REDUCTION OF BLAST FISHING IN TANZANIA: ANALYSIS OF OUTCOMES AND DETERRENCE MEASURES

Melissa O'Connor Hampton-Smith

B. Social Sciences

Submitted in [partial] fulfilment of the requirements for the degree of
Master of Science

School of Environmental and Rural Science
University of New England
2021

Keywords

blast fishing; bomb fishing; dynamite fishing; coral reefs; fisheries management; marine protected area (MPA); social–ecological systems; community based management (CBM)

Abstract

Blast fishing (known variously as dynamite and bomb fishing) has caused long-term damage to reefs and coastal livelihoods in Tanzania and across the globe for decades. Blasting reefs with explosives has provided fish for commercial and consumption purposes, but the practice has also led to large-scale destruction of coral reef ecosystems by reducing the populations of coral colonies and reef species. In 2015 and 2016, a Tanzanian government campaign against blasting was initiated along the entire coastline. Subsequently, a significant and near uniform reduction in blasting was observed. The aim of my study was to: (1) assess the current global status of blast fishing, and to elucidate broad causes, implications and solutions to the problem; (2) analyse causal factors underlying involvement in blast fishing and reduction of the activity in Tanzania; and (3) assess how Tanzania's coastline communities and their fish stocks have been affected by the reduction of blast fishing. My literature review analysed 212 papers from seven databases and found that ineffective enforcement and governance structures drive blasting; socioeconomic causes may contribute but are not dominant. A combination of deterrence measures and co-managed marine protected areas (MPAs) emerged as the most effective solution to blasting. I surveyed 98 households and 19 fisher focus groups with 243 fishers in four Tanzanian regions with historically high levels of blast fishing. Survey sites were purposively chosen based on previous records of blasting activity, including controls with low blasting histories; respondents were systematically selected. My primary data show that the profitability of blasting is its primary cause. The government campaign against blasting is regarded by the majority of respondents as the primary cause of the reduction. Fish catches are widely reported as having increased following the campaign. These data support the literature review as well as previous studies conducted in the region. Further research incorporating geographic and market factors will deepen understanding of destructive fishing in developing coastal fisheries.

Certificate of Dissertation

I certify that the ideas, experimental work, results, analyses, software and conclusions reported in this dissertation are entirely my own effort, except where otherwise acknowledged. I also certify that the work is original and has not been previously submitted for any other award, except where otherwise acknowledged.

Signature: [redacted]

Date: 5th August 2021

Acknowledgements

I would like to first and foremost acknowledge my supervisors, Dr Sarah Mika, Dr Deborah Bower and Prof Neil Argent for their guidance and support over the past two years. They shaped and refined my ideas, provided invaluable feedback throughout and gave me confidence to carry out this research.

My fieldwork would not have been possible without my host in Tanzania Dr Sayuni Mariki, who provided important assistance in the field, and Sia Jeremiah Temu, who acted as my translator and cultural intermediary during fieldwork and was instrumental in facilitating data collection.

I would also like to thank the numerous individuals in Tanzania who generously gave their time and expertise to assist me during my research, in particular Jason Rubens and Jumanne Mohammed.

Finally, I would like to thank the University of New England for their financial support through the Strategic Scholarship, as well the Sokoine University of Morogoro, Tanzania for hosting me during my time in Tanzania.

Preface

Chapter 2 of this thesis has been submitted to a journal and is currently under review. Minor formatting modifications have been made to submitted manuscript.

Publication	Author	Contribution
Hampton-Smith, M., D. Bower and S. Mika (2021) A review of the current global status of blast fishing: causes, implications and solutions. *Under review.*	Melissa Hampton-Smith	80%
	Deborah Bower	10%
	Sarah Mika	10%

Chapters 3 and 4 draw upon the same primary dataset. Therefore parts of Chapter 3 methods (sections 3.2.1, 3.2.2 and 3.2.3) are duplicated in Chapter 4 methods (sections 4.2.1, 4.2.2 and 4.2.3). The discussion of the ethics and limitations of the study in Chapter 3 (section 3.3) are duplicated in Chapter 4 (section 4.3).

Hampton-Smith, M., Bower, D. S., & Mika, S. (2021). A review of the current global status of blast fishing: Causes, implications and solutions. Biological Conservation, 262, 109307. doi:10.1016/j.biocon.2021.109307

Table of Contents

List of Figures

List of Tables

Chapter 1: Introduction

1.1 BACKGROUND

Blast fishing is the highly destructive and unsustainable practice of using explosives to stun and kill fish for commercial gain and consumption, which has been an ongoing concern in Tanzania since the 1960s (Jiddawi & Öhman, 2002). Also known as bomb or dynamite fishing, it occurs in Southeast Asia, as well as the Red Sea, West Africa, South America and parts of Asia. Blast fishing results in the destruction and degradation of coral reefs, and has associated negative impacts on species abundance and diversity, as well as catch sizes (Fox, Pet, Dahuri, & Caldwell, 2003; Hughes et al., 2017; Rogers, Blanchard, & Mumby, 2018). In Tanzania, uncontrolled blasting in the 1980s and 1990s resulted in considerable reduction of rugosity along much of the coastline (Muhando & Mohammed, 2002; Nzali, Johnstone, & Mgaya, 1998). With a brief respite between 1998 and 2002, blast fishing and its associated negative impacts on catch sizes and key fish populations has continued to occur since then (McClanahan et al., 2015; Rubens, 2016). However, in 2016 the rate of blasting decreased considerably in all recorded regions in Tanzania, which has been attributed to a coordinated government campaign (Rubens, 2019). These historically low rates of blasting have, with some isolated exceptions, continued to the present day (Rubens 2019, Tanzania Blast-Fishing Monitoring Network, 2018).

