



# An Assessment of Economic Viability of the Ascension Island Tuna Longline Fishery Management: Implications for Marine Protected Area Planning and Future Fisheries Management

Angela Muench<sup>1\*</sup>, Elena Mengo<sup>1</sup>, Sam Weber<sup>2</sup>, Diane Baum<sup>3</sup>, Andrew James Richardson<sup>3</sup>, Hannah Thomas<sup>4</sup> and Paul Whomersley<sup>1</sup>

<sup>1</sup> Centre for the Environment, Fisheries and Aquaculture Science (CEFAS), Lowestoft, United Kingdom, <sup>2</sup> Bioscience, University of Exeter, Exeter, United Kingdom, <sup>3</sup> Conservation and Fisheries Department, Ascension Island Government, Georgetown, United Kingdom, <sup>4</sup> Marine Management Organisation (MMO), Newcastle upon Tyne, United Kingdom

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### \*Correspondence:

Angela Muench  
angela.muench@cefass.co.uk

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The designation of large scale marine protected areas (MPAs) has increased in recent years to address global issues such as biodiversity loss and the conservation of vulnerable marine habitats. While designing a large scale MPAs in the Exclusive Economic Zone (EEZ) of Ascension Island, the monitoring and enforcement costs were estimated for the two options under consideration: partial closure or full closure of the EEZ for the international commercial fleet. It was found that number of licenses to be sold to the international fleet to allow them access to the EEZ of Ascension Island would need to be increased to fund the monitoring and enforcement cost in case of a partial closure of the EEZ of Ascension Island. In this study, the future economic viability of the licensed big eye tuna fishery was addressed. The study explored economic drivers thought to be linked to license sales. It was shown that cost of licenses had not caused the observed decline in license sales but a shift in consumer demand toward lighter tuna species resulted in a decrease in Japanese imports for bigeye tuna (*Thunnus obesus*). This change in demand led to global changes in fishing effort and a drop in demand for licenses to fish within the Ascension Island EEZ. This study provided a valuable insight into the economic viability of the bigeye tuna fishery within the Ascension Island EEZ which informed the subsequent decision to close the bigeye tuna fishery as part of the designation of an Ascension Island highly protected large-scale MPA.

**Keywords:** MPA (marine protected area), bigeye tuna, global demand and supply, fisheries management, economic assessment, sustainability

## INTRODUCTION

To achieve the United Nation Sustainable Development Goal “Life below Water:—Conserve and sustainably use the oceans, seas and marine resources for sustainable development” the UK government introduced in 2016 the Blue Belt Program. This program has supported the UK Overseas Territories to enhance marine protection across more than 4.3 million square kilometers

of marine environment. One of the UK Overseas Territories which was assisted by this program is Ascension Island.

Ascension Island (7°56'S, 14°22'W) is an isolated volcanic island in the equatorial waters of the South Atlantic Ocean, around 1,600 km (1,000 mi) from the coast of Africa. The island is about 88 km<sup>2</sup> large and inhabited by about 800 people (Burns et al., 2020). The island's shallow nearshore marine biodiversity is a mix of both east and west Atlantic biota (Nolan et al., 2017). Habitat diversity is relatively low due to the absence of tropical coastal habitats such as mangroves, seagrass beds and coral reefs which are generally associated with high biodiversity. The main subtidal habitats include volcanic rock, rhodolith beds and expanses of sand interspersed with boulder fields. Marine invertebrate diversity is considered to be low (Brewin et al., 2016) and fish communities characterized as extremely abundant with low species richness and a high level of endemism (Nolan et al., 2017). Ascension Island is also the most important tropical Atlantic breeding site for seabirds, supporting 11 species and over 400,000 individuals and an important breeding site for the endangered green turtle, hosting the largest number of breeding turtles (3,000+) in the South Atlantic (Ascension Island Conservation Centre, 2018).

Away from the island, features including seamounts and canyons which are often hotspots of pelagic biodiversity and attract higher abundances of commercially targeted species (Ascension Island Government, 2021; Thompson et al., 2021) are found within the Ascension Island Exclusive Economic Zone (EEZ). In addition to the seamount complex's, four hydrothermal vents exist, distributed along the mid-Atlantic ridge at depths ranging from 1,700 to 3,600 m, they support highly specialized ecosystems that have adapted to survive in the extreme conditions and live off the chemicals emitted from the vents (Vrijenhoek, 2010). The remainder of the Ascension Island EEZ is characterized as pelagic habitat with an average depth of 3,300 m. This pelagic environment supports populations of flying fish, giant marlin, sharks and shoals of tuna (Ascension Island Government, 2021).

Historically, Ascension Islands water were never explored by a commercial inshore fishing, only some recreational fishing activity (Burns et al., 2020). The main commercial offshore fishery that was in operation within and around the Ascension Island EEZ at the time of composing this article was a pelagic (drifting) longline fishery primarily targeting bigeye tuna (*Thunnus obesus*) (Reeves and Laptikhovskiy, 2014; Matsumoto, 2016; ICCAT, 2018a). Since 1988, international vessels which wished to fish in the Ascension Island's EEZ were required to purchase a license. The revenues generated from license sale were used by Ascension Island Government to resource the monitoring and enforcement of the license conditions and to combat illegal, unregulated and unreported (IUU) fishing (Thomas et al., 2018; Rowlands et al., 2019). In recent years, license uptake has been low with only 1–2 licenses issued per year. To conserve and protect their habitats and biodiverse marine communities, the Ascension Island Government in 2021 successfully designated the whole of their EEZ as a highly protected marine area (Brickle et al., 2017). This was preceded by the creation and publication of the Ascension Island marine protected

area (MPA) management plan (Ascension Island Government, 2021), resulting in a ban on commercial fishing within the Ascension Island EEZ.

