ADBInstitute

ADBI Working Paper Series

VESSEL DAY SCHEME AND TUNA CATCH IN THE PACIFIC ISLAND REGION

Champa Bati Dutta, Mark Ivekolia,
and Debasish Kumar Das

No. 1417
October 2023

Asian Development Bank Institute

Champa Bati Dutta is a PhD student at the School of Business, University of New South Wales, Canberra, Australia. Mark Ivekolia is a fisheries economist at MI – Consulting Limited, Papua New Guinea. Debasish Kumar Das is a PhD student at Arndt-Corden Department of Economics, Crawford School of Public Policy, Australian National University, Canberra, Australia.

The Working Paper series is a continuation of the formerly named Discussion Paper series; the numbering of the papers continued without interruption or change. ADBI's working papers reflect initial ideas on a topic and are posted online for discussion. Some working papers may develop into other forms of publication.

Suggested citation:

Dutta, C. B., M. Ivekolia, and D. K. Das. 2023. Vessel Day Scheme and Tuna Catch in the Pacific Island Region. ADBI Working Paper 1417. Tokyo: Asian Development Bank Institute. Available: https://doi.org/10.56506/JDKT5846

Please contact the authors for information about this paper.

Email: c.dutta@unsw.edu.au

Asian Development Bank Institute
Kasumigaseki Building, 8th Floor
3-2-5 Kasumigaseki, Chiyoda-ku
Tokyo 100-6008, Japan

Tel: +81-3-3593-5500
Fax: +81-3-3593-5571
URL: www.adbi.org
E-mail: info@adbi.org

Abstract

The Pacific Island nations heavily rely on the tuna fishery for government revenue and economic growth. Since the conversion of some nations to the Vessel Days Scheme (VDS) from the fishing Quota system, the region's domestic catch has significantly increased. VDS has stimulated economic return but raised concerns about tuna overexploitation. We apply Difference in Difference to investigate the effects of the VDS on domestic catch levels in the Pacific region using data on domestic catches from 17 Pacific countries from 2000 to 2020. The estimated result indicates that tuna catches increased by more than 200% in VDS nations relative to non-VDS nations in the region.

Keywords: Vessel Day Scheme, tuna fishery, total fleet catch, Pacific island countries

JEL Classification: F55, O11, O13, O56, Q22, Q27, Q28

Contents

1. INTRODUCTION 1

2. THE PACIFIC ECONOMY 2

3. TUNA FISHERIES IN THE WESTERN AND CENTRAL PACIFIC OCEAN 3

   3.1 Tuna Fishing in the Pacific 3
   3.2 Importance of Tuna Fishery in Pacific Island Countries 5
   3.3 Institutional and Policy Background 5
   3.4 Vessel Days Scheme (VDS) 6

4. ESTIMATION STRATEGY 7

   4.1 Data and Variables 7
   4.2 Econometric Methods 9

5. IMPACT OF VDS ON TUNA CATCH IN WCPO 10

   5.1 Impact of VDS on Pacific Tuna Fleet Catch 10
   5.2 Impact by Species—Heterogeneity Analysis 12
   5.3 Impact by Fishing Gears 12
   5.4 Robustness 13

6. CONCLUSIONS AND POLICY IMPLICATIONS 14

REFERENCES 15

APPENDIX 18

1. INTRODUCTION

The Western and Central Pacific Ocean (WCPO) tuna fishery is the world's most valuable and largest tuna fishery. Globally, 57% of the world's tuna is caught in WCPO fisheries (World Economic Forum 2022). Tuna exploitation and the use of destructive fishing practices by distant waters fishing nations has led the tuna fishery to become a topic of considerable debate over fishing management. Due to the highly migratory nature of tuna, which involves the sovereign boundaries of numerous countries that share the resource, regional cooperation has become essential for the management of the tuna fishery and for independent states to exercise their sovereign rights under the United Nations Convention on the Law of the Sea. The Vessel Day Scheme is an implementation of endeavor rights-based management in the Pacific region. According to Squires et al. (2017), effort rights-based management systems promote revenue and capture maximization. As a result, they generate an incentive to increase input use and costs and to adopt new technology in order to boost productivity.

In 2007, eight Pacific nations instituted the Vessel Days Scheme (VDS), a transferrable effort program, to strengthen their rights over tuna resources and control of economic and environmental trends (Havice 2013). Until now, the literature on VDS policy has focused on the economic, political, and environmental aspects of VDS. Aqorau (2009) argued that VDS provides Pacific Island nations with authority and control over tuna fisheries in the Pacific as opposed to nations that fish in distant waters. Havice (2010) discussed the evaluation of VDS structures that engage relevant variables to attain economic and environmental management goals. In addition, the paper examined the various political factors that countries must consider when implementing the scheme. After a comprehensive review of the VDS policy, Havice (2013) concluded that the VDS has substantially increased economic returns and improved data reporting, but its structures have made it difficult to directly target the biological concerns of individual species within a multispecies fishery. Bernadett (2014) described the VDS agreement as a fruitful international negotiation that has resulted in an increase in marine resource revenues. Despite the fact that there are multiple papers on the subject, there are none that analyze the quantitative impact of VDS on the tuna catch, which is an essential metric for evaluating the agreement's environmental consequences.

This study intends to refocus the ongoing discussion on fisheries management in the Pacific by presenting quantitative evidence on the relationship between the VDS and domestic catch levels. The evidence strongly indicates that the policy has a negative impact on the environment. Due to the common ownership of fisheries, economic theory implies that fishers will attempt to catch as many fish as possible to maximize their profits. This will inevitably lead to an excess of capital in the form of efficient technology and equipment to maximize profits. As the fisheries remain a common property, the same analysis applies to the VDS, with the exception that the perverse incentive of exploitation is likely worse due to the limited time allotted to each vessel. This principle is similarly reflected in the literature. According to Yeeting et al. (2016), stock analysts predict that daily fish mortality will increase as a result of investments in labor, capital, and technology by VDS-participating vessels to improve their efficiency at capturing fish.

The purpose of this paper is to demonstrate to policymakers the connections between the VDS scheme and domestic catch levels as well as the type of policy measures necessary for the sustainable management of tuna fisheries. The second section provides context for the Pacific economy. The third section describes tuna fishing in Pacific nations, highlighting the significance of the WCPO exclusive economic zones (EEZs) and the economics of the VDS within an institutional and policy context. The third section describes the variables and data utilized in the study. The fourth section describes the model specification and methodology employed in the study. Results and a conclusion are discussed in the final section.