1.2 CONTEXT

Blast fishing occurs within the broader context of Tanzania's socioeconomic development, its rich marine biodiversity and the significance of fishing to local livelihoods. Tanzania is considered amongst the poorest countries in the world, with a ranking of 151 out of 186 countries on the United Nations Human Development Index (Jahan, 2015). Within Tanzania, some of the most disadvantaged regions are those that also heavily rely on fishing as a primary food and income source and are therefore especially vulnerable to decreases in living standards and household income (Research and Analysis Working Group (R&AWG), 2005). In 2005, 38% of the general population was living under a poverty line of $US0.26 per person per day, which is low from a regional and international perspective (R&AWG, 2005). As for the 25% of the population that relies on fishing, the average daily income of fishers is estimated at between one to two US dollars per day (Barr, 2010; Budeba, 2016). After accounting for inflation and the costs of boats, fishing gear and other associated expenditures, it can be assumed that the majority of fishers are living close to, or below, the international poverty measure of $US1.90 per day (World Bank & International Monetary Fund (IMF), 2016).

Tanzania's coastline stretches 1,434 km along the western Indian Ocean and mainly comprises mangroves, seagrass beds and coral reefs with considerable biodiversity (Griffiths, 2005). The coastline runs north-south and can be broadly divided into four areas: the northern Tanga region, including Pemba and Maziwe Island; the region surrounding Dar es Salaam, including Zanzibar; the Kilwa district, including the Songo Archipelago, Mafia Island, Nyororo Island, Shungi Mbili Island and Mbarakuni Island, and the southern Lindi and Mtwara regions. There are two marine parks, the Mafia Island Marine Park (MIMP) and the Mnazi Bay Ruvuma Estuary Marine Park (MBREMP), and ten marine reserves, covering coastal areas in Dar es Salaam, Tanga, Zanzibar, and several smaller islands near the three main islands of Pemba, Zanzibar and Mafia (Wagner, 2004). These Marine Protected Areas (MPAs) have designated no-take zones, as well as areas where fishing is restricted to certain quotas (*Marine Parks and Reserves Act* 1994). In 1995, the MIMP was the first marine park to be established in Tanzania and is a multiple use area that includes a variety of biotopes, especially coral reefs, and supports a large number of species (Garpe & Öhman, 2003; Kamukuru, Mgaya, & Öhman, 2004). The importance of the marine areas in the south was recognised in 2000 with the establishment of the MBREMP, a large, multiple use area incorporating rich biodiversity (Machumu & Yakupitiyage, 2013; Wagner, 2004). Although fishing in both marine parks is largely for local consumption and makes no significant contribution to the national economy, local families depend heavily on the marine environment as a source of income and food (Mndeme, 1998; Tobey & Torell, 2006).

There have been several studies conducted in Tanzania to determine the factors associated with blast fishing; however, as yet a broad consensus has not been found. Some aspects of poverty, such as insecure food supplies and lower standards of living are positively associated with destructive fishing methods (Cinner, 2010; Silva, 2006). These findings concur with the broad literature on poverty traps and coastal fisheries, whereby the poor, due to limited access to resources, are trapped in behaviour cycles that reinforce their own poverty (Short, Gurung, Rowcliffe, Hill, & Milner-Gulland, 2018). However, ownership of destructive gear was the single biggest contributing factor to destructive fishing, followed by access to credit, which does not point to poverty as the overriding driver of blast fishing (Silva, 2006). Anecdotal evidence suggests that the profitability of blasting, a lack of viable income alternatives and a lack of appropriate enforcement were also important contributors (Guard & Masaiganah, 1997; Slade & Kalangahe, 2015; Wells, 2009).

A deeper analysis of blasting causation is complicated by the recent reduction in blasting and a paucity of data. Thus far, the majority of available data on fishing communities and blasting have been published during periods when blast fishing was commonplace, i.e. before and after the 1998-2002 reduction (Barr, 2010; Sesabo & Tol, 2005; Silva, 2006). Large-scale studies focused on the spatial distribution of poverty that could contribute longitudinal income data have either not publicised their data or are too broad-scale to be of use when examining specific coastal communities (e.g. Francis, Wagner, Mvungi, Ngwale, & Salema, 2002; Tanzanian National Bureau of Statistics (NBS), 2015; R&AWG 2005). Empirical data on deterrence measures against blasting are also scarce. A majority of fishers surveyed attributed the recurrence of blast fishing to an inconsistent enforcement of deterrence measures (Katikiro & Mahenge, 2016). Qualitative assessments concur that a consistent and coordinated approach from the Tanzanian judiciary, government, and fishing communities would prove effective in reducing blast fishing (Slade & Kalangahe, 2015; Wells, 2009). Overall, the literature does suggest that increased enforcement would result in a reduction of illegal fishing, and the recent reduction of blast fishing in Tanzania in conjunction with the increase in government action has provided an ideal situation in which to critically examine this hypothesis.