During the design phase and designation process of the Ascension Island MPA, information was gathered on the condition of marine/terrestrial habitats and species within the Ascension Island EEZ but also on the financial implications of monitoring and protecting such a large and remote MPA (Thomas et al., 2018; Rowlands et al., 2019; Appleby et al., 2021). Two design options were proposed with regards to permitted activities and future monitoring and enforcement costs: option 1: partial closure which permitted some commercial fishing within certain areas of the EEZ, and option 2: full closure of the EEZ which prohibited all commercial fishing within the Ascension Island EEZ (Figure 1).

This study explored whether Ascension Island Government could have increased their license sales to cover its fisheries management cost if option 1 would have been chosen. Therefore, the impact that latest changes in local licensing conditions in conjunction with changes in preferences for tuna on the world market may have had on the economic viability of an Ascension Island longline fishery were assessed. We start by describing the fisheries management and licensing scheme that has recently been implemented in Ascension Island and discusses potential drivers linked to the international tuna market which may have impacted the uptake of licenses sold for fishing within the Ascension Island EEZ. The study presents an empirical analysis that links the local and international changes in the tuna fisheries to the number of licenses sold. The aim of this study was to identify the main driver for the decrease in the number of licenses sold, to be able to give advice relating to the design of the Ascension Island MPA and on future tuna fisheries management within the EEZ of Ascension Island.