2. THE PACIFIC ECONOMY

The Pacific Islands region consists of hundreds of islands dispersed over 15% of the planet's surface. The combined EEZ of the island states encompasses approximately 30,569,000 km^2 of the WCPO, or approximately 28% of all EEZs worldwide (Gillett 2005). Papua New Guinea (PNG) and Kiribati occupy approximately 17% and 19% of the EEZs, respectively. In contrast, the total land area of these island states is 552,789 km^2, of which PNG covers about 89.7% of the total land mass of the region. There is a vast diversity throughout the region, ranging from PNG, the largest country with a population of over 9.9 million, to Tuvalu and Nauru, both of which have populations of over 11,000. Tokelau and Niue have populations of less than 2,000, making them the world's least populous countries. Kiribati is one of the world's most remote and geographically dispersed nations, making it extremely vulnerable to climate change and natural disasters. EEZ as a major institutional development defining the jurisdictional boundaries empowered the Pacific Island countries to control access to the fisheries and other mineral resources. The tuna stocks that are located within the EEZs are the EEZs' most valuable resource. As depicted in Table 1, Kiribati, the Federated States of Micronesia (FSM), PNG, etc., have larger EEZ areas to access oceanic resources.

Many of the Pacific Island states fall in the lower-middle to upper-middle-income countries, measured in terms of gross domestic product (GDP) per capita. The Cook Islands has the highest per capita GDP at $14,822. This distinguishes them from the rest of the countries and positions them in the World Bank category of high-income countries. The Cook Islands are associated with New Zealand, from which they receive economic assistance, and their residents have migrated to New Zealand in significant numbers and send remittances to family members on the islands. There are only slightly more than 15,000 people living on the island. Palau and Nauru have per capita income over $10,000. At the bottom, Kiribati, PNG, Solomon Islands, and Vanuatu have the lowest per capita income, making them the poorest countries in the region.

Although many of the countries have different geographical and economic conditions, many of them face the same problems, including climate change; food security; low GDP; high population growth; high unemployment; ineffective governance systems; corruption; and, in some cases, political and social instability.

Table 1: Pacific Island Countries

Country	Land Area[a] (km^2)	EEZ[b] (km^2)	Population[c] (2021)	GDP per Capita[d] (2021 US$)
FSM	702	2,992,415	113,131	3,571
Kiribati	811	3,437,345	128,874	1,606
Marshall Islands	181	1,992,232	42,050	6,172
Nauru	21	308,506	12,511	10,648
PNG	452,860	2,396,575	9,949,437	2,672
Palau	459	604,289	18,024	12,083
Solomon Islands	27,986	1,597,492	707,851	2,304
Tuvalu	26	751,797	11,204	5,632
Cook Islands	236	1,960,027	15,040	14,822
Fiji	18,274	1,281,122	924,610	4,646
Niue	260	316,584	1,619	9,443
Samoa	2,821	131,812	218,764	3,857
Tokelau	12	319,049	1,318	7,445
Tonga	717	664,853	106,017	4,426
Vanuatu	12,189	827,626	319,137	2,996

[a]Central Intelligence Agency (2022), [b]Claus et al., (2014); via www.seaaroundus.org, [c,d]World Bank (2023).

3. TUNA FISHERIES IN THE WESTERN AND CENTRAL PACIFIC OCEAN

3.1 Tuna Fishing in the Pacific

The tuna fisheries in the WCPO are incredibly diverse. They range from small-scale operations in the coastal waters of Pacific states to large-scale, industrial purse-sein, pole-and-line, and longline operations in the EEZs of Pacific states and in international waters (Hare et al. 2021).

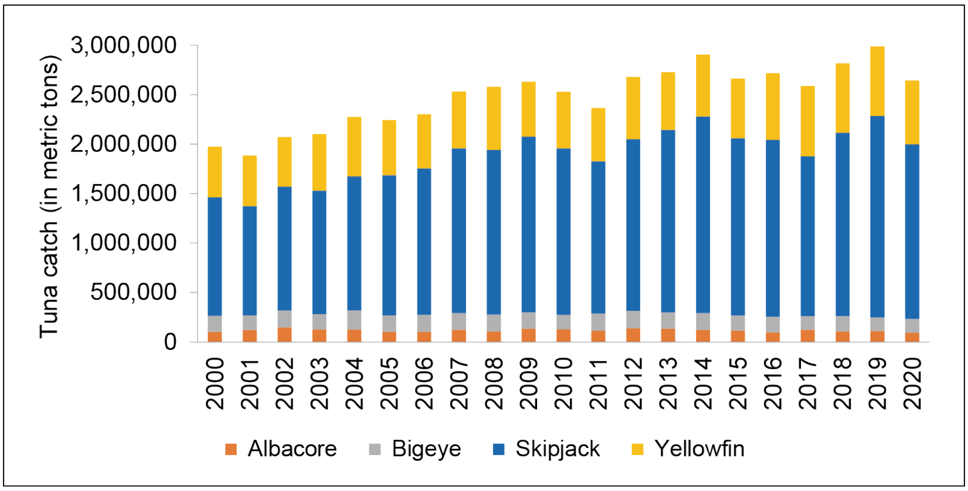
The main four tuna species targeted in WCPO are albacore (*Thunnus alalunga*), bigeye (*Thunnus obesus*), skipjack tuna (*Katsuwonus pelamis*), and yellowfin (*Thunnus albacares*). The fish species are highly migratory and can be found in all parts of the EEZs and the high sea pockets. Skipjack tuna is abundant, and it accounted for about 67% of total tuna catches in the region in 2020 (WCPFC 2020). Yellowfin mortality has increased in recent years but is still estimated to be below maximum sustainable yield. Yellowfin and bigeye are the two species subject to monitoring by the Western and Central Pacific Fisheries Commission (WCPFC), and albacore tuna has greater market value in international markets. Table 2 summarizes the features of the four types of tuna considered in this study.

Tuna is caught using a wide variety of gear types. Albacore tuna is mostly found in northern and northern Pacific waters, living in the surface and subsurface water and preferring temperatures ranging from 15°C to 19°C. Bigeye tuna live in deeper layers with temperatures ranging from 13°C to 29°C. Pacific Island countries with bigeye tuna include the tropical islands with latitudes 10 N to 20 S. Skipjack is primarily caught by purse-seine fishing for canning. Other harvesting gear used include pole and line; ring net; gillnet; handline; and seine net. Yellowfin harvesting ranges from small-scale artistical fishing in the Pacific islands and parts of the Southeast Asian waters to large scale longline and purse seiners that operate widely in the tropical and equatorial waters.