1.3 AIMS AND OBJECTIVES

The primary goal of my thesis was to understand the impact of the blasting reduction on coastal fishing communities in Tanzania, as well as on the ecological standing of the coral reef ecosystems. Given the global nature of blasting, I also focused on blast fishing as a world-wide phenomenon. My thesis aimed to (1) assess the current global status of blast fishing, and to elucidate broad causes, implications and solutions to the problem; (2) investigate causal factors underlying involvement in blast fishing and reduction of the activity in Tanzania; and (3) analyse how Tanzania's coastline communities and their fish stocks have been affected by the reduction of blast fishing.

The main issue that my thesis addressed with these aims was the lack of empirical knowledge about the factors that caused the recent reduction of blast fishing in Tanzania, as well as its social, economic, and ecological impact on fishing communities and fisheries. Without an understanding of causality and impact, the ability to predict whether blast fishing will reoccur is limited, as is the understanding of impacts of the reduction. I determined indicators associated with a previous engagement in blast fishing, and assessed which factors caused previous blast fishers to cease. I then determined the impact of the blasting reduction on fishing in general, fish availability and fishing derived income, with a focus on blast fishing history as a predictive indicator.

My thesis updated and enhanced the body of knowledge concerning push factors towards blast fishing and the impact of deterrence measures, both in Tanzania and globally. Understanding this will not only improve the future outlook for Tanzania, but also potentially provide solutions to be implemented in other regions struggling with similar issues. Through gathering primary data in coastal villages, my study took a broad paradigmatic approach to help us understand the complex nature of sustainable fisheries management in Tanzania. This will help to bridge the gap between theory and praxis to assist with maintaining the currently low level of blast fishing into the future.

1.4 THESIS OUTLINE

Chapter 2 explores the global distribution of blasting and its causes, implications and possible solutions through a systematic literature review. Chapter 3 assesses the drivers of blasting in Tanzania and the causes of the recent reduction. Chapter 4 investigates the impacts of the reduction in blasting on Tanzanian coastal fishing communities and fish stocks. Finally, Chapter 5 provides a synthesis of the research findings on blast fishing both globally and in Tanzania, and proposes research priorities to further understanding of blast fishing and marine resource management in developing coastal fisheries.

1.5 REFERENCES

Barr, R. F. (2010). *Conditional cash transfers in the coastal context of Mtwara Development Corridor, Tanzania: economic and livelihood analysis.* Care International & World Wildlife Fund (WWF). 40 pp.

Budeba, Y. L. (2016). *The Tanzanian Fisheries Sector: Challenges and Opportunities*. Dar Es Salaam, Tanzania: Tanzanian Ministry of Agriculture Livestock and Fisheries. 40 pp.

Cinner, J. E. (2010). Poverty and the use of destructive fishing gear near east African marine protected areas. *Environmental Conservation, 36*(04), 321-326. doi:10.1017/s0376892910000123

Fox, H. E., Pet, J. S., Dahuri, R., & Caldwell, R. L. (2003). Recovery in rubble fields: long-term impacts of blast fishing. *Marine Pollution Bulletin, 46*(8), 1024-1031. doi:10.1016/s0025-326x(03)00246-7

Francis, J., Wagner, G. M., Mvungi, A., Ngwale, J., & Salema, R. (2002). *Tanzania National Report – Phase 1: Integrated Problem Analysis.* United Nations Environment Programme. www.researchgate.net/publication/268054477_Tanzania_National_Report_-_Phase_1_Integrated_Problem_Analysis. 70 pp.

Garpe, K. C., & Öhman, M. C. (2003). Coral and fish distribution patterns in Mafia Island Marine Park, Tanzania: fish–habitat interactions. *Hydrobiologia, 498*(1-3), 191-211.

Griffiths, C. L. (2005). Coastal marine biodiversity in East Africa. *Indian Journal of Marine Sciences, 34*(1), 35-41.

Guard, M., & Masaiganah, M. (1997). Dynamite fishing in southern Tanzania, geographical variation, intensity of use and possible solutions. *Marine Pollution Bulletin, 34*(10), 758-762.

Hughes, T. P., Barnes, M. L., Bellwood, D. R., Cinner, J. E., Cumming, G. S., Jackson, J. B., . . . Morrison, T. H. (2017). Coral reefs in the Anthropocene. *Nature*, *546*(7656), 82-90. doi:10.1038/nature22901

Jahan, S. (2015). *United Nations Human Development Report*. Washington DC, USA: United Nations Development Programme. 288 pp.

Jiddawi, N. S., & Öhman, M. C. (2002). Marine fisheries in Tanzania. *Ambio, 31*(7), 518-527.

