Marine Policy 95 (2018) 189–198

Contents lists available at ScienceDirect

Marine Policy

journal homepage: www.elsevier.com/locate/marpol

The impact of industrial tuna fishing on small-scale fishers and economies in the Pacific

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ARTICLE INFO

Keywords:
Food security
livelihoods
fisheries interactions
trade-offs
distribution effects
Tuvalu

ABSTRACT

Industrial fishing for tuna is a major revenue earner in the Pacific Islands region. Capturing more benefits from this fishery is a key priority of Pacific Island country governments and people. Many Pacific countries have done this by allowing transhipping — the transfer of fish from industrial purse-seine fishing vessels to carrier vessels in port. This paper investigates one such port, Funafuti in Tuvalu. Using a unique dataset, the analysis (for the first time) demonstrates that there are a number of negative impacts on small-scale fishers associated with allowing transhipping in port. These negative impacts include lost employment days, reduced catches and, potentially, fresh fish availability and lower incomes within the artisanal fishery. The analysis also demonstrates that there are benefits associated with transhipping, such as spending in local businesses and bycatch off-loads. This paper provides a number of considerations for governments to optimise the benefits from transhipping and minimise costs.

1. Introduction

Fish and fisheries contribute significantly to the economies, livelihoods, food security and income of Pacific Island countries [1]. Fisheries contribute between 0.6% and 10% of the gross domestic product (GDP) of many Pacific Island countries and account for USD 820 million in exports across the region [2]. In 2015, purse-seine and longline vessels of member countries of the Pacific Islands Forum Fisheries Agency (FFA) contributed USD 276 million to the countries' GDPs [3]. Offshore, locally based, industrial tuna vessels employ about 23,000 people in FFA member countries (authors calculations from data in [2] and [4]) and globally 56% of the world's tuna comes from the Pacific [5]. Small-scale subsistence and semi-commercial fishing is no less important as it provides most of the catch and protein in Pacific island countries [2,6]. Among Pacific island countries, 27% of households participate in fishing activities and 8% of households rely on fishing as a primary source of income. Current fish consumption is significant in the Pacific region averaging between 20 kg and 110 kg/person/year [7], with many Pacific Island countries expected to face a local production shortage of fish by 2030 [6].

The distribution and types of benefits from each fishing sub-sector may be very different, with small scale fisheries potentially only capturing a small fraction of the benefits of oceanic resources. Barclay and Cartwright [8] state that the 'most prominent desire' among small-scale fishers and Pacific Islanders is to capture more of the wealth created by their domestic pelagic resources, according to the principles of social equity and sustainability. Currently, most of this value comes from access and license fees. In 2014, USD 349 million in license fees were paid by distant water fishing operators to Pacific Island nations [2].

Some Pacific Island countries have captured additional benefits from distant water fishing nations through the development of local businesses and services in transhipping ports in countries such as Tuvalu, Marshall Islands and Solomon Islands [8]. These income sources contribute significantly to national economies and often make up a critical component of government budgets. Industrial operations, on the other hand, may impact important local small-scale fisheries. It is conceivable that local fishers are losing out as a result of these attempts to capture more value domestically as the benefits of the operations do not directly accrue to small scale fishers.

The United Nations Fish Stocks Agreement, requires signatories to consider the interests of artisanal and subsistence fishers, and avoid the adverse impacts of industrial fishing on these fishers [9]. Yet, Pacific Island coastal communities have become increasingly concerned about the impact of industrial fishing on the depletion of fish stocks on which they depend [10].

The potential for interactions between small-scale artisanal fishers

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https://doi.org/10.1016/j.marpol.2018.03.021
Received 18 December 2017; Received in revised form 1 March 2018; Accepted 19 March 2018
Available online 24 March 2018

and industrial fishing is increasing. With climate change degrading coral reef ecosystems, coastal fishers must move farther off shore and increasing rely on oceanic species for their catch [11]. As a result, Bell *et al.* [11] estimate that oceanic tuna will need to provide 25% of all fish consumption in the Pacific by 2035. The stated policy aim of Pacific Island countries and territories is to increase the amount of tuna available for domestic consumption by 40 000 t in 10 years [12].

The importance of interactions between small-scale fishers and industrial vessels has been noted by Shomura *et al.* [13], who remarked that knowledge of the interactions is essential for rational fisheries management, a statement that remains true more than 25 years later. The interactions literature is dominated by the analysis of biological and fish stock interactions, largely noting the reduction in the availability of fish for small-scale fishers [13–15]. There are also some studies documenting accidents and incidents at sea, but these are often poorly reported [16]. Behavioural and land-based interactions, however, are poorly understood [17,18]. Understanding and managing interactions within the oceanic fishery will be critical in achieving the Sustainable Development Goal (SDG) related to oceans (SDG 14), and the priorities in Pacific regional documents that guide Pacific Island countries' fisheries policies [19]. The Regional Roadmap for Sustainable Pacific Fisheries [20] states that the goals of coastal fisheries are to ensure resilience, protect livelihoods and empower communities. For oceanic fisheries, ensuring sustainability while extracting the greatest value, employment and food security outcomes are central [21]. The overarching goal of the Pacific region's "New Song for Coastal Fisheries" [22] is 'improved wellbeing for coastal communities'. Policies designed to contribute to these outcomes will be inefficient and potentially less effective without a good understanding of the trade-offs associated with fishers' behaviour [23].

The scientific literature indicates that there are some impacts on the availability of oceanic pelagic resources to small-scale fishers as a result of industrial vessels fishing in local waters, particularly when they are close to shore [14,15,24–27]. Leroy *et al.* [15] commented that 'industrial purse-seine fisheries may impact upon artisanal and subsistence fishers by reducing local fish availability', and SPC [26] found that industrial vessels 'largely catch similar sized fish to the artisanal fleet', suggesting that the two fisheries fish the same portion of the stock. However, SPC [26] do not suggest that industrial vessels directly impact the catch of artisanal or subsistence fishers.