Table 2: Tuna Characteristics

	Albacore	**Bigeye**	**Skipjack**	**Yellowfin**
				
Where do they live?	Swim between surface and subsurface layers of the water but go deeper than yellowfin.	Descend to deeper layers	Live in the surface layer of the ocean.	Swim between surface and subsurface layers of the water.
Fishing method	Longline fishing.	Purse-seine fishing of juveniles at the ocean surface. Longline fishing of mature fish in deeper waters.	Purse-seine and pole-and-line fishing on the surface of the waters.	Purse-seine and pole-and-line fishing of juvenile fish on the surface waters. Purse-seine and longline fishing of mature fish.
Demand	Use in canneries.	High value Japanese sashimi market.	Sold fresh, frozen, canned, dried, salted, and smoked.	Juveniles sold fresh, frozen, canned, dried, salted, and smoked. Mature fish for high value Japanese sashimi market.
Population	Above target	Near target level	Near target level	Above target
Harvest (2020)	92,129 metric ton	140,225 metric ton	1,767,117 metric ton	643,628 metric ton
Catch Value (2020)	323 US$ million	576 US$ million	2,536 US$ million	1,498 US$ million

Figure 1: Tuna Catches in the WCPO, 2000–2020



Source: Based on Western and Central Pacific Fisheries Commission (WCPFC) 2020b).

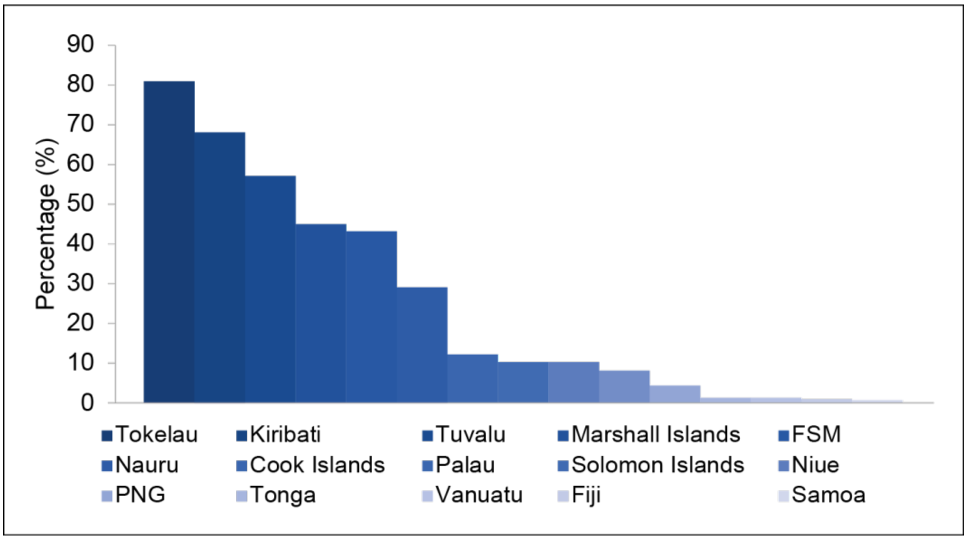
Catches from albacore, bigeye, skipjack, and yellowfin tuna have increased over the years and are estimated to account for about 25% to 30% of the total WCPO catches. Fishing has a negative impact on the biomass of the other two species—yellowfin and bigeye—particularly in terms of very large fish within populations. Yellowfin and bigeye have been targeted by sashimi longline ships, but the purse-seine fishery has caused significantly more harm. In this location, purse seiners typically target skipjack but may also target yellowfin. In some types of purse-seine fishing involving fish aggregating devices, juvenile yellowfin and bigeye become entangled with schools of skipjack.

Yellowfin and bigeye capture rates have not to date been considerably limited by regulations.

3.2 Importance of Tuna Fishery in Pacific Island Countries

Tuna is the most valuable economic resource in many small island states and catalyzes other economic activity and social sustenance. Figure 2 demonstrates that the fees collected from the tuna industry are not equitably distributed, but rather reflect higher endowments in the waters of certain countries compared to others. The figure highlights the contribution of the access fee to the government revenue of five Pacific Island nations, notably Tokelau (81%), Kiribati (68%), Tuvalu (57%), the Marshall Islands (45%), and the FSM (43%).

Figure 2: Fees as a Percentage of Government Revenue (2016–2018)



Source: FFA Tuna Economic Indicators (2019).

3.3 Institutional and Policy Background

Due to the socioeconomic importance of the tuna resource and its extremely migratory status in the region, the Western and Central Pacific Fisheries Commission (WCPFC) was established in 2004 to address issues concerning the management of high seas fisheries. Illegal, unreported, and unregulated (IUU) fishing over capacitation, the reflagging of vessels to evade regulatory controls, the lack of reliable data for management purposes, and the lack of multilateral cooperation among fishing nations have all contributed to the overexploitation of fish stocks (Ram-Bidesi and Tsamenyi 2004; Hampton et al. 2005; WCPFC 2020a). The UN Fish Stocks Agreement is the basis for the WCPFC Convention on multilateral cooperation. The commission's 27 members include all Pacific Island nations, Southeast Asia, the European Union, and the United States.

Member states have diverse geographical and socioeconomic conditions. Nonetheless, many of them share the problems of low economic development; high population growth; climate change; food security; and, in some cases, social and political instability (FAO 2008; World Bank 2019). Given these conditions, the growth of domestic tuna industries and the long-term maximization of tuna rents are of the utmost importance. Hanich and Tsamenyi (2009) argued that considerable effort has been devoted to comprehending the industry's dynamics and the reasons that regional policies have failed to maximize the industry's economic returns.

The market for fishery access rights allows for the maximization of economic returns in the tuna industry. Numerous case studies, such as Miller (2007), Hannesson and Kennedy (2008), Havice (2010), and Grafton and Kompas (2019), have described how eight Pacific island nations with the most productive tuna waters used market mechanisms to negotiate the Parties to the Nauru Agreement (PNA) in the early 1980s. Members consist of the Federated States of Micronesia, Kiribati, the Marshall Islands, Nauru, Papua New Guinea, Palau, Solomon Islands, and Tuvalu. The purpose of the agreement was to harmonize the licensing terms and conditions for fishing vessels that gave domestic vessels precedence over foreign-flagged vessels. Given that these eight nations accounted for more than 50% of the world's tuna catch, it was anticipated that the agreement would enhance the members' bargaining power and raise the rents.

At the beginning of the 1990s, the PNA tuna was at the focus of a controversy regarding the overexploitation of targeted species. In response, the PNA countries reached the Palau Arrangement to regulate the number of fishing licenses issued for large school skipjacks and yellowfin tuna. The Palau arrangement had two primary goals (Dunn, Rodwell, and Joseph 2006): first, to limit the number of licenses to increase tuna prices and rents; and second, to encourage the domestication of fishing vessels so that genuine operators would invest locally by utilizing domestic goods and services and creating jobs.