Kamukuru, A. T., Mgaya, Y. D., & Öhman, M. C. (2004). Evaluating a marine protected area in a developing country: Mafia Island Marine Park, Tanzania. *Ocean & Coastal Management, 47*(7-8), 321-337. doi:10.1016/j.ocecoaman.2004.07.003

Katikiro, R. E., & Mahenge, J. J. (2016). Fishers' Perceptions of the Recurrence of Dynamite-Fishing Practices on the Coast of Tanzania. *Frontiers in Marine Science, 3*, 1-14. doi:10.3389/fmars.2016.00233

Machumu, M. E., & Yakupitiyage, A. (2013). Effectiveness of marine protected areas in managing the drivers of ecosystem change: A case of Mnazi Bay Marine Park, Tanzania. *Ambio, 42*(3), 369-380.

McClanahan, T. R., Muthiga, N. A., Abunge, C., Kamukuru, A. T., Mwakalapa, E., & Kalombo, H. (2015). What happens after conservation and management donors leave? A before and after study of coral reef ecology and stakeholder perceptions of management benefits. *PLoS ONE, 10*(10), 1-24. doi:10.1371/journal.pone.0138769

Mndeme, Y. E. S. (1998). Efforts to save the marine environment in Tanzania. *Naga, the ICLARM Quarterly, 21*(3), 10-12.
Muhando, C. A., & Mohammed, M. S. (2002). Coral reef benthos and fisheries in Tanzania before and after the 1998 bleaching and mortality event. *Western Indian Ocean Journal of Marine Science, 1*(1), 43-52.
Nzali, L. M., Johnstone, R. W., & Mgaya, Y. (1998). Factors affecting scleractinian coral recruitment on a nearshore reef in Tanzania. *Ambio*, 717-722.
Research and Analysis Working Group (R&AWG). (2005). *Tanzania Poverty and Human Development Report 2005*. (9987449018). Dar es Salaam, Tanzania: Tanzanian Ministry of Planning Economy and Empowerment. 43 pp.
Rogers, A., Blanchard, J. L., & Mumby, P. J. (2018). Fisheries productivity under progressive coral reef degradation. *Journal of Applied Ecology, 55*(3), 1041-1049. doi:10.1111/1365-2664.13051
Rubens, J. (2016). *Review of the status of blast fishing in Tanzanian marine waters: with recommendations for priority interventions*. Dar es Salaam, Tanzania: Hotel Association of Tanzania (HAT) & BEST Dialogue. 61 pp.
Rubens, J. (2019). *Combating blast-fishing in Tanzanian marine waters: Progress, achievements & lessons 2016-2018*. Dar es Salaam, Tanzania: Hotel Association of Tanzania (HAT) & BEST Dialogue. 38 pp.
Sesabo, J. K., & Tol, R. S. J. (2005). *Factors affecting income strategies among households in Tanzanian coastal villages: Implications for development-conservation initiatives*. 42 pp.
Short, R., Gurung, R., Rowcliffe, M., Hill, N., & Milner-Gulland, E. J. (2018). The use of mosquito nets in fisheries: A global perspective. *PLoS ONE, 13*(1). doi:10.1371/journal.pone.0191519
Silva, P. (2006). *Exploring the linkages between poverty, marine protected area management, and the use of destructive fishing gear in Tanzania*. The World Bank. http://econ.worldbank.org. 43 pp.
Slade, L. M., & Kalangahe, B. (2015). Dynamite fishing in Tanzania. *Marine Pollution Bulletin, 101*(2), 491-496. doi:10.1016/j.marpolbul.2015.08.025
Tanzania Blast-Fishing Monitoring Network. (2018). *Blast records*. Retrieved from: www.tz-blast-monitoring.net/
Tanzanian National Bureau of Statistics (NBS). (2015). *National Panel Survey (NPS) - Wave 4, 2014 - 2015*. Retrieved from: www.nbs.go.tz
Tobey, J., & Torell, E. (2006). Coastal poverty and MPA management in mainland Tanzania and Zanzibar. *Ocean & Coastal Management, 49*(11), 834-854. doi:10.1016/j.ocecoaman.2006.08.002
Wagner, G. M. (2004). Coral reefs and their management in Tanzania. *Western Indian Ocean Journal of Marine Science, 3*(2), 227-243.
Wells, S. (2009). Dynamite fishing in northern Tanzania - pervasive, problematic and yet preventable. *Marine Pollution Bulletin, 58*(1), 20-23. doi:10.1016/j.marpolbul.2008.09.019
World Bank Group. (2016). *Global monitoring report 2015/2016: Development goals in an era of demographic change*. Washington DC, USA. 307 pp. doi:10.1596/978-1-4648-0669-8

Chapter 2: A review of the current global status of blast fishing: causes, implications and solutions

2.1 ABSTRACT

Blast fishing (known variously as dynamite and bomb fishing) has caused long-term damage to reefs and coastal livelihoods for decades. Blasting reefs with explosives provides fish for commercial and consumption purposes across the globe, but the practice has also led to large-scale destruction of coral reefs in much of Southeast Asia, Tanzania, the Red Sea, and other areas in Asia, Africa, Europe and South America. Despite its destructive nature and widespread dispersion, there have been few reviews that offer insight to assist in analysing and managing this broad-scale threat. We address this gap with a comprehensive global analysis of the blast fishing literature to explore the distribution of blast fishing, primary drivers, ecological and economic implications and solutions. Our review analysed 212 papers from seven databases. Blasting is widespread, misreported, and ongoing. Lack of effective enforcement and governance drives blasting; socioeconomic causes may contribute but are not dominant. A combination of deterrence measures and co-managed marine protected areas (MPAs) emerges as the most effective solution to blasting. Our review provides a basis upon which further analysis can build in order to better understand blast fishing and thereby improve conservation outcomes for coral reef ecosystems, as well as the outlook for fishing communities.