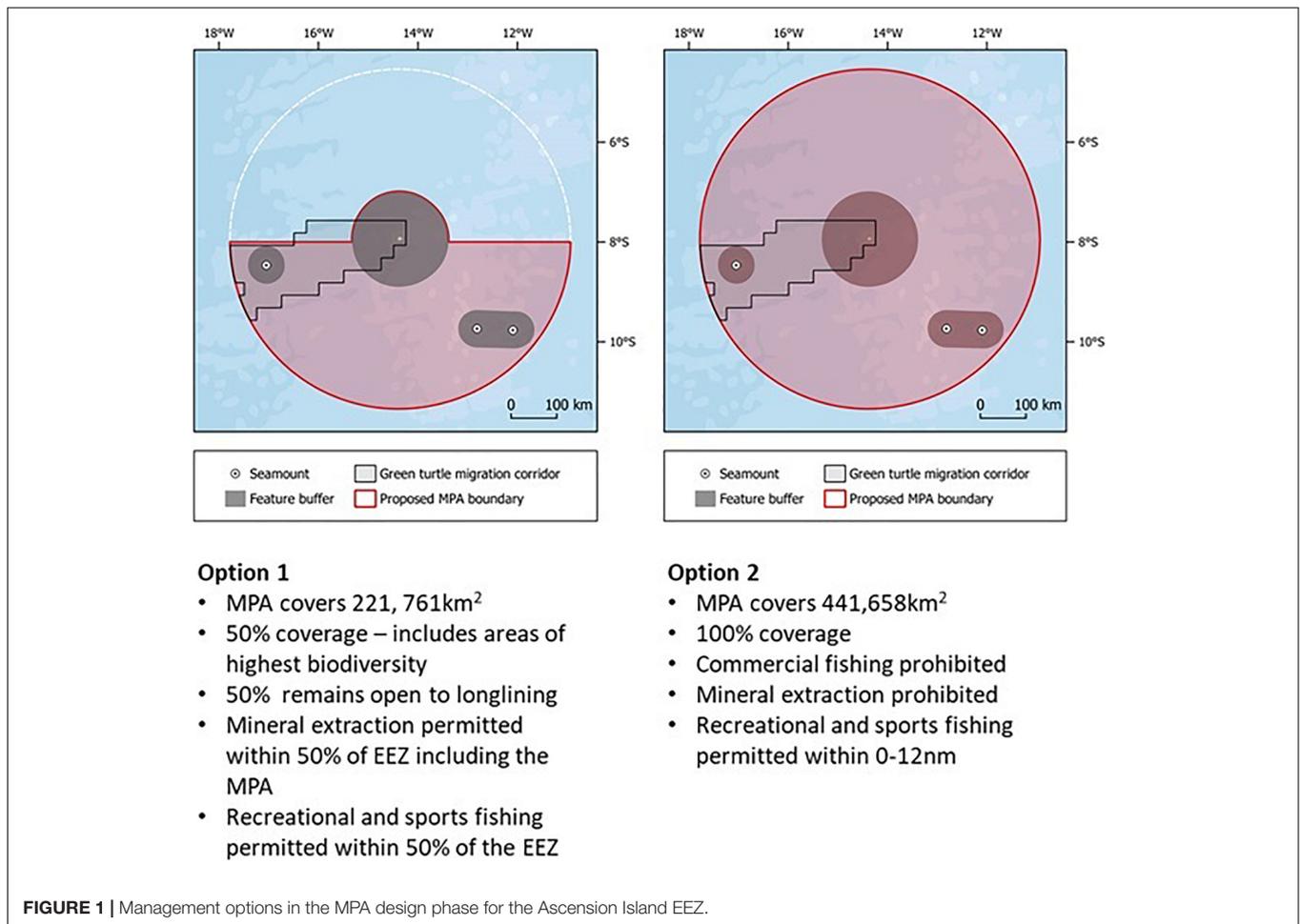
## MATERIALS AND METHODS

### Data

#### Local Drivers: The Ascension Island fishery

The main commercial fishery that occurs within and around the Ascension Island EEZ is a pelagic (drifting) longline fishery primarily targeting bigeye tuna (*Thunnus obesus*) (Reeves and Laptikhovskiy, 2014). Since 1988, international vessels which wish to fish in the Ascension Island's EEZ are required to purchase a license. The Ascension Island fishery was then closed between 2005 and 2009 while the Ascension Island fisheries management council decided on how to manage its own license system. A second closure of the Ascension Island fishery which was linked to a review of management options occurred between 2013 and 2014. A new Fisheries Ordinance was then implemented in 2015 which resulted in 52.6% of the Ascension Island EEZ remaining closed to the international tuna fishery. This closure encompassed the Southern part of the EEZ and 50 nm around the island's mainland, i.e., already in preparation for implementing option 1.

In the empirical analysis the number of fishing licenses sold by Ascension Island Government over the period of



1988–2016 was used as dependent variable. The number of fishing licenses sold permitting the harvesting of tuna by the international fleet in Ascension Island's EEZ peaked in the 1990s with 134 licenses sold in 1996. However, license uptake decreased before the area was closed for the first time in 2005. After the first closure, license uptakes in the years 2010–2012 returned to similar level as those reported for the joint licensing system prior to 2000. However, the number of licenses sold in years 2015–2017 dropped to 1–2 licenses per year.

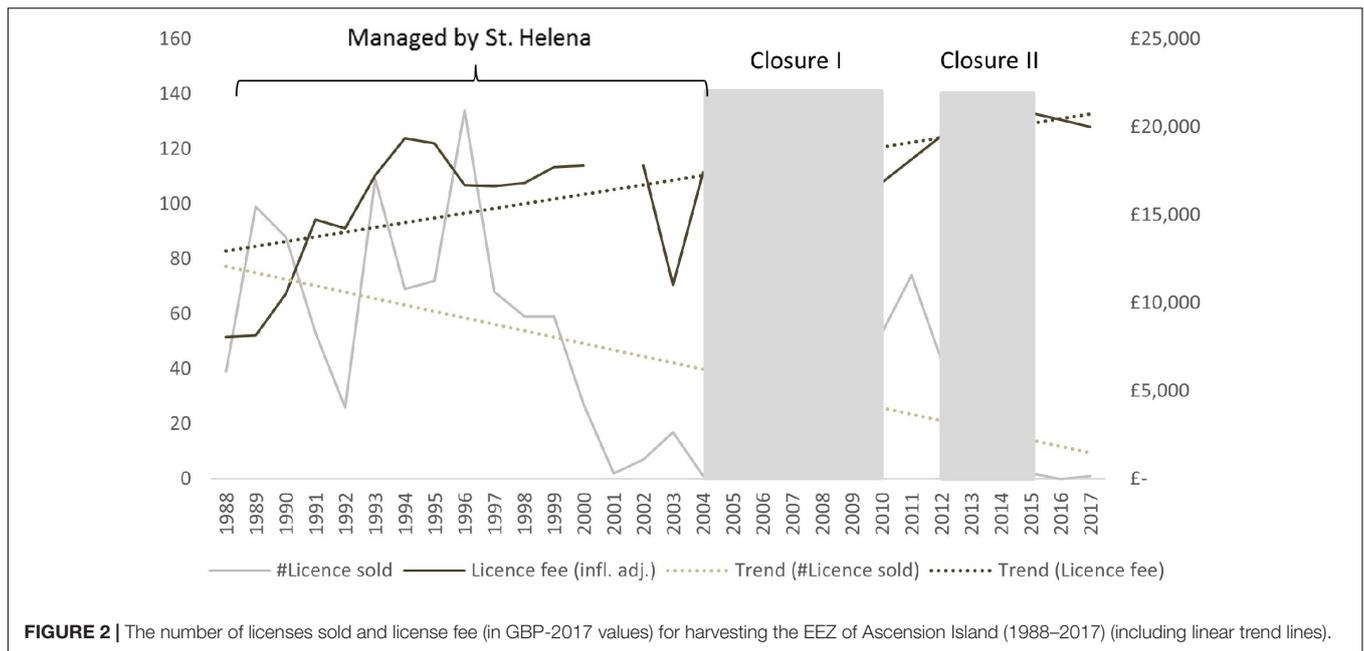
Parallel to the decrease in license sales, a gradual increase in license fee took place, starting from approx. £8,000 in 1988 up to £20,000 in 2017 (Inflation adjusted to 2017-values). The license fee to be paid by the international fleet to fish within Ascension Island's EEZ for the upcoming period, was included in the empirical analysis as one of the local explanatory variables. A development of the number of licenses sold and license fee over the years can be found in **Figure 2**.

Another local explanatory variable entering the empirical estimation was the previous year's CPUE of Ascension Island (i.e., catch per fishing day). The latter was included to gauge if there was an incentive for the international fleet to buy a license to fish within the EEZ of Ascension Island at the

beginning of the season, when the actual within season CPUE was unknown. It was assumed for the purpose of this study that high levels of CPUE for the previous year motivated vessel owners to buy a license for the next season, following the argument of Polachek (2006) that CPUE is main driver for harvest decisions.

