) either (a) the number of each species, or (b) weight in kilograms obtained from the fishing effort; or
(2) the total revenue from multiple species, obtained from the fishing effort.

In the current fishery trials, the data is for one vessel and the most accurate records are for the number of species caught.

For the construction of the total revenue estimate from catch we have two possible approaches:

(i) use the average weights of fish recorded in the trials and the price achieved by these fish to give a trip total revenue. Trip level weight and price data is not available.
(ii) use the records for the fishing effort and number of species caught and apply average weights per species and average prices achieved by species available from DAFF records. This is fishery wide data and effectively weights the results of the number of fish caught by fishery wide average weight and price data.

The second approach is preferred due to using the available fishery wide data.

The following data for the average weights of the key species in the fishery in the period are reported in Table 1.

Table 1: The Average weight of each species in the South African pelagic longline fishery (2010-2014) (Source: DAFF).

	Kilograms (kg)							
Year	**Average of bigeye weight per fish**	**Average of skipjack weight per fish**	**Average of swordfish weight per fish**	**Average of yellowfin weight per fish**	**Average of mako shark weight per fish**	**Average of blue shark weight per fish**	**Average of albacore weight per fish**	**Average of southern bluefin weight per fish**
2010	42.2	7.0	48.5	31.1	20.3	21.2	13.5	57.0
2011	37.9	7.4	48.2	31.0	21.4	19.6	13.6	68.5
2012	38.5	7.8	49.7	31.4	23.7	20.1	13.7	67.9
2013	36.3	5.7	49.2	35.3	22.6	18.3	13.2	68.0
2014	39.4	5.1	49.5	32.5	21.9	13.6	12.0	55.8
Average	**38.9**	**6.6**	**49.0**	**32.2**	**22.0**	**18.5**	**13.2**	**63.4**

The price data was available from DAFF for all exports in the 2012-14 period as reported in Figure 4.

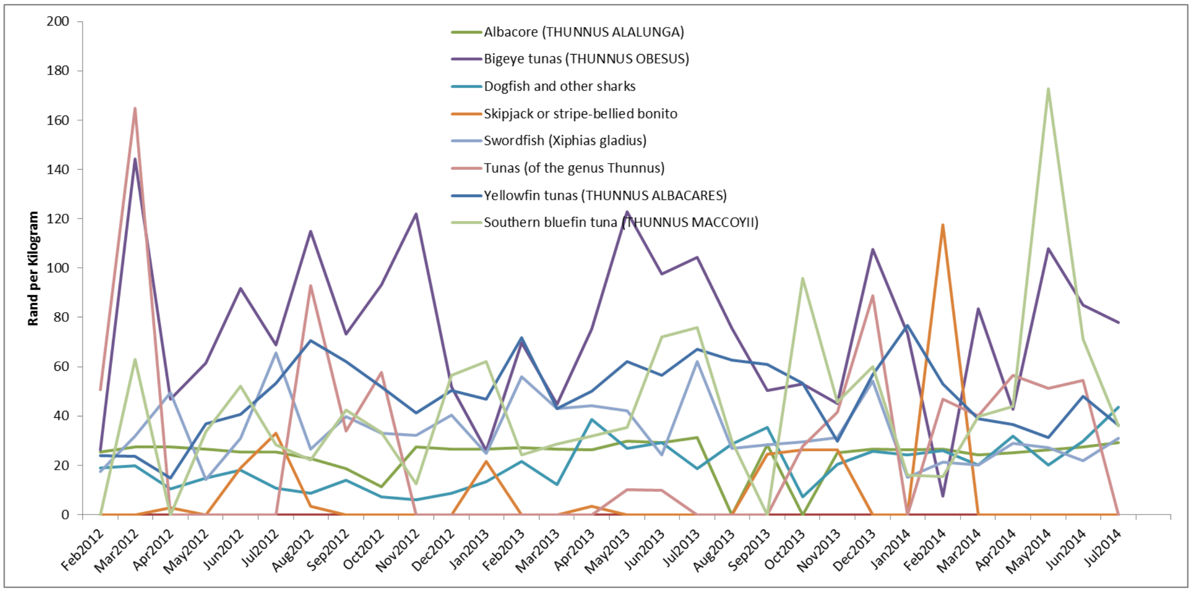

Figure 4: The average monthly price of SAPLLF exports in the July 2012-July 2014 period (Source: DAFF).