2.2 KEYWORDS

blast fishing; coral reefs; fisheries management; marine protected area (MPA); social-ecological systems; community based management (CBM)

2.3 INTRODUCTION

Characterised by its devastating long-term environmental effects and complex causal factors, blast fishing is among the most direct and destructive human impacts on coral reef ecosystems (Fox, Pet, Dahuri, & Caldwell, 2003). Fishing with explosives, known variously as blast, dynamite or bomb fishing, occurs across the globe and has a broad range of ecological, socio-political and economic considerations. There are records of blast fishing across Africa, Asia, South America and Europe, and its use dates back to the end of the nineteenth century (Norton-Kyshe, 1971 [1898]). Blast fishing is a fundamentally destructive practice that at its most extreme, can reduce hard coral structures to rubble, thereby decreasing the abundance and diversity of species that rely on coral reefs as their primary habitat (Friedlander & Parrish, 1998; Knudby, LeDrew, & Brenning, 2010; Marcus, Samoilys, Meeuwig, Villongco, & Vincent, 2007). It is classified as a type of illegal, unreported and unregulated (IUU) fishing and presents a high risk of damage to both target fish populations and related ecosystems (FAO & UNEP, 2010). Although the United Nations Environment Programme (UNEP) and the United Nations (UN) Fisheries and Agriculture Organisation (FAO) have long-standing campaigns against all types of IUU, and have made blast fishing and other types of destructive fishing the focus of numerous conferences and reports, it continues to occur across the globe (e.g. (Flores & Silvestre, 1987; Sudara, 1996; Wilcox et al., 2021; Willoughby, Nikijuluw, & Suradisastra, 1996).

Human and non-human species rely heavily on these systems to provide a myriad of complex intertwined services. From a human perspective, the most recent data suggest that more than 275 million people worldwide live within 30 kilometres of reefs, the majority of whom are in developing countries where reef species are an important protein and income source (Burke, Reytar, Spalding, & Perry, 2011). These data almost certainly underestimate the current number of reef-reliant communities, given high population growth rates in many sea-bordering countries (Neumann, Vafeidis, Zimmermann, & Nicholls, 2015). Moreover, there are at least six million coral reef fishers worldwide, of which a quarter are reef gleaners (Teh, Teh, & Sumaila, 2013). Reefs also deliver essential ecosystem services worldwide such as storm protection and sand production (Costanza et al., 2014; Liquete et al., 2013), have the highest biodiversity of all marine habitats, and are among the most productive and biodiverse habitats in the world (Wilkinson & Buddemeier, 1994). In addition to the threats posed by overfishing and destructive fishing, coral reefs are also vulnerable to the effects of climate change, including ocean acidification, sea-level rise and increased water temperature (Hoegh-Guldberg et al., 2018). The effects of climate change may also accelerate over time, resulting in destructive nonlinear feedback loops between factors such as declining ocean aragonite saturation and coral reef health (Hoegh-Guldberg et al., 2007). Together, destructive fishing and the effects of climate change make reefs less resilient to disruptors (Hughes et al., 2017; Tim R McClanahan et al., 2012), and create unprecedented challenges for coral reefs.

Significant changes have occurred in the intensity and location of blast fishing since the last global review was published (Burke et al., 2011). Therefore, the purpose of this review was to: (1) summarise the available literature on blast fishing and analyse its breadth and coverage; (2) evaluate the overriding themes of the literature search results; 3) elucidate information to better understand blast fishing drivers, implications and the effectiveness of current management practices; and (4) highlight research priorities.

2.4 METHODS

The approach adopted for this review is based on the systematic guidelines for conservation and environmental reviews outlined by Pullin and Stewart (2006). Analysing every paper referring to blast fishing would be an enormous undertaking, with initial searches without limiters producing approximately 6,000 results. Therefore, searches were defined to produce a more focused review. All records containing the key words “blast fishing”, “dynamite fishing” or “bomb fishing” were searched for across seven databases: ProQuest Central, Web of Science, EBSCO Databases (Greenfile was searched separately), Informit Databases (REEFS was searched separately), Scopus, CAB Abstracts, and Taylor & Francis Journals. Searches were performed from October 2018 to April 2020 and limited to records published after 1960. All searches and abstract screenings were performed by MHS. No languages were excluded, and both published journals and grey literature were examined. In addition to database search results, material was also obtained through personal contacts, media reports from credible outlets and snowball sampling from citations within foundational articles. The searches returned 1 288 results. After duplicates were removed, the abstracts of the remaining 1 164 publications were evaluated. 313 publications were selected based on their direct observation of blast fishing and its effects, or their discussion of blasting management and deterrence measures. The full-texts were assessed for relevance, and the final selection contained 212 records. Data extracted from blast fishing literature included geographical area, year published, type of publication, a binary measure of whether empirical evidence of blast fishing was obtained, the specific location of blasting if available, and the time span of the blast fishing observation or experience. Results were classified by their focus on ecological, socio-political or economic considerations of blasting, and by year and type of publication (Figure 1). Ecological considerations were defined as including biological, geographical, environmental or ecological aspects; socio-political as dealing with social, cultural or political elements of blast fishing and the management thereof; and economic as encompassing financial drivers and fiscal aspects of blast fishing and its deterrence. Papers were classified by their primary, secondary and tertiary focus on these three themes. A formal meta-analysis was not conducted due to the wide variety of papers included in the final sample, and because too few papers reported data collection details and effect sizes. The final sample does not represent all material relating to blast fishing, rather a selection designed to provide a comprehensive overview.