The data on number of licenses sold, license fee and CPUE in the EEZ of Ascension Island were provided by the Government of Ascension Island for the years 1988–2016.

In the past, most licenses to harvest the Ascension Island's EEZ were bought by the Taiwanese/Chinese and Japanese longline fleet which was targeting tuna predominantly in the South of the Atlantic Ocean (Matsumoto, 2016; ICCAT, 2018a). The main catch of the international longline tuna fleet in the EEZ of Ascension Island is bigeye tuna (*Thunnus obesus*). During the years 2011–2013 bigeye tuna represented 74–82% of catches in the EEZ of Ascension Island (Reeves and Laptikhovskiy, 2014). Catch-return data provided by Ascension Island Government shows that in 2016 the proportion of catch of bigeye tuna increased to 95% of the total reported catch from within the Ascension Island EEZ (Diane Baum, Director of Conservation and Fisheries, Ascension Island Government, Personal Communication, August 2018).



It was assumed that in the years the effort in the general area around Ascension Island was low, it was also less likely for a vessel owner to invest in a license to fish within the EEZ of Ascension Island. In contrast, when fleet effort was high in the general area, the increased competition for the bigeye tuna stock may encourage vessel owners to extend their harvestable areas by purchasing a license to fish within the EEZ of Ascension Island. As the Taiwanese/Chinese and Japanese longline fleet which targets predominantly tuna in the South of the Atlantic Ocean, are the ones who bought in the past licenses to harvest the Ascension Island EEZ, the overall annual effort of the Japanese and Chinese/Taiwanese longline fleets in the Atlantic Ocean for the years 1988–2016 was included as explanatory variables (ICCAT, 2018b).

### International Drivers: The International Tuna Market for the Atlantic Ocean

In general, global tuna production is driven by the demand of two markets: (1) the traditional canned tuna market mainly supplied by white meat species and (2) the Japanese sushi and sashimi market, in which red meat species are dominant (Fernandez-Polanco and Llorente, 2016). Bigeye tuna is a fatty, red-meat tuna and besides bluefin tuna mainly used for sashimi in Japanese cuisine. Hence, one of the biggest importers of bigeye tuna is Japan, with frozen tuna mainly supplied by China/Taiwan (Globefish, 2018). In recent years, a shift in tuna consumption in Japan was observed with demand for fatty/red-meat sashimi tuna becoming more seasonal, associated with festivals and special occasions. At the same time, western style nutrition increased which encompasses the consumption of lighter and/or less costly tunas in sashimi, such as yellowfin, albacore, skipjack or rancher bluefin tuna (Kurokura et al., 2012; Globefish, 2018). Thus, the decline in demand for bigeye tuna in recent years led to a decrease of imports of fresh and frozen bigeye tuna in Japan while total

frozen tuna imports of yellowfin tuna and skipjack increased (Globefish, 2018). This development was also reflected in the value per ton of fresh and frozen bigeye tuna imports. While in the last decade the import values per ton of fresh bigeye tuna decreased by an average of 1% and frozen by 7% between 1988 and 2016, the value per ton for yellowfin tuna or albacore remained at similar levels over the same time period (FAO, 2016; Globefish, 2017, 2018). To approximate the demand for bigeye tuna, the import quantity (fresh and frozen) and the Japanese domestic production of bigeye tuna (in tons, Source: FAO, 2019) for the years 1988–2016 was included into the analysis. The analysis was restricted to market demand for bigeye tuna in Japan based on the rationale that the main market for bigeye tuna is for sashimi in Japanese cuisine when compared with the western preference for lighter tuna such as yellowfin tuna or albacore (Globefish, 2018).

The market value of bigeye tuna was identified as one major driver for fishermen's harvest decision (Nishida and Izawa, 2005). Due to the lack of actual national market value data, the annual average import values per ton of frozen and fresh tuna worldwide for the years 1988–2016 were included in the analysis instead (FAO, 2016, 2019). The values were converted into 2015-values of the Pound Sterling using the annual average spot exchange rate published by the Bank of England (Series: XUAAUSS) and the consumer price inflation index published by the Office for National Statistics (Series: CPI INDEX 01.1: FOOD 2015 = 100).

While the market value primarily explains the harvest decisions (location and target species) of the tuna fishers (Nishida and Izawa, 2005), the catch-per-unit effort (CPUE) needs to also be considered (Polachek, 2006). With regards to the shift in demand combined with the decrease in market value, the total supply of bigeye tuna on international markets has shifted as well. While total supply of bigeye tuna peaked in 1994, followed immediately by a decrease of total supply until 2006, since 2007

a steady supply is reported (Figure 3). A major part of bigeye tuna catch is fished by vessels using longlines which have reported reduced catches in recent years, in contrast to purse seiners or bait boats whose catches have remained relatively stable (ICCAT, 2018a,b). This decline in catch reported by the longline fishery was partly driven by a reduction in fishing effort by the two largest suppliers of bigeye tuna, the Japanese and Chinese/Taiwanese flagged longline fishing fleet (ICCAT, 2015; Sharma et al., 2018). Since 2005, all vessels harvesting bigeye tuna have also been subject to a total allowable catch (TAC) regulation. This fisheries management measure was implemented due to a decrease in stock abundance probably exacerbated by the effects of warming seawater temperatures (Lynch et al., 2018). The observed decline in stock abundance was not fully balanced out by the decline in effort of the main fleet, thus resulted in a lowered CPUE (ICCAT, 2015; Lynch et al., 2018). The recovery of the stock of bigeye tuna, and there with the CPUE, has been slowed by recent overfishing of the stocks (Figure 3). In 2016–2017, total landings of bigeye tuna were estimated to have exceeded the TAC by 23% in 2016 and 18% in 2017 (ICCAT, 2018b).