The fish trials -set data

The trial data recorded the fishing effort in numbers of hooks set and the numbers of fish caught. There were observations of catch for 17,546 hooks set in 27 completed sets with the two treatments in 2014.

3.4 Estimation

The available data was used to estimate three versions of the basic production function:

(i) Catch measured by numbers fish, summed across all species was regressed against effort and a binary dummy variable included for the smart tuna hook treatment;

(ii) The average weight of each species in the fishing period was applied to the numbers of each species and a total weight of fish across all species was also regressed against effort with a binary dummy variable; and

(iii) Additional average price information for each species enabled a total revenue across all species to be estimated and then was regressed against effort and a binary dummy variable included for the smart tuna hook treatment.

3.5 Results

The data for fishing effort and catch by numbers were transformed to create catch by weight and value. The observed data totals are reported in Table 2 below.

Table 2: The observed catch, total weight and total revenue data for the two fishing treatments ($ = Rand).

species	ALB	BET	BSH	SBF	SMA	SWO	YFT	Total
Con. (no.)	**124**	**99**	**1,388**	**23**	**112**	**57**	**143**	**2010**
Sth (no.)	**97**	**93**	**1,415**	**25**	**106**	**58**	**142**	**2004**
Av. wt.kg. 2014	12.0	39.4	13.6	55.8	21.9	49.5	32.5	
Con. (wt. kg.)	1,488.0	3,900.6	19,420.8	1,283.4	2,452.8	2,821.5	4,647.5	36,014.6
Sth (wt. kg.)	1,164.0	3,664.2	19,502.4	1,395.0	2,321.4	2,871.0	4,615.0	35,533.0
Av . Price (2014)	$ 25.94	$ 98.24	$ 20.37	$ 58.16	$ 20.37	$ 33.78	$ 48.37	
Con (total $)	$ 38,605	$ 383,186	$ 395,625	$ 74,636	$ 49,966	$ 95,298	$ 224,800	$ 1,262,116
Sth (total $)	$ 30,199	$ 359,963	$ 397,287	$ 81,127	$ 47,290	$ 96,970	$ 223,228	$ 1,236,062

The observed data for catch numbers indicates the similarity in the number of fish caught between the two treatments. The transformations to total weight and total value also show similar values.

The three regressions were used to test the data for any significant differences between the treatments. The estimated coefficients are reported in Table 3.

Table 3: Regression estimates for the catch, effort model with a binary dummy variable for the STH treatment.

	Constant	Effort	Gear dummy	R^2
Catch -numbers	58.763	-0.037	-3.054	0.004
	(1.409)*	(-0.114)	(-0.325)	
Total Weight	923.676	1.387	27.216	0.001
	(0.832)	(0.16)	(0.109)	
Total revenue	-914.616	349.617	4446.637	0.026
	(-0.016)	(0.768)	(0.34)	
	Constant	ln Effort	Gear dummy	R^2
Ln catch numbers	5.46	-0.338	-0.089	0.008
	(1.143)	(-0.342)	(-0.319)	
Ln total weight	6.665	0.024	0.005	0.001
	(1.268)	(0.022)	(0.018)	
Ln total revenue	5.092	1.098	0.039	0.032
	(0.898)	(0.936)	(0.117)	
df= 29; t values in parenthesis	* significant at 10%			

In Table 3 we can see there in only one coefficient that is significantly different at a 10% level of confidence. The data reflects limited amount of fishing in the trial, the grouping of the treatments by sets, and the relatively low number of comparative sets limiting the degrees of freedom. The remedy to this would be a much larger fishing experiment beyond the scope of the current trial.