Anecdotal evidence supports the conclusions from the literature and suggests that many fishers believe that industrial fishing is depleting stocks of coastal recourses (authors' discussions with a range of Pacific Island communities). In Tuvalu, data collectors, Fisheries Department staff, and fishers have all described the same pattern: the presence of industrial vessels means that fewer artisanal fishers go fishing and catches are reduced. Abernethy *et al.* [17] describes our understanding of small-scale fishers' behaviour as 'at best rudimentary', yet this underpins fishers' day- to-day decisions, and without a basic understanding of the behavioural dynamics, policy will be inefficiently designed and likely to fail. Muallil *et al.* [18] also call for a greater understanding of the factors impacting a fisher's willingness to exit a fishery. Developing data-driven evidence and understanding the behavioural drivers of artisanal fishers and the impacts of their behaviour is important, and policy-makers need to fully understand these trade-offs when making decisions.

This paper looks to address this gap in the literature with an initial analysis of the impact of transhipping on the willingness of fishers to go fishing in Funafuti, a small but important transhipping port. We go onto use this modelled relationship to estimate potential losses with the artisanal fishery as a result of transhipping activity.

Tuvalu is a Pacific Island nation in the central Pacific, consisting of nine atolls, and is one of eight members of the Parties to the Nauru Agreement (Fig. 1). Together, the member countries of the Parties to the Nauru Agreement control the largest tuna purse-seine fishery in the world, via the implementation of collective management arrangements

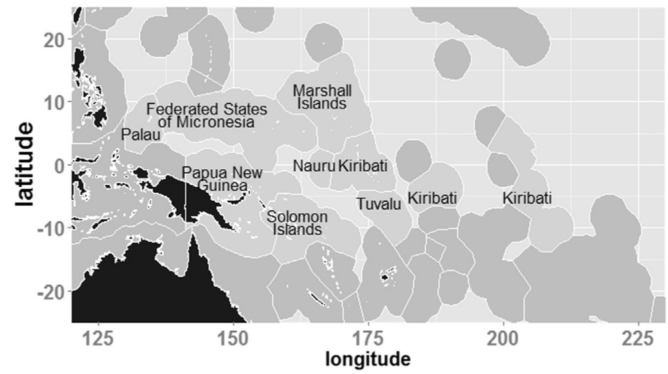

Fig. 1. : Location of Tuvalu relative to other member countries of the Parties to the Nauru Agreement.

[11].

The difficulty in quantifying interactions between artisanal and industrial fisheries is largely due to poor artisanal catch data [15]. At the Pacific Community (SPC) Head of Fisheries meeting in 2011 Tuvalu placed a high priority on understanding the potential for interaction between regional tuna fisheries and local artisanal fishing [24]. As a result, SPC provided support for artisanal catch monitoring in Tuvalu in 2013 to address critical data deficiencies and allow improved investigation into the interactions. This dataset provides a unique opportunity to investigate the interactions between artisanal and industrial vessels from a social and biological perspective. We use this and other datasets from Tuvalu to reveal the impact of industrial vessels on the willingness of artisanal fishers to go fishing. This revealed preference technique is a new approach to the problem of interactions between the two important sub-sectors of the tuna fishery.

Broadly, this paper considers three aspects of the interaction between industrial and artisanal fishing: 1) Does the presence or absence of industrial fishing vessels in the port of Funafuti affect a fisher's willingness to go fishing? 2) If so, what are the impacts on key livelihood indicators such as employment, income and the availability of locally produced fish? 3) To fully understand the trade-offs facing decision-makers we estimate the benefits of allowing transhipping in port and compare these to the modelled impacts in the artisanal fishery.

2. Materials and Methods

2.1. Data

Three complimentary datasets were analysed: artisanal landing survey data, individual artisanal logsheet data and commercial vessel monitoring system (VMS) data. Artisanal landing survey and individual logsheet data collection ceased in Tuvalu in 2016 in favour of a creel-based survey methodology due to changing objectives associated with data collection. Data are therefore available from 2013 to 2016, although 2016 is incomplete. The VMS data used for the impact analysis was for the period 2012 to 2016. The VMS system receives and records the position, course and speed of every vessel every two hours. We were also provided with transhipment data from 2014 and 2015, which aided in some of our calculations and allowed us to corroborate some of our findings.

The number of artisanal vessels fishing each day is calculated from landing site activity logs. These are collected by fisheries officers who report the number of boats returning to each landing site from a fishing trip each day. The number of vessels observed is a snapshot of how many vessels are actually fishing each day. To obtain the total daily fishing activity, the data were grouped into discrete time blocks. This allows us to scale the daily observed fishing activity to total daily fishing activity. The greatest number of boats observed returning from a fishing trip were between 04:00 and 12:00; after 12:00, the entries were less regular. Thus, the morning was divided into two blocks and the afternoon into a single block. The first discrete time period was between 04:00 and 07:59, followed by 08:00 until 11:59, and finally from 12:00 to 18:00. The number of hours within each time block a port observer spent on site was identified along with the total number of artisanal vessels observed in that time block. To scale the data to daily activity the number of vessels observed was compared to the total hours within each time block an observer was present at the landing site, this gave a proportion of time block observed and allowed a scaling of vessels for the remainder of the time block. The number of vessels per discrete time block was then adjusted from the proportions and, thus, a daily number of artisanal vessels were calculated.

In order to identify the number of commercial purse-seine vessels, longline vessels and carrier vessels (collectively referred to as 'industrial vessels') in port on any particular day, VMS data were used. Here, vessel data were filtered to identify those that were stationary in port at Funafuti. These data were cross-referenced with transhipment data, where available. The data were then merged with artisanal data by day.

As with other economic and fisher behaviour studies, utility (economic gross benefit) drives individual choice. In this study we assumed a binary choice on the part of the artisanal fisher as to whether or not to go fishing on any one day possibly impacted by the presence of industrial vessels. Artisanal fishers normally leave very early in the morning or late in the evening the day before. This helps them ensure they reach the fishing grounds at the best times to target the larger fish before the fish move to deeper water. To capture this behaviour the number of industrial purse-seine vessels was lagged by day to capture.