In 1995, the PNA nations created a new agreement known as the FSM Arrangement. The primary objective of the FSM arrangement was to promote the domestication policy in order to generate spin-off benefits and tangible economic development for the PNA countries by creating jobs for locals and outsourcing services to small and medium-sized businesses (Fisheries Forum Agency 2020). Regardless, the common problem under the FSM and Palau arrangement was unavoidable and resulted in an increase in the total number of FSM-issued licenses without a corresponding decrease in non-FSM licenses (Hanich, Tsamenyi, and Parris 2010).

3.4 Vessel Days Scheme (VDS)

In December 2007, the PNA countries implemented the VDS to issue licenses based on the number of fishing days as opposed to the Palau Arrangement's vessel number strategy (Havice 2010). The scheme establishes the total number of permissible fishing days in PNA waters and distributes them to member states for allocation to nations that fish in distant waters (Aquora 2009). The scheme's primary objective is to restrict access to fishing sites in PNA waters to increase competition and, consequently, the price and rents generated from the sale of fishing days.

To implement the VDS, the PNA countries established a Marshall Islands-based secretariat to supervise the VDS's sustainable management. In addition to data collection, the PNA cartel facilitates commercial arrangements with fishing operators and major tuna processors for value-adding in home countries, thereby creating job opportunities, tax revenues for governments, and spin-off benefits for small- and medium-sized businesses. Members negotiate the allocation of fishing days in accordance with the PNA's guidelines and scientific data on the status of the fish population. Multiple parties participate in the negotiation of access agreements. These include the PNA members through their respective competent authorities; the distant water fishing nations through their government officials; development partners; the fishing industry association; commodity trading firms; and individual fishing companies (Aqorau 2009).

Access agreements typically detail the provisions for vessels fishing in distant waters, the terms and conditions for fishing operators, the reporting requirements, and vessel identification. Havice and Campling (2010) classified access arrangements into two types: the first-generation agreements, also known as “cash for access”, and the second-generation agreements that target long-term investments. There are two types of first-generation access agreements: bilateral and multilateral. Bilateral access agreements in the Pacific are frequently negotiated with Japan; the Philippines; Taipei,China; the Republic of Korea; and the People’s Republic of China, with development programs emerging as a result. The only multilateral agreement in the Pacific is the US Treaty, which allows US-flagged vessels access to Pacific waters for fisheries.

The second-generation access agreements involve the domestic registration of the fishing company and the establishment of a domestic investment or processing facility (Havice and Campling 2010). By registering a local business, fishing companies can purchase the VDS at a discounted rate due to the value addition and other benefits provided. In some instances, a domestically registered company may be eligible for duty-free exports, as is the case with PNG companies operating under the EU’s Interim Economic Partnership Agreement (Campling, Havice, and Ram-Bidesi 2007). Nonetheless, this depends on the locational advantages of each PNA nation.

The benefits of the VDS can be viewed from a political, socioeconomic, and conservation standpoint. Since the inception of the VDS, the PNA countries’ domestic capture efforts have significantly increased, although there is less evidence to support the VDS’s success in general. This is because the majority of domestic tuna investments and vessel operators are foreign owned. PNG, Solomon Islands, and the Marshall Islands are the only PNA nations to have engaged in tuna processing. Typically, the purse-seine produce is canned and loined for value addition, job creation, and other spin-off opportunities. PNG has the greatest onshore tuna processing capacity with approximately 79,000 metric tons per year, and it employs approximately 11,000 people.

4. ESTIMATION STRATEGY

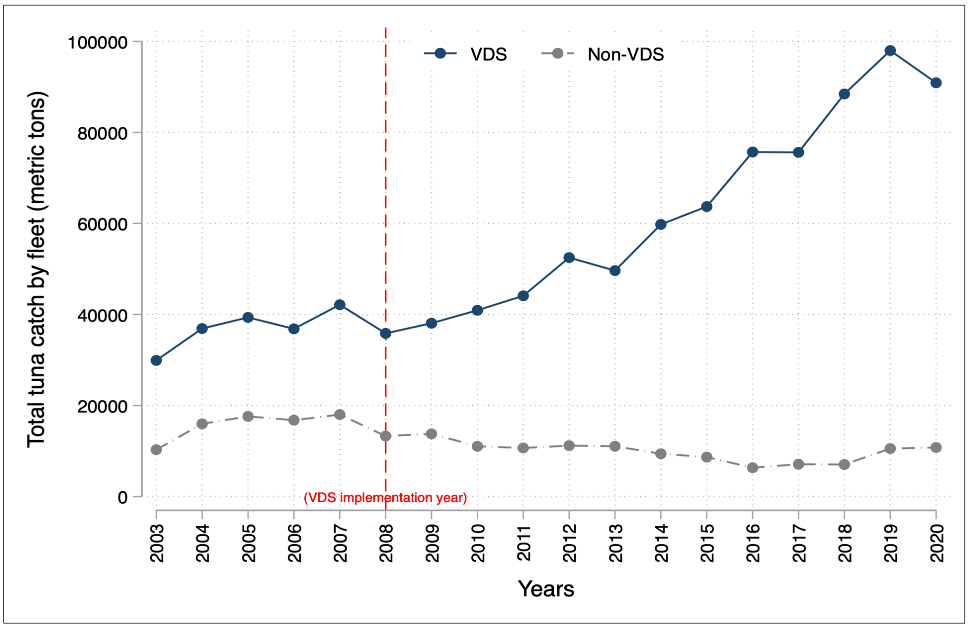
4.1 Data and Variables

The research builds a panel database of countries exposed to the VDS as well as those not exposed to the VDS between the PNA and the non-PNA groups from 2000 to 2020. The PNA country list includes the Federated States of Micronesia, Kiribati, the Marshall Islands, Nauru, Palau, Papua New Guinea, Solomon Islands, and Tuvalu. All non-PNA countries consist of Australia, Cook Islands, Fiji, New Zealand, Niue, Samoa, Tokelau, Tonga, and Vanuatu. All PNA countries plus Tokelau are exposed to the VDS, and the rest of the non-PNA countries are not exposed to the VDS. Tokelau is the only non-PNA member that is exposed to the VDS. All observations are at the country level and are extracted from the FFA and WCPFC databases.[1] The dataset contains the pre-VDS period from 2000 to 2007 and the post-VDS period from 2008 to 2020. After the implementation of VDS in 2008, the volume of tuna catches in VDS countries

[1] Value of WCPFC-CA Tuna Fisheries 2020, https://www.ffa.int/node/425.

significantly increased relative to non-VDS countries. This is reflected in the sharp increase in the catch levels as indicated in Figure 3.

Figure 3: Trends of Tuna Catch between VDS and Non-VDS Countries



Source: Based on *Value of WCPFC-CA Tuna Fisheries* data, Western and Central Pacific Fisheries Commission (2020).