A further factor considered was the running costs of the fishing fleet/vessels. Vast distances are covered by the longline fleet so fuel prices can influence how far fleets are willing to travel to target specific species. Fuel prices were based on the annual average of closing price for crude oil (West Texas Intermediate in US-\$/barrel, inflation adjusted, Source: Macrotrends, 2019) as a proxy for bunker oil prices used by fishing vessels as fuel. Bunker oil price data for such a long time (1988–2016) was not available. It was assessed for a shorten time-series available that crude oil prices and bunker oil prices were highly correlated, therefore crude oil prices were believed to be an appropriate proxy for fuel cost levels for the fishing fleet.

An overview of the data included in the empirical analysis can be found in Table 1.

## Empirical Analysis

Data was tested for serial correlation of the dependent variable and in the error-term (Cumby-Huizinga-Test), heteroskedasticity (Breusch-Pagan/Cook-Weisberg test) as well as multicollinearity within the estimation model (variance inflation factor). The tests for serial correlation of the dependent variable “license sold” revealed significant results. An autoregressive regression model with 2-years lag [AR(2)] resulted in best model fit and stability results under altering parameters describing the autocorrelation and stationarity in the data structure. A high pairwise correlation (Pearson’s pairwise correlation of 0.764,  $p < 0.1$  including Bonferroni correction) of bigeye tuna caught by the Japanese fleet in the Atlantic Ocean, the corresponding CPUE and the number of licenses sold for harvesting the EEZ of Ascension resulted in multicollinearity issues. Therefore, the annual catch variable was excluded from the empirical analysis while CPUE was included as lagged variable. Similar correlation issues causing multicollinearity were detected for the worldwide average market value of fresh and frozen tuna, which therefore entered the estimation as total annual average. Otherwise, no further multicollinearity and

heteroskedasticity issues were detected (i.e., variance inflation factor below 6).

The final model to estimate the drivers of license uptake can be stated as follows:

$$\hat{Y}_t = \phi_1 Y_{t-1} + \phi_2 Y_{t-2} + \beta_n X_t + \epsilon_t \text{ with } \epsilon_t \sim N(0, \sigma^2) \quad (1)$$

With  $\hat{Y}_t$  denoting the license sale for the years  $t$  1988 to 2016, and  $X_t$  matrix of the explanatory variables: license fee, effort of the Japanese and Chinese/Taiwanese longline fleet in the South Atlantic, last years catch per unit effort in the EEZ of Ascension Island, the average import unit value of bigeye tuna and the price of crude oil,  $\phi$  is the autoregressive coefficient,  $\beta_n$  the coefficients of the variables in the explanatory matrix, and  $\epsilon_t$  the normal distributed error-term.

Due to co-integration issues between the variables identified as main explanators for license uptake, a Vector-Auto-Regressive [VAR(1)] model with one year lag was employed to explore the connectivity of the effort of the longline fleet in the Atlantic area (indicated by the effort of the Japanese and Taiwanese/Chinese fleet) and the market demand for bigeye tuna (indicated by average import prices and the Japanese import volume). It was assumed that crude oil prices served as exogenous factors. The VAR estimated can be formulated as follows:

$$\begin{aligned} Effort_{t,Japan} = & \phi_{11} Effort_{t-1,Japan} + \phi_{12} Effort_{t-1,Taiwan} \\ & + \phi_{13} Price_{t-1,fresh} + \phi_{14} Price_{t-1,frozen} \\ & + \phi_{15} Demand_{t-1,Japan} + \beta_1 Oilprice_{t-1} + w_{t,1} \end{aligned}$$