The data from artisanal catches (predominantly tunas and tropical oceanic fish such as Wahoo (*Acanthocybium solandri*), Mahi Mahi (*Coryphaena hippurus*) and Rainbow Runner (*Elagatis bipinnulata*) was analysed separately from the number of artisanal boats departing the port. Catch data are by vessel by day, giving weight and number by species caught along with the fishing method, number of hours spent fishing and the number of fishing lines or hooks used per day. Because the majority of data consisted of troll fishing, this was used to construct a dataset of average catch rates per hour per day per fishing line (numbers of hooks had a considerable amount of missing data and was not used). The data were merged with the industrial vessel presence data as above, although this time the number of industrial vessels was not lagged. The artisanal catch data (by species and weight) were then used to assess the implications of the industrial vessel presence on artisanal catch rates.

To understand the on-land spending patterns of industrial vessel crew members, we undertook a survey of the eight main restaurants, bars and hotels in Funafuti known to be regularly frequented by industrial vessel crews. This survey was administered and designed by the authors. It gathered basic information from owners or managers regarding the number of patrons who were from industrial fishing vessels, how often the establishment was frequented by these patrons, approximate spending per group/person and type goods purchased.

2.2. The model

The basis of the preceding analysis is the modelled relationship of the number of artisanal boats fishing and the catch per unit of effort of these fishing trips against the number of industrial vessels in Funafuti port. With these relationships established we can then identify a counterfactual of what the artisanal fishing activity and catch would have been with zero industrial vessels in port and thus assess the impact of reality against this counterfactual in terms of lost fishing days, reductions in fish landed, employment and income generation.

For modelling count data (i.e. variables that are integers and are non-negative random variables), we used the Poisson model. A Poisson distribution describes the frequency of an event per unit of time; for example, events such as the number of cargo ships damaged by waves [28] or discoveries and/or accidents. The Poisson model is described as:

$$log(\mu) = \alpha + \beta x \tag{1}$$

where the expected value of y = E(y) = μ the rate of occurrence, is a linear function of the regressor(s) βx. The exponential form of the regressors in Eq. (1) ensures that the expected values are non-negative. However, on fitting Poisson models with discrete time data, these data admit more variability than expected and, thus, the greater variability predicted results in over-dispersion (i.e. the variance is greater than the mean). This is especially a feature of simple models with few parameters that contain data with a number of zero counts, which leads to underestimates of the variance of the parameter. To circumvent the issue of over-dispersion in Poisson count models, it is advised that alternative models are investigated; for example, the negative binomial model that is a derivation of the Poisson distribution and has an extra parameter to model the over-dispersion and as such can correct the standard error estimates (for a detailed description see [29,30]). For this analysis, the only regressor variable is the lagged (t-1) number of industrial vessels (Ind_Vessel) per day (t), with the dependent variable being the count of artisanal vessels (totart) per day (2). For the analysis of how industrial vessels affect artisanal catch rates in kilograms (kg) per hour per line per day (t), Eq. (3) was used (CPUE). A simple Poisson model was developed and, based on the outcomes in terms of over-dispersion, a negative binomial model was explored using R software to implement the analysis [31]. The count models are compared by using Akaike information criteria (AIC; [32]) and, for goodness of fit, using Pearson's chi-squared test. Other potential regressors were investigated, including weather, hours spent fishing, location and fuel used.

$$totart_t \sim \alpha + \beta i * IndVessel_{t-1} \tag{2}$$

$$CPUE_t \sim \alpha + \beta i * IndVessel_t \tag{3}$$

The modelled relationships (Eqs. 2 and 3), artisanal catch and catch composition data, and artisanal logsheet information allows us to estimate the impact of the presence of industrial vessels over the four years in which we have sufficient data. The results were compared with the identified counterfactual to determine the expected impact on artisanal fishers of the presence of industrial vessels in port at Funafuti. Similar models using regressors of hours at sea, hours fished or fuel used (as a proxy of location choice) were also tested.

2.3. Identifying the counterfactual

In order to identify the impact of industrial fishing vessel presence on livelihoods and fresh fish availability, a counterfactual dataset of artisanal fishing activity and catch was constructed. This counterfactual assumed that Funafuti port was closed to industrial fishing vessels although these vessels were allowed to continue fishing within Tuvalu's exclusive economic zone (EEZ); thus, government revenue from access fees was still captured.

To develop the counterfactual the modelled relationships above were used (Eqs. 2 and 3). The models provided an expected number of artisanal boats fishing and an expected catch rate associated with zero to 20 industrial vessels in port. The counterfactual calculation assumed zero industrial vessels were in port (i.e. Ind_Vessel_{t-1} and Ind_Vessel_t both equal 0) and thus the modelled relationships allowed us to calculate the predicted values for catch per unit effort ($CPUE_t$) and expected number of trips ($totart_t$) for zero vessels in port. This provided a predicted number of fishing trips per day over the four-year study period and an expected catch rate for zero vessels in port. Sundays were excluded from the analysis because little to no fishing occurs on that day due to religious and community commitments. The counterfactual provided the foundation for further exploration of the impact of industrial vessels on the artisanal fishery.