The dataset contains a range of country-level information, including total tuna catch in fleet; tuna catch by species; GDP per capita; import prices by major international market (Japan and Thailand); price of marine diesel oil representing fishing cost; and sea surface temperature. Table 3 provides the list of variables used in the study.

i. **Total tuna catch** is taken to be the catch from fleets and measured in metric tons.

ii. **Data on tuna species** refers to four of the nineteen tuna species of high commercial value targeted by the fishing operators. These includes skipjack, yellowfin, albacore and bigeye tuna.

iii. **VDS** represents the status of the sample countries regarding their adoption of the VDS policy in tuna fishing. VDS is 1 if a country is exposed to VDS and 0 otherwise.

iv. **TC** refers to the treatment and control groups of the sample countries. TC takes value 1 for a treatment county that is exposed to VDS and 0 for a control country that is still practicing the quota system in fishing.

v. **GDP per capita** in US dollars of each country is used as an indicator of the size of the domestic market and the country's living standard. It is assumed that a growing GDP per capita trend can influence demand for consumer goods (i.e., tuna fish) and bring economic benefits to the industry, such as employment in tuna fishing.

Table 3: Variables Used in the Study

Variables	Variable Description
Dependent variable	
$Ln(Catch)_{it}$	Log of Total Tuna catch in fleet
$Albacore_{it}$	Log of Albacore catch in fleet
$Bigeye_{it}$	Log of Bigeye catch in fleet
$Skipjack_{it}$	Log of Skipjack catch in fleet
$Yellowfin_{it}$	Log of Yellowfin catch in fleet
Treatment	
$VDS \times TC$	Difference-in-Difference (DID) variable
VDS	1 = if country is exposed to the VDS in 2008, 0 = otherwise.
TC	1 = treatment country if country I is exposed to VDS and 0 = control country who are still in quota system.
Control variable	
$GDPpc_{it}$	GDP per capita
$Freshprice_{it}$	Market price of fresh Tuna (Japan, Thailand).
$Frozenprice_{it}$	Market price of frozen Tuna (Japan, Thailand).
$Diesel_{it}$	Price of marine diesel oil
Sea_{it}	Sea level temperature

vi. The **prices of both fresh and frozen tuna** reflect the earnings of operators. The prices differ based on market conditions, the cost of transport to the market, the species, and the type of gear used. As a result, there is no singular price for fish that indicates price trends to operators. The Thailand import price is the primary indicator for the tropical skipjack and yellowfin species captured with a purse seine for processing using comparative cost advantages. The import price to Japan is the primary indicator for the longline fishery that targets bigeye and yellowfin for the sashimi market. In Japan, prices for fresh and refrigerated tuna reflect the fact that consumer preferences can be differentiated. All prices are nominally indicated in US dollars per metric ton.

vii. The primary fishing expenses incurred by operators are wages; the provision of baits; food supplies; and fuel. The **price of marine diesel oil** is used as the primary indicator of fishing cost trends in this paper. The price of marine diesel oil in Singapore is a reliable indicator of the expenses incurred by longline and purse-seine vessels in the region. All prices are indicated per metric ton in US dollars.

viii. **Sea surface temperature** is used as the main indicator to identify El Nino conditions that affect the tuna catch.

4.2 Econometric Methods

Difference-in- Difference

The study's approach is to use a Difference in Difference (DID) model to evaluate the impact of the VDS on the total tuna catch in the WCPO region. The DID model is commonly used both in the public and private sectors to assess the causal relationship between policy interventions and potential outcomes. The version of the model can be found in Imbens and Wooldridge (2009). In a typical DID model, three main assumptions hold: the unconfoundedness or selection of unobservables of simple regression models; selection is on time-invariant unobservables; and in the absence of treatment, both the control and treated group are assumed to have a common growth path in the post-treatment period (Wing et al. 2018).

This model version is a two-group multiperiod design comprised of country-level data observed over 21 years (2000–2020). The first group is the control group, and the second group is the group under treatment. The first group period ranges from 2000 to 2007 and the second group period from 2008 to 2020 during which the VDS policy is observed. Both the control and treatment group make up the population under study. In the first group period, both the PNA and non-PNA members are exposed to the control conditions (a quota system) in which fishing vessels can catch up to the total allowable catch limit in each licensed period. In the second group period from 2008 to 2020, the treatment takes effect and is observed under the PNA plus Tokelau group but not in the non-PNA group. A generic representation of the model is provided as follows:

$$Ln(Catch)_{it} = (VDS \times TC)'_{it}\beta + X'_{it}\delta + \mu_i + \eta_t + \varepsilon_{it}$$

In this DID model, $Ln(Catch)_{it}$ is the outcome variable of interest, that is, the total tuna catch of each country. The treatment variable is the product of the two dummy variables VDS and $TC,$ and thus, the β coefficient of $(VDS \times TC)$ captures an estimate of the treatment effect which tells us how much the tuna catch increased between treatment and control counties over time after the VDS was initiated in 2007. The variable X includes the control variables GDP per capita; prices of tuna; price of marine diesel oil; and sear surface temperature.

The crucial identifying assumption in estimating the equation is that β is equal to zero in the absence of the treatment of VDS at the time of measurement. Statistically, the zero conditional mean of errors is required. This assumption is most plausible when the control countries are very similar to the treatment countries (Meyer 1995). This can be empirically visualized by observing the parallel trend assumption.

Event Study

Event Study is employed to observe the differences between the VDS and non-VDS periods by including observed controls X using the following model.

$$Ln(Catch)_{it} = \beta_0 + \sum_{\tau}^{T} \beta_\tau d\tau_t + X'_{it}\delta + \varepsilon_{it}$$

5. IMPACT OF VDS ON TUNA CATCH IN WCPO

5.1 Impact of VDS on Pacific Tuna Fleet Catch

Table 4 presents the estimated treatment effects on the total fleet catch. These models excluding country fixed effects and year fixed effects indicate that the domestic catch of the PNA countries plus Tokelau increased by 89% to more than 100% because of the VDS and is statistically significant (models 1 and 4). The standard error of the coefficient estimate is relatively small, indicating the small variation in the sample mean from the true population. This reflects the absence of important parameters in the model. By allowing the country fixed effects in models 2, 3, 5, and 6, the results indicate that the VDS has led to an increase in the domestic catch by about 193% to 230% and is statistically significant at the 1% significance level. However, the treatment effects indicate to be much less than with the covariates. The ultimate effect is that the

VDS has led to a substantial increase in the domestic catch values of PNA countries plus Tokelau as compared to the non-PNA countries.