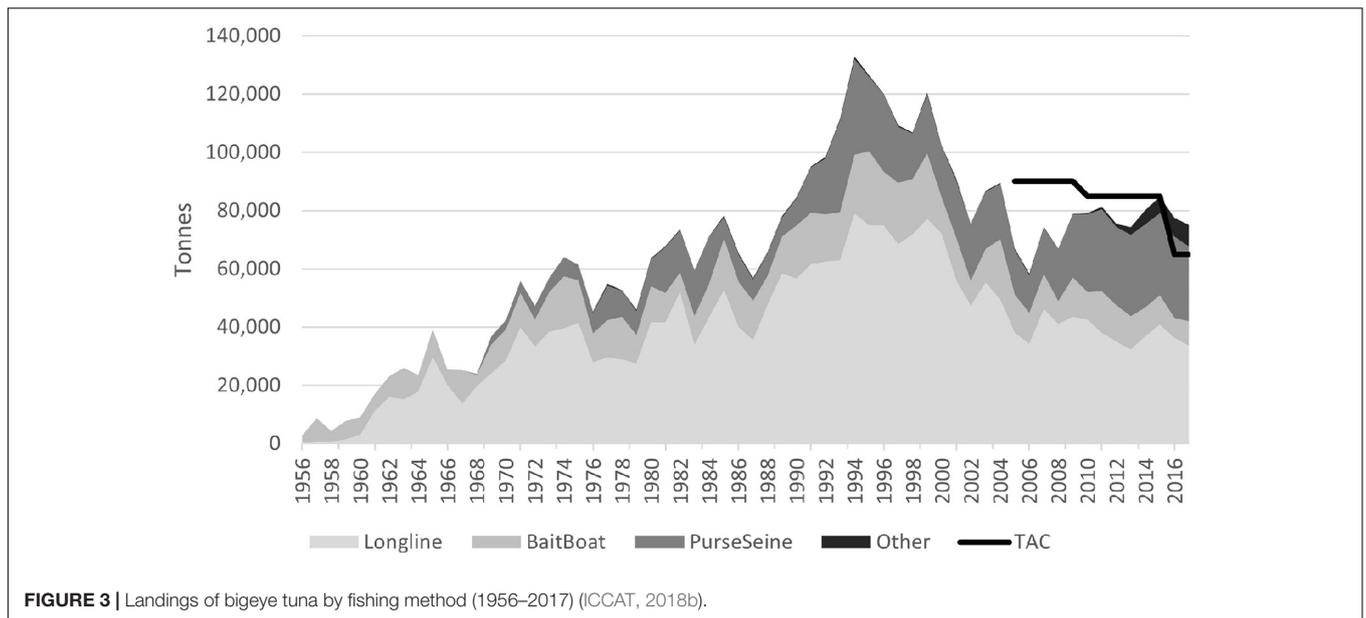
$$\begin{aligned} Effort_{t,Taiwan} = & \phi_{21} Effort_{t-1,Japan} + \phi_{22} Effort_{t-1,Taiwan} \\ & + \phi_{23} Price_{t-1,fresh} + \phi_{24} Price_{t-1,frozen} \\ & + \phi_{25} Demand_{t-1,Japan} + \beta_2 Oilprice_{t-1} + w_{t,2} \end{aligned}$$

$$\begin{aligned} Price_{t,fresh} = & \phi_{31} Effort_{t-1,Japan} + \phi_{32} Effort_{t-1,Taiwan} \\ & + \phi_{33} Price_{t-1,fresh} + \phi_{34} Price_{t-1,frozen} \\ & + \phi_{35} Demand_{t-1,Japan} + \beta_3 Oilprice_{t-1} + w_{t,3} \end{aligned}$$

$$\begin{aligned} Price_{t,frozen} = & \phi_{41} Effort_{t-1,Japan} + \phi_{42} Effort_{t-1,Taiwan} \\ & + \phi_{43} Price_{t-1,fresh} + \phi_{44} Price_{t-1,frozen} \\ & + \phi_{45} Demand_{t-1,Japan} + \beta_4 Oilprice_{t-1} + w_{t,4} \end{aligned}$$

$$\begin{aligned} Demand_{t,Japan} = & \phi_{51} Effort_{t-1,Japan} + \phi_{52} Effort_{t-1,Taiwan} \\ & + \phi_{53} Price_{t-1,fresh} + \phi_{54} Price_{t-1,frozen} \\ & + \phi_{55} Demand_{t-1,Japan} + \beta_5 Oilprice_{t-1} + w_{t,5} \end{aligned}$$

With  $w_{t,i}$  ( $i \in 1:5$ ) as autoregressive error-term. The empirical analysis was conducted within Stata 15.1.

**TABLE 1 |** Descriptive statistics.

Variable	Period	Min	Mean	Max	N	Source
Number of licenses sold	1988–2016	0	37.97	134	29	Ascension Island Government
License fee	1988–2016	3,879.31	11,977.3	20,000	21	Ascension Island Government
Effort Japan	1988–2016	41,208	90,030.2	135,576	29	ICCAT
Effort Taiwan	1988–2016	59,373	106,437	182,598	29	ICCAT
CPUE ASC (tons/day)	1988–2016	0.29	0.89	1.89	22	Ascension Island Government
Price BET (£/ton)	1988–2016	6,585.81	9,511.14	12,939.63	29	FAO
Price BET fresh (£/ton)	1988–2016	8,798.81	11,347.90	15,226.13	29	FAO
Price BET frozen (£/ton)	1988–2016	3,916.52	7,674.42	11,497.69	29	FAO
Crude Oil Price (£/Gallon)	1988–2016	14.42	44.71	99.67	29	Macrotrends

## RESULTS

An autoregressive model was estimated including the first and second lag of the stationary process as well as explanatory variables such as the license fee, the general effort of the fleet in the area, success (measured as CPUE) in the EEZ of Ascension Island in the previous period, the market value of bigeye tuna and the cost of harvesting (approximated by the international crude oil price, **Table 2**). Results from the model show decreasing levels of license uptake were not linked significantly to the increasing level of the license fee. Instead, the license uptake was found to be on higher levels when the general effort of the Japanese fleet in the Atlantic Ocean was about 3.5% higher or the effort of the Taiwanese fleet was about 2.2% lower than usual. Neither, last year's catch per unit effort in the EEZ of Ascension Island, the average import unit value of bigeye tuna nor the price of crude oil could be significantly related to the number of licenses sold. However, as already shown in **Figure 2**, the number of licenses sold followed a significant negative trend over the time period 1988–2016.