VMS data show that in reality, the total number of days that industrial vessels were in Funafuti port was 4647 days between March

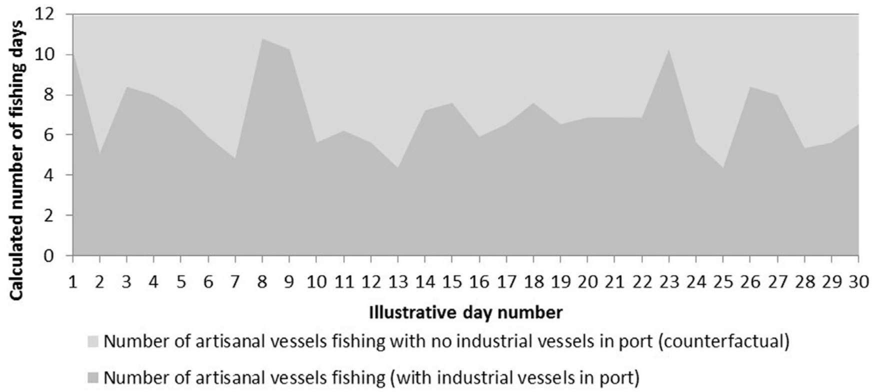

Fig. 2. : Illustrative example of counterfactual and modelled fishing activity.

2012 and March 2016 (this includes arrival and departure days).

2.4. Fishing days

To estimate the number of artisanal fishing days forgone (due to the presence of industrial fishing vessels), the modelled relationship in Eq. (2) was used. For each day of the study period (excluding Sundays) the predicted number of artisanal vessels expected to fish was calculated based on the modelled relationship and the number of industrial fishing vessels in port based on VMS data (dark grey area in Fig. 2). And for each day, this was compared to the counterfactual (difference between the counterfactual and reality is the light grey area in Fig. 2).

Fig. 2, provides an example of one months activity. According to the relationship in Eq. (2) about 12 artisanal vessels are expected to fish when there are no industrial vessels in port, this represents the counterfactual. The actual number of industrial vessels in port across a one month period is used to model the predicted artisanal fishing activity on any one day. The dark grey shows the number of artisanal vessels that are predicted to fish on any given day given the number of industrial vessels in port. The light grey area therefore represents the reduction in the number of artisanal vessels each day that go fishing as a result of industrial vessels presence in port.

2.5. Fish catch

The expected catch was estimated from the average number of hours spent fishing per trip by artisanal vessels (identified from artisanal logsheet data) and the predicted CPUE from Eq. (3). This was compared against the counterfactual, and the resultant reduction in the catch rate of artisanal fishers associated with the presence of industrial vessels calculated.

2.6. Fresh fish availability

To assess the impact on local fresh fish availability, the estimated reductions in catches were converted from total catch weight to edible weight, using a whole weight conversion factor [33]. The conversion factor used was for gutted and gilled fish because it is not uncommon for the heads and other parts of the fish to be consumed in the Pacific islands.

To provide an indication of the number of person equivalents that this figure represents, average consumption data were used. Bell *et al.* [6] indicates two levels of fresh fish consumption. First a minimum level for good nutrition as recommended by the World Health Organization [6] of between 34 and 37 kg fish/person/year. Second, from household income and expenditure survey data, estimated current levels of fish consumption per person per year in Tuvalu were divided by urban and rural locations [34]. Funafuti is considered an urban location; therefore, the estimate of fish consumption used in this study was 68.8 kg/person/year. This was converted to an estimate of fresh fish consumed, which is approximately 73% in Funafuti [35]. Based on actual consumption figures, this suggests a fresh fish consumption rate of 50.2 kg/person/year.

2.7. Revenue impacts

Attributing a price of AUD 4/kg to the catch weight (the standard selling price in Funafuti for all fish) provides an estimate of the value of the catch, and thus the potential income or revenue to the artisanal fisher. Applying the same AUD 4/kg figure to the counterfactual provides an estimate of the value of catch that could have been achieved without the presence of industrial vessels. This is used to represent the expected revenue in the artisanal fishery that could be earned from the catch being sold on the local market in Tuvalu.

2.8. Employment impacts

The artisanal logsheet data show that most small fishing boats in Funafuti are crewed by two to three people (including the skipper) per trip. The artisanal logsheet data also indicate the length of each fishing trip, with almost all trips lasting a single seven- to eight-hour day. The developed model was used to calculate the total number of fishing days lost, which was converted to full time equivalent employment days by using the crew and trip information reported in the artisanal logsheet data.

2.9. Framework for assessing the benefits of transhipping to Tuvalu's economy

Transhipping and the presence of industrial vessels within Tuvalu's exclusive economic zone (EEZ) has the potential to bring benefits to the wider economy and the Tuvaluan people through immediate spending and secondary multiplier effects of this spending. Although the direct benefits may not be felt by the fishers who face the negative consequences. To fully understand the trade-offs that decision-makers face, we identify and discuss some of these benefits in comparison to the estimated losses associated with the artisanal fishery as a result of allowing transhipping. Much of the data below are not in the public domain and, therefore, we have provided our best estimates of the benefits to Tuvalu from industrial fishing vessels. We have kindly been provided with some additional transhipment data to assist in our calculations.

The revenue earned by the government from EEZ fishing access fees or fishing licenses is a key component of government revenue, and are critical to the social well-being of Tuvaluans. In 2014, the Government of Tuvalu collected approximately USD 18 million (AUD 22 million) in access fees [36], representing more than 55% of the government's recurrent budget. However, the majority of the fishing access fees would still be captured by Tuvalu even if it did not allow transhipping; therefore, in this framework, fishing access fees are not considered a specific benefit of transhipping.

Any vessel entering the port of Funafuti must pay a range of port and environmental charges, the level of which is dependent on type, size and gross tonnage of each vessel. We calculated port charges per vessel per day using data from WCPFC [37] and Tidd *et al.* [38], which provide vessel specification data on each vessel identified as transhipping in Funafuti according to the VMS data.

Allowing transhipping means Tuvalu is also able to levy charges on the amount of fish transhipped in its port. Tuvalu charged USD 3 to USD 10 (AUD 3.60 to AUD 12.20) per tonne of fish transhipped in 2015 [2], although these charges have since increased and are now differentiated by type of fish. New transhipment charges range of AUD 10/mt to AUD 15/mt according to the grade fish have been levied since 2016. We use data on the quantity of fish transhipped by grade to estimate the government revenue from these transhipment charges.