Table 4: Impact of VDS on Pacific Tuna Fleet Catch

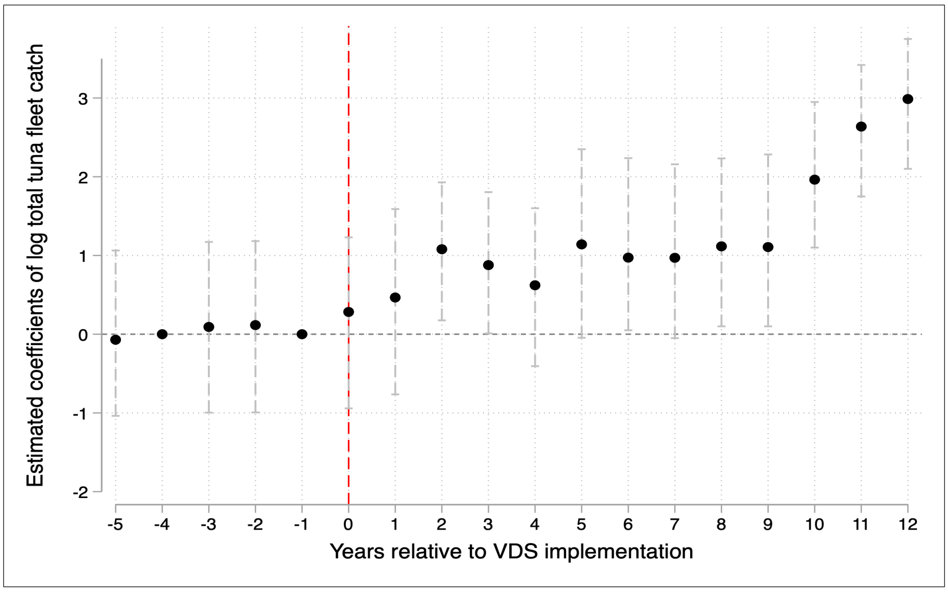
	Log of Total Fleet Catch					
Variables	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
VDS × TC	1.037**	1.931***	2.302***	0.895*	2.080***	2.235***
	(0.418)	(0.233)	(0.339)	(0.506)	(0.319)	(0.343)
Observations	357	357	357	357	357	357
R-squared	0.017	0.835	0.846	0.024	0.840	0.846
No. of Countries	17	17	17	17	17	17
Country FE	No	Yes	Yes	No	Yes	Yes
Year FE	No	No	Yes	No	No	Yes
Covariates	No	No	No	Yes	Yes	Yes
F	6.153	68.83	46.22	1.089	9.971	23.87

Note: Robust Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1, Covariates included: GDP per capita; tuna market price–fresh (Japan, Thailand); tuna market price–frozen (Japan, Thailand); price of marine diesel oil; and sea level temperature.

Given the strict exogeneity assumption of the DID design, the fixed effects are also applied to eliminate the bias from the time or group invariant factors. The results are presented in models 3 and 6. The estimated results indicate to be statistically significant at the 1% level. This reflects that the endogeneity of the treatment effects on the outcomes are not independent.

We also apply the event study methods to estimate the effect of VDS on tuna fleet catch and obtain results that support the DID results. Figure 4 shows that the estimated coefficients of total tuna catch significantly increased after the VDS implementation in 2008. The catch levels consistently increased relative to the VDS implementation year.

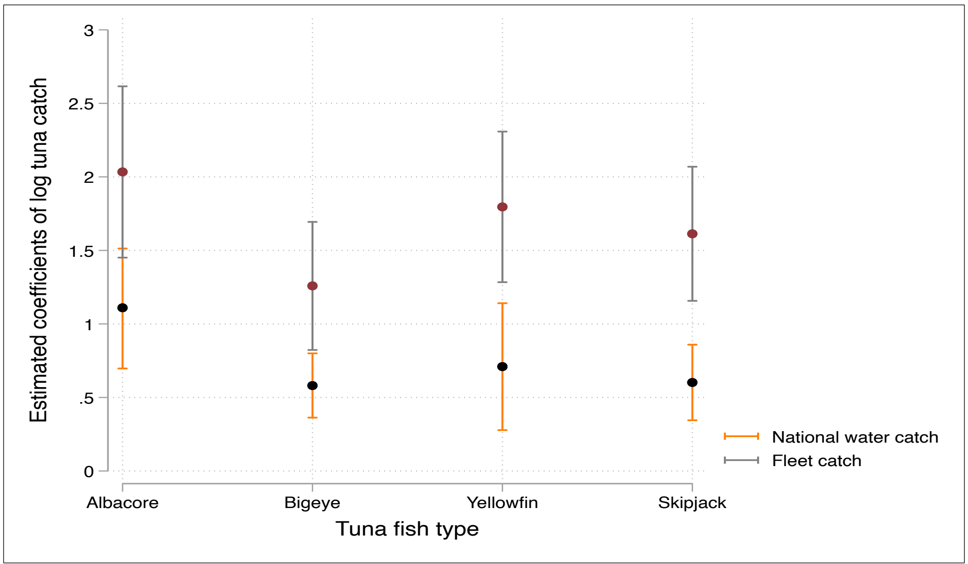
Figure 4: Result of Event Study



5.2 Impact by Species—Heterogeneity Analysis

In order to test for the heterogeneity of treatment effects, we conducted the analysis for four types of tuna species—Albacore, Bigeye, Yellowfin, and Skipjack. Figure 5 contains the coefficient plot showing the estimated coefficient of log tuna catch in national water and fleet for each tuna type. The results indicate that VDS nations typically capture 1.25 to 2 times more tuna in fleet than non-VDS nations. The catch of albacore and bigeye tuna have significantly increased, perhaps due to the higher-priced canned albacore tuna or yellowfin for the valuable sashimi market (Hamilton et al. 2011). The albacore, skipjack, and yellowfin tuna stocks in the WCPO remain relatively healthy but are nearing their limits. Even though these stocks are not presently considered overfished, our findings align with the scientific assessments that indicate they are unlikely to continue to support the growth in fishing effort and catch observed in the past (World Bank 2016).

Figure 5: Estimated Coefficient Plot by Tuna Species



5.3 Impact by Fishing Gears

We also extend the analysis by fishing gear, namely longline; purse seine; pole and line; trolling; and other gear. Purse seine and longline are the two major types of fishing gear in the WCPO. Whether it was coincidental or not, purse-seine tuna catch of tuna species, notably yellowfin and skipjack, were also accompanied by the rapid increase in the VDS countries. The estimated coefficient in Table 5 indicates that the tuna catches in the VDS nations increased 219% in purse-seine fishing while it decreased in similar manner in longline gear. Purse seiners typically use large commercial fishing vessels equipped with advanced fish-finding technology to locate schools of tuna covering large areas in the water. In 2020, about 850,000 metric tons of tuna landing comes from purse seiners, which is 72% of the total tuna catch in the Pacific region. While the longline catch decreased, VDS greatly increased purse-seine catch in VDS member countries compared to non-VDS countries (see Appendix figure A.1). For example, the total purse-seine catch from VDS member countries increased from 66% (in 2000) to 82% (in 2008) to 92% (in 2020).