Although restricted by data availability, a VAR(1) was estimated to explore the relationship between the effort to catch

bigeye tuna from the Japanese and Taiwanese fleet and the worldwide import values of bigeye tuna (frozen and fresh) and the Japanese domestic demand. Results shown in **Table 3** show that the trends of effort by the Japanese fleet follow the trends of import value for frozen bigeye tuna, i.e., higher monetary values of frozen bigeye tuna increased the following year's level of effort about 16%. The lack of significant evidence for a link between the value of fresh bigeye tuna per ton and effort appears to be a result of the time-lag, i.e., the effort level of the Japanese fleet is significantly correlated with the import values of fresh tuna of the same year (i.e., Pearson's pairwise correlation of 0.724,  $p < 0.1$  including Bonferroni correction).

Unsurprisingly, fishing effort of the Japanese and Taiwanese fleet in the Atlantic targeting bigeye tuna was higher in years following years of high levels of demand. The previous year's demand for bigeye tuna on the Japanese market was also found to cause higher levels of import of frozen bigeye tuna in the following year.

In years when the cost of fishing (approximated by crude oil market price) was high, the effort of the Japanese fleet and the Japanese demand was low. This relationship was not the same for the Taiwanese fleet. While, it is reasonable to expect the level of

**TABLE 2** | Results of an AR(2) estimation model explaining the number of licenses sold (1988–2016).

Variables	Number of licenses sold
License fee	0.000558 (0.00407)
Effort Japan	<b>0.0351***</b> (0.00636)
Effort Taiwan	<b>-0.0220***</b> (0.00259)
CPUE Ascension Island (lagged)	-19.06 (41.51)
Import value BET	0.00282 (0.0687)
Price crude oil	0.0318 (0.318)
AR(1)	<b>-0.983***</b> (0.173)
AR(2)	<b>-0.875***</b> (0.187)
Sigma	<b>10.95***</b> (3.262)
N	17
Wald chi2(8)	2,545.06***
AIC	154.22

Reported are coefficients and standard errors in brackets. \*\*\* $p < 0.01$ ; BET, bigeye tuna. Coefficients of significant estimates are highlighted in bold.

effort to decrease when operational costs are high, it is unclear why demand appears also to be low in the years of higher crude oil price but the average worldwide import value of bigeye tuna does not seem to be significantly impacted.

The two estimation models [AR(2) and VAR] fulfilled the stability conditions and none of the included variables showed signs of unit-roots. However, low levels of co-integration were detected in the VAR estimation model.

## DISCUSSION

This economic study was undertaken to assess the main reasons for an observed drop in fishing license sales. This information, in combination with the additional costs of administrating and managing such a fishery was used to inform the design and designation process of the Ascension Island MPA.

The empirical analysis did not identify any significant link between the increasing license fee and the decline in license sales. This result concurs with a study conducted by Reeves and Laptikhovsky (2014) which estimated that a fee of up to £20,000 should not impact license sales. The recommendation on the license fee level was based on estimated tuna revenues and the assumption that the license fee should not exceed 6% of tuna revenues to meet a competitive price level. Considering the amount of catch harvested in the EEZ of Ascension Island and the average market prices for bigeye tuna, it was calculated that the license fee was on average approximately 1% of the revenue, hence far below the recommendation of 6%. Thus, it is unlikely that a decrease in the license fee would lead to an increase in license sales.

The observed drop-in the number of licenses sold coincided with the closure of 52.6% of the Ascension Island EEZ, and the introduction of stricter license requirements and enforcement (mainly related to vessel safety). The stricter requirements were argued to be caused by some widely media-covered cases of human-trafficking (Reeves and Laptikhovsky, 2014). Additionally, a case was made in February 2016, demonstrating the tightening of enforcement when one vessel fishing in the EEZ of Ascension Island was successfully prosecuted and eventually fined £1k for the breach of license conditions (i.e., insufficient number and conditions of life jackets and retaining of one shortfin mako shark—both violating license requirements in place). While these changes in fisheries management may have decreased the incentive for the Japanese and Chinese/Taiwanese fleet to buy a license to harvest the EEZ of Ascension Island, this study did not include the cost of compliance for the fleet into the empirical estimation (Rowlands et al., 2019). It was instead focused on the local drivers of license sale (license fee) which can be altered by the Ascension Island Government, but it can be assumed that cost of compliance for the fleet would explain another part of the picture.

Nishida and Izawa (2005) postulated that market value is the most important dominator of tuna fishermen's behavior, a result

**TABLE 3** | Results of a VAR estimation model.

	Effort Japan	Effort Taiwan	Import value BET fresh world	Import value BET frozen world	Demand Japan
Effort Japan <sub>t-1</sub>	<b>0.275**</b> (0.140)	-0.107 (0.285)	-0.0740 (0.335)	-0.134 (0.455)	3.729 (4.384)
Effort Taiwan <sub>t-1</sub>	<b>-0.288***</b> (0.0796)	<b>0.514***</b> (0.162)	-0.0741 (0.191)	-0.287 (0.259)	<b>6.335**</b> (2.500)
Import value BET fresh <sub>t-1</sub>	-0.0369 (0.0617)	-0.103 (0.126)	<b>0.977***</b> (0.148)	0.303 (0.201)	3.174 (1.940)
Import value BET frozen <sub>t-1</sub>	<b>0.160**</b> (0.0672)	0.137 (0.137)	-0.0800 (0.161)	0.243 (0.219)	1.448 (2.110)
Demand Japan <sub>t-1</sub>	<b>0.0183***</b> (0.00395)	<b>0.0154*</b> (0.00806)	0.00764 (0.00949)	<b>0.0249*</b> (0.0129)	<b>0.536***</b> (0.124)
Price crude oil	<b>-4.035*</b> (2.427)	-0.753 (4.953)	-0.0594 (5.832)	-10.79 (7.904)	<b>-164.6**</b> (76.24)
N	28	28	28	28	28
R <sup>2</sup>	0.991	0.975	0.994	0.977	0.996