Changes in fresh fish availability depends on the amount of fish that is off-loaded from the industrial vessels. To estimate this we use observer and logsheet data and estimates by local port agents and Tuvalu Fisheries Department.

On-land spending patterns were characterised by a survey of restaurants, bars and hotels carried out by Tuvalu Fisheries Department staff and described in detail earlier in this paper.

Industrial fishing vessels often employ local people to assist with transhipping. While there are no official data on this, estimate suggest that between four and nine local persons per day are employed by each vessel depending on vessel size and catch (Local port agent pers. comm.). The presence of transhipping is also likely to stimulate some additional employment within the Fisheries department and enforcement authorities. However, this employment is not included in these calculations as it is uncertain exactly which jobs are directly and exclusively the result of the presence of transhipping.

3. Results

3.1. Model results

The result from the Poisson model (Table 1) show that the variable for the number of industrial vessels (Ind_Vessel) is highly significant ($P < 0.001$) and means that for every one unit increase in industrial fishing vessels in port, the expected log count of artisanal fishers leaving port would decrease by 0.05. The model, however, does not fit well (i.e. the residual deviance over the degrees of freedom 2666.6/299 give a dispersion parameter of 8.9), suggesting that this is not the correct model for the analysis. Another analysis was performed using the negative binomial model, and results of this are presented in Table 1. There was very minimal over-dispersion, and because the Poisson model is nested within the negative binomial model, a likelihood ratio test was performed and verified that this was the correct model to use along with the supporting smaller AIC. The Pearson's chi-squared value of 324 on 299 d.f. with a *p*-value of 0.1, shows no evidence of lack of fit. In order to understand the model, industrial vessel predictors were simulated (0:20) and these predicted the number of vessels that went fishing (Fig. 3). Results from Fig. 3 show that when zero industrial vessels are in port, 11 artisanal vessels, on average, will go fishing in contrast to 5 artisanal vessels when there are between 17 and 20 industrial fishing vessels in port.

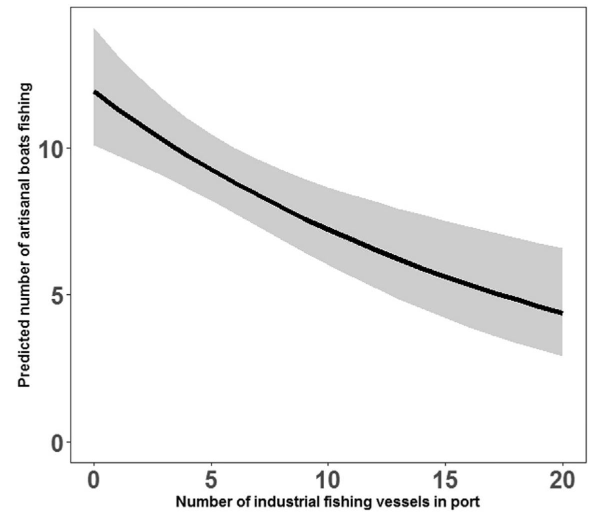

Fig. 3. : Predicted number of artisanal boats fishing versus number of industrial fishing vessels boats in port with 95% confidence interval shading.

When investigating the effects of industrial vessels on artisanal catches, the most suitable model for the analysis was the negative binomial (see Table 2). The negative binomial models showed very little over-dispersion compared to the Poisson model, and the AIC was smaller and the Pearson's test for goodness of fit confirmed this was the correct model to use. Fig. 4 shows the relationship between artisanal CPUE and the presence of industrial purse-seine vessels, and demonstrates that catch rates were higher when no industrial vessels were in port. Catch rates decreased as the number of industrial vessels in port increased (e.g. 10 industrial vessels resulted in an artisanal catch rate of 8 kg/hour/line/day). Supporting the conclusions in the biological literature [13–15].

Results from similar models using regressors of hours at sea, hours fished or fuel used (as a proxy of location choice), were all insignificant, suggesting that there is no relationship between the presence of industrial vessels and fishing behaviours once the binary choice ‘to go

Table 1
Estimation of Poisson model (a) and negative binomial model (b), Eq. (2).

Poisson	Estimate	Std. Error	z value	
intercept	2.502049	0.024747	101.11	***
Ind_Vessel	−0.05578	0.004544	−12.28	***
Residual dev	2663.6			
d.f	299			
Pearsons chi sq	3543			***
AIC	3670			
neg.binomial	Estimate	Std. Error	z value	
intercept	2.47801	0.08536	29.03	***
Ind_Vessel	−0.05002	0.01298	−3.854	***
Residual dev	364.26			
d.f	299			
Pearsons chi sq	324			.
AIC	1989			

Statistical significance at ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1

Table 2
Estimation of Poisson model (top) and negative binomial model (bottom), Eq. (3).

Poisson	Estimate	Std. Error	z value	
intercept	2.524354	0.025459	99.152	***
Ind_Vessel	−0.03909	0.005436	−7.191	***
Residual dev	2174.2			
d.f	218			
Pearsons chi sq	2621			***
AIC	2986			
neg.binomial	Estimate	Std. Error	z value	
intercept	2.54686	0.08466	30.084	***
Ind_Vessel	−0.04632	0.01571	−2.948	**
Residual dev	245.58			
d.f	218			
Pearsons chi sq	243			.
AIC	1514			

Statistical significance at ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1

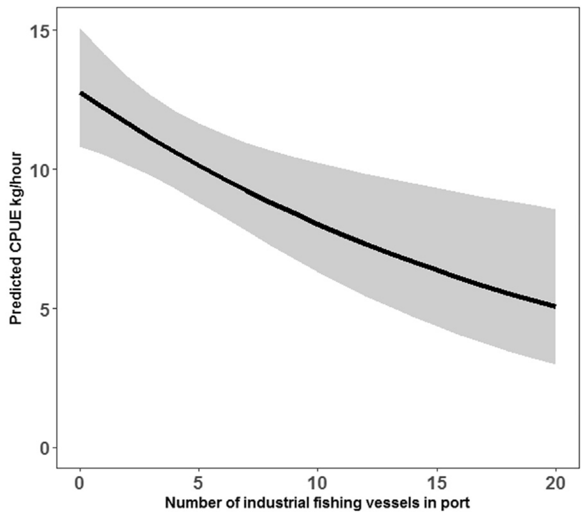

Fig. 4. : Predicted number of artisanal catch per unit effort (kg/hour/line/day for trolling trips only) versus number of industrial fishing vessels in port with 95% confidence interval shading.

fishing' has been made. The impact of variables such as weather patterns were also tested in predicting the number of vessels in port (e.g. sheltering) or artisanal vessels fishing and proved insignificant.