Table 5: Impact of VDS by Fishing Gear

	(1)	(2)	(3)	(4)	(5)
	Log of Fleet Catch				
Variables	**Longline**	**Purse Seine**	**Pole and Line**	**Troll**	**Other Gear**
VDS × TC	–2.063***	2.194***	1.035***	1.589***	0.859***
	(–0.468)	(0.325)	(0.269)	(0.215)	(0.131)
Observations	357	357	357	357	357
R-squared	0.099	0.915	0.701	0.819	0.93
No. of Countries	17	17	17	17	17
Country FE	No	No	No	No	No
Year FE	No	No	No	No	No
Covariates	Yes	Yes	Yes	Yes	Yes
F	4.769	9.339	7.772	10.27	21.9

Note: Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1, Covariates included: GDP per capita; tuna market price–fresh (Japan, Thailand); tuna market price–frozen (Japan, Thailand); price of marine diesel oil; and sea level temperature.

5.4 Robustness

We extend the analysis to the catch value (in USD) of the tuna in fleet and national water. Table 6 presents the estimated treatment effects on the domestic catch values using with covariates. These models with other parameters indicate that the domestic catch values of the PNA countries plus Tokelau increases by about 1.2 times in fleet catch and 0.5 times in national water catch as a result of the VDS and, is statistically significant at the 1% significance level. The standard error of the coefficient estimate is relatively small indicating the small variation in the sample mean from the true population. The ultimate effect is that the VDS has led to a substantial increase in the domestic catch values of PNA countries plus Tokelau as compared to the non-PNA countries.

Table 6: Robustness Check

	(1)	(2)	(3)	(4)
Variables	**Log of Total Fleet Catch Value**	**Log of Total Fleet Catch Value**	**Log of Total National Water Catch Value**	**Log of Total National Water Catch Value**
VDS × TC	1.121***	1.234***	0.553***	0.590***
	(0.155)	(0.164)	(0.112)	(0.119)
Observations	357	357	357	357
R-squared	0.892	0.902	0.927	0.934
No. of Countries	17	17	17	17
Country FE	Yes	Yes	Yes	Yes
Year FE	No	Yes	No	Yes
Covariates	Yes	Yes	Yes	Yes
F	18.74	28.80	35.74	30.77

Note: Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1, Covariates included: GDP per capita; tuna market price–fresh (Japan, Thailand); tuna market price–frozen (Japan, Thailand); price of marine diesel oil; and sea level temperature.

6. CONCLUSIONS AND POLICY IMPLICATIONS

This paper has examined the impact of the VDS on the domestic catch levels using the DID model. During 2000 to 2020, the volume of tuna catch in VDS countries remained significantly high compared to non-VDS countries. Though VDS has been strikingly successful in terms of raising government revenue and providing sizeable profit to the PND countries, higher catch volume has important implications for future tuna stock in the region. As evidenced by our findings of a two-fold increase in tuna catch by VDS countries, if this trend continues, it potentially threatens the sustainability of tuna stocks in the EEZs of the affected Pacific states. It particularly raises concern about the sustainability of tuna species, especially Bigeye as it has higher demand in the Japanese market while its spawning is the most depleted of the four main species in the WCPO (World Bank 2016).

Coupled with other factors, such as an increase in sea surface temperature and climate change, the extent of the effect may be even deeper. A study by the World Bank (2016) predicted that in 20 years. tuna stocks may begin to migrate out of the WCPO EEZs toward the Central and Eastern Pacific Ocean. A recent study put forward a similar prediction that about 13% of key commercial species may move out of the EEZ of the 10 Pacific states into the high seas by 2050 (Bell et al. 2021). Under the VDS setting, this creates the threat of a fall in license fee revenue by up to 13% as foreign vessels will be able to take advantage of fishing freely in international waters.

Maximizing economic returns from tuna fishing in the Pacific requires a combination of sustainable fishing practices, effective VDS management strategies, and market-oriented approaches. First, a number of Pacific countries with significant tuna resources may benefit from promoting domestication and modernization of the cannery industry. This includes the promotion of entirely domestic or public–private partnerships that target either the commercial fishing sector or post-harvest processing (MRAG Asia Pacific 2022). This policy is particularly useful in the Pacific countries where there is existing fish processing and a distribution network, a stable tuna supply, and an adequate workforce. This policy may boost domestic benefits, such as employment opportunities; rents; and tax revenues. Although tax revenues are the main form of benefits from domestic cannery expansion, this may also promote other benefits, such as skill acquisition and technology transfer to the host country (Campbell 2006).

Second, the Pacific nations may benefit from facilitating labor mobility policies towards PNG, where tuna processing and canning industries have recently undergone a significant growth. In 2018, the PNG government instituted a rebate scheme in which tuna processors in the country receive USD 400 per metric ton of tuna if domestic or foreign vessels land in their tuna catch for domestic processing (The National 2022). The PNG rebate policy provides increased incentives to process tuna in PNG and is expected to increase revenue and job creation. A policy on labor mobility in PNG will complement this objective and benefit all participating nations.

Third, efforts should be undertaken to address these challenges in onshore tuna processing: limited infrastructure; high production costs; and competition from other regional or global processing hubs through regional cooperation, technology upgrades, and capacity building initiatives to strengthen the competitiveness and sustainability of the sector.

REFERENCES

Aqorau, T. 2009. Recent Developments in Pacific Tuna Fisheries: The Palau Arrangement and the Vessel Day Scheme. *The International Journal of Marine and Coastal Law* 24(3): 557–581.

Bell, J. D. et al. 2021. Pathways to Sustaining Tuna-dependent Pacific Island Economies during Climate Change. *Nature sustainability* 4(10): 900–910.

Bernadett, L. D. 2014. The Parties to the NAURU Agreement's Vessel Day Scheme: Accounting for the Rare Success of an International Agreement. *Chicago-Kent Journal of International and Comparative Law* 14: 105.

Campbell, H. F. 2006. Tuna Resource Management—Measuring the Benefits of Domestic Tuna Processing. *Pacific Economic Bulletin* 21(3): 88–97.

Campling, L., E. Havice, and V. Ram-Bidesi 2007. *Pacific Island Countries, the Global Tuna Industry and the International Trade Regime—A Guide Book*, Pacific Islands Forum Fisheries Agency, Honiara. https://www.researchgate.net/publication/259442868_Pacific_Island_Countries_the_Global_Tuna_Industry_and_the_International_Trade_Regime_–_A_Guidebook.

Central Intelligence Agency. 2022. *The CIA World Factbook 2022*. New York, NY: Skyhorse Publishing Inc.