Making meaningful comparisons between areas where blast fishing occurs requires a standardised measure of intensity and cumulative damage. However, a dearth of empirical data, the wide range of study types and the non-standardised nature of current reef monitoring programs has interfered with efforts to accurately estimate blasting intensity. Examples of reef monitoring programs include the National Oceanic and Atmospheric Administration's (NOAA) National Coral Reef Monitoring Program and the Australia Institute of Marine Science's (AIMS) Long-Term Monitoring Program. We combined data from our own literature searches and Reef Check blast fishing damage data to provide an overview of blasting distribution and damage (Figure 2). Reef Check, a non-profit organisation, collects data on reef environmental conditions, human impacts, fish counts, shellfish counts, substrate composition and the abundance of key indicator organisms, as well as blast fishing damage (Reef Check, 2018). The consistent methods and global reach of Reef Check data provide a useful comparison point to the emergent trends in the literature, as well as allowing comparisons among countries. This is particularly relevant in cases where data are sparse, and their use has precedence in other similarly exploratory studies (Waheed et al., 2015).

The combination of different datasets and indicators to measure reef health and disturbance is best practice for coral reef assessments and social-ecological system assessments (Gurney & Darling, 2017; Hill & Wilkinson, 2004), and the Reef Check data corroborate findings in the literature. As expected, some countries that did not appear in the literature searches appeared in the Reef Check data, mainly in Central America (Figure 2). Likewise, the literature searches also highlighted several countries not included in the Reef Check surveys, especially in West Africa, as well as areas with inland blast fishing such as Afghanistan and India (Hussain, Debashish, Toge, Mahesh, & Singh, 2016; Nafees, Ahmed, & Arshad, 2011). In the absence of standardised data collection on intensity, the literature search results and Reef Check data provide an approximate assessment of the distribution and damage of blast fishing.

2.5 RESULTS AND DISCUSSION

The literature search returned 212 records of blast fishing across 31 countries (Table 1, Table 1C (see Appendix C)). Of these records, 130 contained empirical evidence of blast fishing, either by directly hearing or witnessing blasts, or through indirect observations of blasting damage on reefs or fish caught by blast fishing. Reef Check data showed a similar dispersion of blasting to the literature, with damage concentrated in Southeast Asia and East Africa (Figure 2). There is considerable overlap between prominent blasting areas and areas with a high concentration of threatened reefs due to factors such as pollution, blasting, or climate change related disruptors (Burke et al 2011). While the majority of publications have been produced in the last decade, this should not be interpreted to mean that blasting was at its highest for that time period, rather that the effects of blasting on reefs and reef-dependent species has been increasingly recognised (Figure 1). It should be noted that given the illegality of blast fishing and the consequent difficulties in collecting data, these findings likely misreport both the distribution and damaging effects of the practice. Although papers focusing solely or primarily on ecological impacts dominated the literature, approximately 15% were interdisciplinary articles addressing all three themes, highlighting the dependencies between ecological, socio-political and economic aspects (Figure 1).

2.5.1 Causes

2.5.1.1 Poverty

The earliest research on blast fishing argued that poverty was either strongly associated with or was the cause of blast fishing (Francis, Wagner, Mvungi, Ngwale, & Salema, 2002; Galvez, Hingco, Bautista, & Tungpalan, 1989; McManus, 1997; Wagner, 2004). Coastal reef fishers have historically experienced high levels of absolute and relative poverty, which has been attributed to high dependency on local marine resources, general resource degradation and remote village locations (Ireland, 2004). Due to limited access to resources, alternative employment and education, fishers were believed to be trapped in behaviour patterns that ultimately reinforced their own poverty. Blast fishing was classified as a type of Malthusian resource use, whereby expanding settlements adjacent to coastal fisheries that are faced with declining catches intensify their fishing efforts, leading to the eventual collapse of the ecosystem and therefore the marine resources available for human consumption (Pauly, Silvestre, & Smith, 1989). In line with this theory, several attempts have been made to establish a relationship between poverty and destructive fishing methods such as blasting, seine net use and mosquito net use. In Tanzania, poverty indicators such as insecure food supplies, low household expenditures, limited capital and lower material standards of living are associated with destructive fishing methods (Cinner, 2010; Silva, 2006), and a study of global mosquito net use identified poverty as the fourth most important driver (Short, Gurung, Rowcliffe, Hill, & Milner-Gulland, 2018). A number of other publications suggested poverty as a causal influence but did not conduct data collection or analyses (e.g. Fauzi & Buchary, 2002).