3.2. Impact of identified changes in the willingness of artisanal fishers to fish

3.2.1. Fishing days

Using the described relationships and artisanal activity data, a predicted loss of 2200 artisanal fishing days over the four-year period was identified, with a range of between 1700 and 2800 days. The highest single-year loss was in 2015 (2016 data was incomplete); 1000 days were predicted to have been lost in 2015 due to the high number of industrial vessels visiting port.

3.2.2. Fish catch

The estimated relationships suggest that between March 2012 and March 2016, 309 mt of fish was not caught by artisanal vessels as a result of the decision not to go fishing due to the presence of industrial vessels in port and the associated changes in CPUE for those that did fish. In 2015, nearly 2400 industrial vessel days were spent in Funafuti port. The forgone catch in the artisanal fishery associated with these vessels is estimated at 180 mt.

3.2.3. Fresh fish availability

When converting catch (from 3.2.2) to edible portions, we estimated that 266 mt of edible fish was lost due to the presence of industrial vessels over the study period, with 150 mt lost in 2015 alone. This reduction in edible fish is the equivalent to the yearly consumption of fresh fish of approximately 8800 adults, based on the WHO consumption recommendations. Using actual current consumption of fresh fish per adult per year in Funafuti (as described in [6] and Section 2.6) the 266mt loss is the equivalent to the consumption of 6200 adults per year.

3.2.4. Income

We estimate the value of the lost catch and potential direct earnings of artisanal fishers is AUD 1.2 million over the four-year study period with the greatest losses of AUD 0.72 million occurring in 2015.

3.2.5. Employment

The modelling and resulting analysis suggests that the loss of full-time equivalent (FTE) employment days, as a result of industrial vessels being in port, is between 3400 and 8400 FTE days, with a central value of 4600 FTE days over the study period, with more than half of these days occurring in 2015.

3.3. Estimating the benefits of transhipping to Tuvalu's economy 3.3.1 Fresh fish availability

As part of Pacific Island country policies to capture more of the oceanic production value, bycatch and discards must be off-loaded at port and not thrown overboard. Observer data from vessels transhipping in Funafuti suggest that the retained bycatch figure was 10mt in 2016. Local estimates by the Tuvalu Fisheries Department and port agents, however, place off-loads closer to 10–30 mt/year, depending on the number of vessels in port.

3.3.1. Government revenue

We estimated that port entry and mooring charges equated to approximately AUD 150/vessel day in port, or upwards of AUD 300 000 in 2015. We have no evidence to value the cost of providing the port infrastructure and operations but it can be assumed that this revenue would be used to pay at least some of these operational costs and, therefore, may not be a direct benefit of transhipping to Tuvalu.

We estimated that, on average, the old transhipment charges were costing vessels AUD 600 per day, while the new charges are estimated to cost vessels AUD 1550 per day that they are in port. If the new charges had applied in 2015, we estimate that revenue from these fees could have provided approximately AUD 3 million in government revenue or the equivalent to 10% of Tuvalu's GDP or 7.5% of the government's recurring budget.

Inspection and other fees are also charged by the Tuvalu government; however, due to the way that these charges are levied (many on a 'per hour of transhipping' basis) we have been unable to estimate these in a credible manner.

3.3.2. Business revenue

The local business survey indicated that average spending per crew member per night was between AUD 16 and AUD 100/person, and median spending per crew member who came into the establishments was AUD 25/person/night. No data are available on the number of crew members who stay onboard each night and the number who come on to land. The survey of establishments indicated that between four and ten crew members would come into an establishment each night a vessel was in port. The vessels that came into Funafuti port generally had a median crew of 29 [37]. In the absence of better information we assume half of the crew remained on board and the other half frequent a local establishment each night the vessel is in port. This suggests that in 2015, over AUD 750 000 could have been spent by industrial fishing crews in Funafuti port, which is equivalent to 2.2% of Tuvalu's yearly GDP.

Support infrastructure and people, such as repair facilities and local shipping agents, that have come about as a result of the presence of industrial vessels are likely to have significant benefits associated with local incomes, revenues and employment. We have not, however, been able to produce a reliable estimate of these benefits.

3.3.3. Employment and individual income

There is no onshore processing of tuna catches in Tuvalu although the Pacific Islands Forum Fisheries Agency [3] estimates that 333 Tuvaluans are employed in the tuna fishing industry across the region. Analysis of the direct jobs created by transhipping over the period of interest showed that industrial vessels accounted for upwards of 15 000 local person days of employment.

The minimum annual salary in the public sector is AUD 3000 (private sector is much lower), which is equivalent to approximately AUD 12/day [39]. As a result, employment associated with transhipping could have provided income to these local workers of AUD 180 000 over the study period.