Claus, S., De Hauwere, N., Vanhoorne, B., Deckers, P., Souza Dias, F., Hernandez, F., and Mees, J. 2014. Marine Regions: Towards a Global Standard for Georeferenced Marine Names and Boundaries. *Marine Geodesy* 37(2): 99–125.

Dunn, S., L. Rodwell. And G. Joseph 2006. 'The Palau Arrangement for the Management of the Western Pacific Purse Seine Fishery—Management Scheme (Vessel Day Scheme)', Pacific Islands Forum Fisheries Agency, Honiara, Solomon Islands. http://macbio-pacific.info/wp-content/uploads/2017/08/Palau-Arrangement.pdf.

Food and Agricultural Organization 2008. *Climate Change and Food Security in Pacific Island Countries.* Food and Agriculture Organization of the United Nations, Rome. http://www.fao.org/climatechange/1700302529d2a5afee62cce0e70d2d38e1e273.pdf.

Fisheries Forum Agency. 2020. '*WCPFC Area Catch Value Estimates'*, Fisheries Forum Agency. https://www.ffa.int/node/425.

Gillett, R. 2005. Pacific Island Countries Region. *In Review of the State of World Marine Resources*. FAO Fisheries Technical Paper 457. Rome. FAO. pp. 144–157.

Grafton, R.Q. and T. Kompas 2019. 'Managing the Western and Central Pacific Tuna Fishery: Concerns and Prospects', Pacific Economic Bulletin, The Australian National University, Canberra, viewed 12 November 2020. https://openresearch-repository.anu.edu.au/bitstream/1885/157837/1/213_managing.pdf.

Hamilton, A., A. Lewis, M.M. McCoy, E. Havice, and L. Campling 2011. Market and Industry Dynamics in the Global Tuna Supply Chain. Fisheries Forum Agency (FFA), Honiara.

Hampton, J., J. R. Sibert, P. Kleiber, M. N. Maunder, and S. J. Harley. 2005. Decline of Pacific Tuna Populations Exaggerated? *Nature* 434: 280–283.

Hanich, Q. and M. Tsamenyi 2009. Managing Fisheries and Corruption in the Pacific Islands Region, *Marine Policy* 33 (2):386–392.

Hanich, Q., M. Tsamenyi, and H. Parris. 2010. Sovereignty and Cooperation in Regional Pacific Tuna Fisheries Management: Politics, Economics, Conservation and the Vessel Day Scheme. *Australian Journal of Maritime and Ocean Affairs* 2(1): 2–15.

Hannesson, R., and J. Kennedy 2009. Rent-maximization versus Competition in the Western and Central Pacific Tuna Fishery. *Journal of Natural Resources Policy Research* 1(1): 49–65.

Hare, S. R., P. G Williams, C. A. C. Jordán, P. A. Hamer, W. J. Hampton, R. D. Scott, and G. M. Pilling 2021. *The Western and Central Pacific Tuna Fishery, 2020 Overview and Status of Stocks*. Pacific Community (Communauté du Pacifique).

Havice, E. 2010. The Structure of Tuna Access Agreements in the Western and Central Pacific Ocean: Lessons for Vessel Day Scheme Planning. *Marine Policy* 34(5): 979–987.

———. 2013. Rights-based Management in the Western and Central Pacific Ocean Tuna Fishery: Economic and Environmental Change Under the Vessel Day Scheme. *Marine Policy* 42: 259–267.

Havice, E., and L. Campling 2010. Shifting Tides in the Western and Central Pacific Ocean Tuna Fishery: the Political Economy of Regulation and Industry Responses. *Global Environmental Politics* 10(1): 89–114.

Imbens, G. W. and J. M. Wooldridge 2009. Recent Developments in the Econometrics of Program Evaluation. *Journal of Economic Literature* 47(1): 5–86.

Meyer, B. D. 1995. Natural and Quasi-experiments in Economics. *Journal of Business and Economic Statistics 13*(2): 151–161.

Miller, K. A. 2007. Climate Variability and Tropical Tuna: Management Challenges for Highly Migratory Fish Stocks. *Marine Policy* 31(1): 56–70.

MRAG Asia Pacific 2022. Policy Options to Increase the Contribution of Tuna Fisheries to National Food Security Across FFA Members. Report prepared for the Forum Fisheries Agency. 75 p.

Ram-Bidesi, V., and M. Tsamenyi 2004. Implications of the Tuna Management Regime for Domestic Industry Development in the Pacific Island States. *Marine Policy* 28(5): 383–392.

Squires, D., M. Maunder, R. Allen, P. Andersen, K. Astorkiza, D. Butterworth, and N. Vestergaard 2017. Effort Rights-based Management. *Fish and Fisheries* 18(3): 440–465.

The National. 2022. Fisheries Authority Phasing Out Rebate Scheme. https://www.thenational.com.pg/fisheries-authority-phasing-out-rebate-scheme/#:~:text=Scheme%20phase%20out&text=Phase%201%3A%202020%20to%202021,with%20production%20of%20170%2C000mt (accessed 31 May 2022).

Western and Central Pacific Fisheries Commission (WCPFC) 2020a. *Convention on the Conservation and Management of Highly Migratory Fish Stocks in the Western and Central Pacific Ocean,* Western and Central Pacific Fisheries Commission. https://www.wcpfc.int/convention-text.

Western and Central Pacific Fisheries Commission (WCPFC) 2020b. Value of WCPFC-CA Tuna Fisheries 2020, Western and Central Pacific Fisheries Commission. https://www.ffa.int/node/425.

Wing, C., K. Simon, and R. A. Bello-Gomez 2018. Designing Difference in Difference Studies: Best Practices for Public Health Policy Research. *Annual Review of Public Health* 39: 453–469.

World Bank. 2016. Tuna Fisheries. Pacific Possible, The World Bank, Washington, DC. https://thedocs.worldbank.org/en/doc/858301461833983033-0070022016/original/PacificPossibleTunaFisheries.pdf.

———. 2019. Weathering Growing Risks, World Bank East Asia and Pacific Economic Update, Washington, DC, October 2019. https://openknowledge.worldbank.org/handle/10986/32482.

———. 2023. *World Bank Development Indicators*. The World Bank. Washington, DC. https://databank.worldbank.org/source/world-development-indicators.

World Economic Forum. 2022. Why Western and Central Pacific Tuna Stocks Must Be Safeguarded. https://www.weforum.org/agenda/2022/11/tuna-fishing-west-central-pacific/.

Yeeting, A. D., S. R. Bush, V. Ram-Bidesi, and M. Bailey 2016. Implications of New Economic Policy Instruments for Tuna Management in the Western and Central Pacific. *Marine Policy* 63: 45–52.

APPENDIX

Figure A.1: Tuna Catch by Purse-Seine and Longline Fishing in 2000, 2008, and 2020