The size of the data panel also affects the fit of the model which is extremely low reflecting the micro panel data from a sample of only two individual fishing vessels over a relatively short time period of a few months. Studies where this regression model has performed well have been fleet wide studies (Campbell and McIlgorm 1996; and Bjorndal 1989). There are also some limitations in the range of the variation of the effort variable, due to the trial design limiting the number of hooks set per treatment (McIlgorm 1995). However the dummy variable can potentially pick up any significant catch effort relationship if they were evident in the data.

In the results there is no evidence of a significant difference in numbers of fish caught between the two hook treatments. The results for the regressions of catch by weight and catch by value had similar results. So for the trials the species mix with different prices was not significantly different from the catch numbers result. This may have reflected the lack of data for the weight of fish from each hook treatment which was not available to the study.

4. Discussion and conclusions

The size of the data sets from the trials was deemed sufficient for the productivity comparison at the individual vessel level. The comparison of the two treatments through regression analysis did not detect any results in which the difference between the control and the smart tuna hook treatments was significantly different. There was no evidence that the use of the STH either significantly increases, or significantly decreases, fish catch or catch value. This is an important result as fishers using the STH have some assurance that catch will not diminish, and that any benefits from reduced bird bycatch will benefit the fishing operation.

The concurrent trial study on seabird bycatch impacts found that the STH led to the reduction of the bycatch of seabirds by between 81.8% and 91.4% (Baker and Candy 2014). The costs and benefits in operations are the incremental cost of using the STH versus the benefits of reduced bird catch from using this device. The expenditure on the STH substantially reduces bird impacts, while not reducing fishing productivity.

The assessment of catch and benefits is set within the policy context where in the SAPLLF operators are only allowed to incidentally kill 25 birds a year as bycatch. Should a vessel kill 25 birds in a year they are to cease fishing and apply further mitigation measures (DAFF 2013). The vessels may also have to cease fishing for that season which would curtail business income and the opportunity to make profit. This limit on the total number of birds that can be impacted in a year by a fishing vessel puts an unknown economic value on each bird impacted by the fishing process. Put another way, if a vessel with standard fishing gear reaches its limit of seabird bycatch by month 9 of the year, the use of the less bird impacting STH could have enabled that vessel to complete the 12 month fishing season. For this example, it is likely that the benefits from completing the annual operation would exceed the additional operating costs in using the STH system.

According to Baker and Candy 2014 the bycatch on a line not using STH would be 0.647-1.411 birds per thousand hooks set, versus 0.059-0.247 birds by the STH. DAFF (2013) indicates that "*The NPOA-SEABIRDS specifies a maximum mortality rate of 0.05 birds/1000 hooks, and lays out bycatch mitigation measures for use in longline fishing".* The STH comes much closer to meeting this standard than the traditional gear. The STH trial compares the STH to longline gear with minimal mitigation e.g. weighted branch lines and night setting.

Given the level of effort in the fishery and the high degree of seabird impact, the adoption of additional mitigation measures is required to meet the annual impact cap. The STH device can contribute to resolving this seabird impact problem. Bird bycatch is currently avoided by a range of setting measures (bird scaring "*tori*" lines, weighted branch lines and night settings) and by self - imposed spatial and temporal closures in areas of the fishery with high sea bird abundance.

The results indicate an economic relationship between the incremental cost of each STH set (A$300 per thousand hooks) and the benefits gained through decreasing bird bycatch. The SAPLLF has an annual bycatch limit per vessel of 25 birds imputing an economic cost on bird impacts.

The degree of bird impact reduction from the STH, and its application with other mitigations measures, makes the STH an attractive potential solution to this issue. The STH can enable vessels to operate with greater flexibility in fisheries where bycatch reduction is a requirement of operation. For example allowing the vessel to fish during daylight hours to target other species and or remove the need for weighted branch lines to increase crew safety and reduce capital costs of fishing gear. Overall the expenditure on the STH can help fishers to maintain fishing access by minimizing bird bycatch within acceptable levels and without compromising fish catch.

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