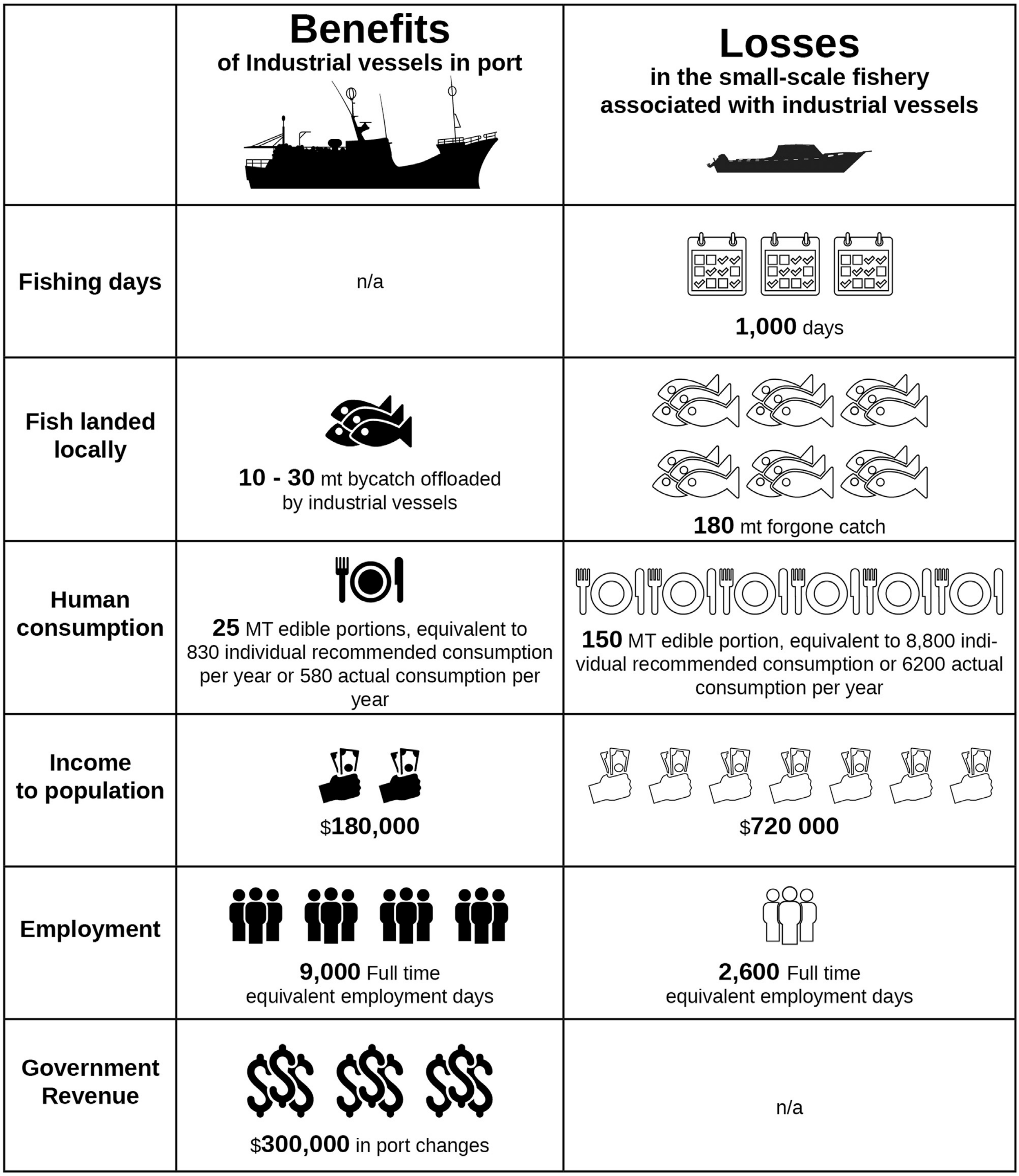

Fig. 5. : Summary of the results from the analysis in this paper (all monetary values in AUD).

4. Discussion

There is no doubt that the presence of a transhipping port brings significant benefits to the economy and people of Tuvalu. Equally, however, the results presented here suggest some very serious negative impacts on the artisanal fishing sector. Fig. 5 presents a summary of the findings. Policy-makers will need to balance the trade-offs associated with the two fishing subsectors to ensure an optimal solution that maximises the benefits and minimises the costs.

The analysis indicated substantial reductions in fresh fish availability, with the loss in the artisanal fishery of more than 150mt in 2015. The fresh fish off-loads represented only 1% of Tuvalu's total estimated demand for fish [6] and where less than 10% of the catch forgone by artisanal fishers. However, it is important to place these figures into context. Total fish production in Funafuti was estimated by Tuvalu's Ministry of Fisheries and Economic Development [40] to be 285mt/year. Therefore, over a period of four years, this analysis suggests that Funafuti lost the equivalent of one year's catch due to the presence of industrial vessels, which discouraged activity by small-scale fishers. This could no doubt have significant impacts on peoples' diets and access to good proteins. However, Bell *et al*. [6] provides an assessment of current fish production and its ability to sustain Pacific island populations, they report no current or projected deficit in fish production in Tuvalu. The data suggesting that current production just about meets the expected demand and therefore at an aggregate level Tuvalu can effectively feed its people. Therefore the impact on fresh fish availability may be less significant than these contrasting figures initially suggest. We do not, however, have any data on food distribution, and it may be that the portion of the population who rely on artisanal fishers for fresh food fish are not those who can access the offloads from the vessels. This would benefit from further research but in the interim, the government needs to consider if redistribution policies maybe needed to ensure that all people have access to sufficient amounts of high quality fresh fish to meet their nutritional requirements.

Excluding fishing access fees, we estimate that the total income to government, individuals and businesses from transhipping was AUD 4.2 million or 12% of Tuvalu's 2016 GDP. This is in line with the extensive investigation of the benefits associated with other transhipping ports undertaken by McCoy [41]. Transhipment fees alone are three to four times higher than the loss of income in the artisanal fishery. However, revenue from fees is captured by the government and not the artisanal fishers and therefore do not directly offset the estimated income loss to artisanal fishers. On the other hand revenue from fees is used by the government to pay local staff salaries and provide public services that benefit all Tuvaluans. Further, fees can provide a valuable source of foreign exchange to the government. So whilst the artisanal fishers may suffer Tuvaluan society as a whole benefits.