Reported are coefficients and standard errors in brackets. \*\*\* $p < 0.01$ , \*\* $p < 0.05$ , \* $p < 0.1$ . Coefficients of significant estimates are highlighted in bold.

we confirmed during our analysis. Higher market value of frozen tuna imports seemed to have incentivized increased fishing effort in the following year, while higher import values per ton of fresh bigeye tuna was significantly linked to higher effort levels in the same year.

We also demonstrated that the demand of the Japanese market influences the following year's import value per ton of frozen bigeye tuna. In addition, the import values per ton of bigeye tuna (fresh and frozen) into the Japanese market are significantly correlated with the worldwide average import value for bigeye tuna, therefore, supporting the argument that the Japanese demand for bigeye tuna has a great influence on the global tuna market (Globefish, 2018).

Our study showed that the major driver for license sale in the EEZ of Ascension Island was the effort of the Japanese fleet. In years when the Japanese fleet was actively targeting bigeye tuna to meet market demands, the license sales for the EEZ of Ascension Island was high. However, in recent years, the demand for tuna for sushi and sashimi shifted from heavy tuna to lighter tuna, reducing the demand for bigeye tuna and therefore a reduction in effort by the Japanese fleet in the North Atlantic (Globefish, 2017). In addition, increasing fuel prices and a decrease in CPUE contributed to an observed drop in fishing effort by the Japanese longline fleet. In recent years, the Taiwanese fleet increased effort to supply the Japanese demand for bigeye tuna. The ability of the Taiwanese fleet to continue to target bigeye tuna even when the market demand had decreased is thought to be due to the high level of subsidies associated with Taiwanese high sea fishery (Sala et al., 2018). The predicted continued decrease in CPUE for bigeye tuna as assessed by ICCAT (2018b) is unlikely to improve the economic viability of the fishery.

It was concluded that the current number of licenses sold would not cover the monitoring and enforcement cost for option 1: partial closure of the EEZ (Thomas et al., 2018; Rowlands et al., 2019). Hence, to make this option feasible such as enforcement and monitoring cost are covered by license revenues, license sale would need to be increased (Rowlands et al., 2019). In contrast, option 2: full closure of the EEZ for the international tuna fishery would imply that IUU would be addressed by the relevant Regional Fisheries Management Organization. This would mean the International Convention for Conservation of Atlantic Tuna (ICCAT) would prosecute and sanction violations of the MPA and with this MPA management cost would decrease significantly for Ascension Island (Thomas et al., 2018).

## CONCLUSION

This study demonstrated that the drop in license sales were not correlated with the increase in license fees. Moreover, it was highlighted that the main drivers affecting license sales were the market demand and value of tuna, in combination with the distribution of fishing effort across both the Japanese and Chinese/Taiwanese longline fleets. Until global demand for bigeye tuna increases, it was deemed highly unlikely that the international fishery will once again become a

profitable enterprise. Especially when the increasing costs of monitoring, reporting in line with international obligations and enforcement are considered.

Our analyses focused on the volatility of license sales which permit fishing within the EEZ of Ascension Island. Understanding the drivers of the license sales allowed decisions to be taken in relation to how to manage the tuna longline fishery in the future while considering the proposed management and design of a large scale MPA. Understanding these drivers and the impacts they could have on the already limited ability of small islands to create income streams from fishing and other activities is crucial for the funding of monitoring and enforcement cost of large scale MPAs.

The study is part of wider consideration on the design of a large-scale MPA. However, it is here shown that the cost of monitoring and enforcement are a crucial consideration and as such funds needs to be secured. In our case, the Government of Ascension Island funded monitoring and enforcement through license sales to the international commercial fishery. While this funding scheme covered in the 1990s the cost for monitoring and enforcement, already in the past years, costs for maintaining a sustainable fishery needed to be funded by other incomes. It is here demonstrated that considering the bigger picture on the drivers for license uptake can help to governments to decide on the future of their fisheries management decisions such as the introduction of a large-scale remote MPA.

## DATA AVAILABILITY STATEMENT

The data analyzed in this study is subject to the following licenses/restrictions: Substantial part of the data is owned and managed by the Ascension Islands Government and subject to its data sharing policy. Requests to access these datasets should be directed to PW, paul.whomersley@cefas.co.uk.

## AUTHOR CONTRIBUTIONS

AM collected the data, conducted the analysis, and wrote the manuscript. SW, EM, and HT provided valuable input in earlier versions of the manuscript. DB and AR provided the fisheries dependent data as well as valuable information and insights into the historic management of the international tuna fleet. PW provided review, valuable comments, and context. All authors contributed to the article and approved the submitted version.

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