Studies on destructive fishing suggest the accessibility and ownership of destructive gear is the biggest contributing factor to destructive fishing. Access to credit, the convenience of destructive methods and increased catches were also identified as bigger drivers than poverty (Short et al., 2018; Silva, 2006). In Tanzania, increased motor boat access to other villages (implying socioeconomic development) where retribution is less likely is a contributing factor (Guard & Masaiganah, 1997), and a review argued that blast fishers are wealthier in comparison with their nonblasting counterparts (Wells, 2009). A study in the western Indian Ocean showed that fish biomass was highest in areas of both low and high levels of socioeconomic development, and lowest at a mid-range development level (Cinner et al., 2009), suggesting that the relationship may not always be linear. In Indonesia, an economic analysis of blast fishing found a clear financial incentive to begin blast fishing and considerable ongoing private net benefits (Pet-Soede, Cesar, & Pet, 1999). It could of course be argued that high blasting incomes indicate that blasting is a pathway out of poverty. However, in contrast to the idea of traditional fishermen being forced into using destructive fishing techniques by poverty, these techniques can be the practice of choice due to their ease and capability to generate high incomes (Pet-Soede & Erdmann, 1998). It has also been observed in some blasting hotspots that rather than blasting leading to higher returns than can be obtained using legal means, already more affluent fishers in urban centres have increased access to illicit materials than poorer rural fishers (e.g. Rubens 2016). It seems likely that while socioeconomic development does have some influence on blasting and other destructive techniques, focusing on poverty as the primary blasting driver is misleading and may have contributed to the failure of some poverty alleviation programs designed to reduce blasting.

2.5.1.2 Alternative theories

Alternative theories to explain the incidence of blast fishing can be divided into ineffective or inadequate enforcement and governance issues leading to resource management and ownership conflicts. Broadly speaking, enforcement can be described as the detection and punishment of blast fishing. Enforcement can take the form of national centralised schemes, locally managed projects run by communities or districts, or a combination thereof, and may be conducted by national armed forces, fisheries officials, local police officials or the community groups themselves. Blast fishing is illegal in all of the countries where blasting is most common and attracts penalties ranging from fines to gear destruction and incarceration. In Indonesia, blasting attracts fines exceeding USD 10 000 and prison sentences of up to ten years, while in Tanzania penalties range from the destruction of gear used by blasters to imprisonment between five to ten years (Ainsworth, Varkey, & Pitcher, 2008; Fisheries Act: Govt. Tanzania, 2003). The enforcement of such laws in fisheries where blasting occurs has received substantial attention in the literature:

approximately 18% of the publications included in this review referenced ineffective or inadequate enforcement as a contributing factor to blast fishing. Although enforcement programs are present to a lesser or greater degree in virtually all countries where blasting occurs, these efforts are often hampered by a lack of funding and resources, weak judiciary systems, a lack of political will and corruption at all levels of government (Arai, 2015). Blasting operations may be sponsored by or affiliated with government officials, which leads to a reluctance of witnesses to come forward with evidence, and a low likelihood of successful prosecution in the event that evidence is obtained. Moreover, cultural and social norms such as close kinship ties to blasters reduce the incentive to report misdemeanours (Cushnahan, 2001). Witnesses may also be intimidated or threatened by blasters, particularly in small villages where the possibility of anonymous reporting is limited. Thus, a complex web of economic, political, social and cultural factors can contribute to the inability of an enforcement scheme to effectively control blasting and other destructive fishing.

Moreover, there is disagreement on whether community-based management (CBM) and education programs truly aid enforcement and enhance compliance (Tim R. McClanahan & Abunge, 2018). In some studies, community resource management is positively associated with a reduction in blasting and other destructive fishing methods (Pomeroy et al., 2015). For example, Malaysia has one of the lowest levels of community-supported enforcement in the Coral Triangle, and has experienced significantly more blasting events over the past five years than other nations (Pomeroy et al., 2015; Reef Check, 2018). Conversely, other papers argue that reductions in blasting are directly linked to enforcement efforts, and that the association between “soft” enforcement or compliance programs and blasting reduction is at best murky (Haisfield, Fox, Yen, Mangubhai, & Mous, 2010; Huber, 1994). Overall, the literature suggests that a lack of enforcement is associated with more frequent blasting.

The contribution that governance structures make to the presence or absence of blasting is even more difficult to disentangle than that of poverty or deterrence measures. Governance structures in coastal fisheries where blast fishing occurs have been widely studied, but explicit links to blast fishing are rare. Conflicting trends have been identified as many of these nations have shifted from traditional systems of governance to more formal centralised fisheries management systems, and then from deregulation to CBM or co-management. On the one hand, some countries such as China have taken a highly centralised approach to coral reef conservation and fisheries management. China has seen drastic declines in coral reef habitat and has experienced recurring episodes of severe blast fishing; these outcomes are attributed to a lack of leadership and failure to engage the public (Hughes, Huang, & Young, 2013), and a lack of fisher involvement in fisheries management (Chan & Hodgson, 2017). In contrast, the Solomon Islands, the Philippines, Tanzania and Indonesia have all to a greater or lesser degree adopted CBM schemes, often with the aim of improving social and economic outcomes for resource users and simultaneously reducing the need for enforcement efforts. In countries where formal institutions are weak or ineffective, CBM can be effective in extending and improving marine resource management (Gorris, 2016).