About AUD 0.75 million of the AUD 4.2 million income is accrued to local bars and restaurants. The equivalent to the loss of income in the artisanal fishery is, therefore, captured by private businesses and individuals outside the fishery sector. This amount of money injected into the local economy from — what is effectively industrial tourism — is likely to have powerful multiplier effects and secondary impacts and, therefore, the total economic benefit is likely to be far larger than the immediate monetary spending of the crews. However, as with the government revenue, it is unlikely that this revenue is captured by the artisanal fishers who actually face a loss of income as a result of industrial vessels in port. Further, governments play a key role in redistributing revenues compared to private enterprises whose revenues are generally spread more narrowly. This can reduce economic disruption from increasing private incomes, especially when businesses are foreign owned [42].

The reduced income of artisanal fishers associated with transhipping is not directly offset by the benefits captured from the vessels. Clearly there is a distributional issue because those in the artisanal fishery are not the ones who capture the gains from transhipping. Therefore, the government could consider a transfer mechanism or support the artisanal fishing industry. Perhaps some hypothecation of transhipping charges could occur to support programmes such as the Tuvalu nearshore fish aggregation device programme, thereby making it easier and potentially more cost effective for artisanal fishers to catch oceanic species [43,44]. Other programmes to support the artisanal fishing sub-sector could be considered such as providing ice, freezers or safety equipment, which would make easier and safer for fishers to fish for oceanic species and benefit from the government revenues from transhipping.

The loss of FTE days in the artisanal fishing sector is offset three times or more by the estimated employment created in the transhipping sector for the Funafuti population. However, as with the changes in fresh fish and income artisanal fishers are unlikely to be the ones employed during transhipping. So whilst leading to an improvement in overall welfare, the improvement is not Pareto efficient. Béné *et al.* [45] demonstrate that return on investment in a small-scale fishery is more than 100 times greater than that from industrial vessels in terms of cost of each job created. With this in mind, a three-to-one replacement ratio is far from efficient. When considering appropriate support to each subsector, decision-makers must consider which sector offers the best return on investment for the policy objective that they are pursuing and be aware of associated trade-offs as the harder to observe negative impacts may outweigh the benefits.

Transhipping in port, under the authority of a country government, means that the country can confirm vessels that are fishing legally, cross-check logsheet records with observed transhipments, and ensure that the vessel is in full compliance with all marine and fishery regulations. These wider benefits have not been quantified in this paper, but nevertheless are likely to be of benefit regionally and thus represent a global or regional public good. McCoy [41] estimated that these benefits range from USD 1000 to USD 8000 (AUD 1200 to AUD 9600) per transhipment, depending on the port, but did not include Funafuti in his analysis.

The social costs associated with industrial fishing are well established, including social cohesion, prostitution, unwanted pregnancy, smuggling, illegal entry, substance abuse and general poor behaviour [46–48]. The survey of the local establishments, however, was not as negative as the literature, and only one establishment had banned crews from entering, and only a quarter of the establishments suggested that they had issues with the crews, this was generally as a result of intoxication of the crew. Nevertheless, the social impacts should be important considerations for countries considering developing transhipping ports.

Artisanal fishing vessels have a number of environmental impacts however are generally more fuel-efficient and generate less waste than their industrial counterparts [49]. The environmental costs associated with transhipping include oil and fuel spillages, marine litter and toilet and hold flushes into the Funafuti lagoon [50]. An evaluation of these impacts, however, is extremely complex and has not yet been attempted. A number of environmental violations have occurred in recent years in Funafuti (Tuvalu Fisheries Department, pers com); therefore, the government must balance the higher environmental risk associated with transhipping compared to artisanal fishing with the benefits that it brings to Tuvalu and its people.

This work provides Tuvalu and other countries that have transhipping ports with information that could allow them to optimise the benefits from being a transhipping port by minimising the losses. Many governments have already attempted to do this by managing bycatch and using some for local food security purposes. As the marginal losses to the artisanal fishery decrease with more vessels being present in port, it is suggested that some coordination of vessels transhipping would be helpful. It would also be advisable to avoid transhipping when artisanal catches are likely to be higher. This could be done by declaring certain times 'non-port' days for all transhipping vessels, particularly on peak artisanal fishing days such as Friday. The artisanal data show that landings are generally lower, on average, on the weekend; therefore, Sunday could be a good day to tranship because there is little or no artisanal fishing activity that day. Although each port considering this as an option to limit the impacts of the transhipping fleet on the artisanal fleet would need to carefully investigate the commercial and operational viability of such an option.

5. Conclusion

This paper confirms, for the first time, the existence of indirect economic interactions between industrial fishing vessels and artisanal fishing vessels. These results are in direct contrast to the requirements under the UN Fish Stocks Agreement to avoid the adverse impacts of industrial fishing on small-scale fishers. The study location, Tuvalu, provided a unique dataset to allow this study. The results should be carefully considered by all country governments that allow, or are planning to allow, transhipping in their ports, particularly those countries with a large artisanal fleet based near or at the main port.

The analysis demonstrates that transhipping has a negative impact on Funafuti's artisanal fishers in terms of reduced income, employment and catch rates. The results also show it reduces the availability of locally-produced fish in Funafuti. However, it is also clear that transhipping brings economic benefits to Funafuti and the local people.

The analysis contrasted the losses within the artisanal fishery with the benefits of transhipping and found that some of the losses were at least partially offset but only at a societal level. It showed that it was likely that a Pareto loss was present as benefits from transhipping do not fall on those whom face the losses. Policy-makers need to strike a balance between the competing demands of the two sub-sectors to ensure Pacific communities can capture the maximum net benefits from the massive tuna resources present in their exclusive economic zones.

Acknowledgements

We are extremely grateful to Tuvalu Fisheries Department staff for their assistance and cooperation in this work, without whom this would never have happened. We also thankful to Boris Colas for developing the graphics in Fig. 5. We are extremely grateful for the detailed comments from the journal reviewers.

Competing interests

The authors of this work have no conflict of interest with the analysis or the conclusions presented.

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