Ostrom's theory of common-pool resources has been highly influential. It argues that sustainable social-ecological systems often require a multi-tiered approach to governance that actively incorporates the priorities and needs of resource users and involves them in the planning and administering of management schemes (Ostrom, 2009). Today, CBM schemes are widespread throughout coastal fisheries but discussion is ongoing as to what degree this leads to positive outcomes for conservation. Fisheries governance is influenced by a wide range of internal, external, social and environmental factors which operate on different temporal and spatial scales, such as the predictability of a system, the information available concerning human-environment interactions and the degree of conflict or complexity in the existing governance structures (Dietz, Ostrom, & Stern, 2003). Therefore, it is not surprising that diverse results have been obtained on the outcomes of CBM in coastal fisheries, and although the vast majority do identify major flaws in the current schemes, the solutions to these perceived shortcomings vary wildly.

A four-year study in Indonesia recommended increasing community involvement in existing CBM programs as a solution to the ongoing problems with destructive fishing, extensive rule breaking and fisher economic vulnerability (Glaser et al., 2015). Another Indonesian study offered more restrained approval, arguing that although CBM shows promise in controlling blast fishing, the challenges facing such programs are extensive and often out of the users' control, including the remoteness of many coastal fisheries and access rights that are neither clearly defined nor adequately enforced (Gorris, 2016). Blast fishing remains a common occurrence in Indonesian waters, despite widespread CBM programs. In Tanzania, current community-led initiatives to combat blasting have been unsuccessful in the absence of efficient government action (Katikiro & Mahenge, 2016). In both Kenya and the Solomon Islands, relying solely on traditional social controls to ensure the sustainability of local fisheries and reef ecosystems was shown to be inadequate and ineffective (McClanahan, Glaesel, Rubens, & Kiambo, 1997; Sulu et al., 2015). Many CBM models assume pre-existing traditional access rights and area closures and rely on the reinforcement of these to be successful, and when these are not present to begin with or become disregarded in modern communities, management efforts are likely to fail.

A study of the effect of collaborative fisheries management in five countries on user livelihoods, compliance and fishery exploitation found that slightly more than half of respondents found co-management beneficial to their livelihoods (Cinner et al., 2012). Nearly 90% of respondents reported near or full compliance with regulations, and that fish biomass was higher in co-managed fisheries than those with no local management (but lower than in no-take areas). These results give some hope that CBM can produce positive social and ecological outcomes even in challenging institutional settings but they also emphasise the complexity of these arrangements and the necessity of context-specific solutions to ensure that resources are harvested sustainably. Governance and blast fishing are likely strongly interlinked, but management frameworks must be constructed with multi-level political and social groups to ensure that long-term sustainable resource use goals are met.

2.5.2 Implications

2.5.2.1 Ecological

Ecological impacts of blast fishing dominated the literature included in this review with 60% of the papers having these as their primary focus; another 13% included these considerations along with other themes (Figure 1). Blast fishing is usually conducted using homemade 0.5-1 kg bombs which are thrown overboard onto schools of fish or reefs. This review focuses on blasting on reefs and associated species, but there is a knowledge gap in regards to the impacts of blasting on free-schooling fish, upon which there has been even less research conducted than on reefs and reef species. Depending on the size of the bomb and the topography, one blast creates a 0.5-1.5 m wide crater in the substrate and damages or destroys scleractinian coral species (Fox et al., 2003; Riegl & Luke, 1999). Simulations using 14 years of data conducted in the Philippines have suggested that blasting can reduce the growth capacity of scleractinian corals by up to one third when compared to areas without disturbances (McManus, Reyes Jr, & Nanola Jr, 1997). The same model found that smaller sparser coral patches are less susceptible to blasting damage, and it could be therefore inferred that over time, the effect of blasting on total coral cover would be reduced as corals diminished. Blasting itself could also be assumed to reduce as coral density declines and profits decrease.

However, the impacts of blasting on reefs are likely non-linear due to the disruptive effect of unstable coral rubble on new coral recruits, and at the point where a blasted reef has lost all structural complexity, a phase shift occurs. Shifting fields of rubble prevent hard coral recruits from settling and growing, making natural regeneration and recovery of the reefs a difficult or impossible task (Fox & Caldwell, 2006; Raymundo, Maypa, Gomez, & Cadiz, 2007). The Philippine simulation was supported by longitudinal studies in Indonesia, in which current strength was negatively associated with reef recovery (Fox et al., 2003). While single blasts had minimal long-term effects, chronic blasting and the resulting rubble resulted in little to no natural recovery over the five years of data collection. Rapid recovery of branching hard corals following near total destruction has been observed in partially protected reefs (Alcala, 2000). However, some blasted reefs have shown no signs of recovery, with natural regeneration estimated to require decades if not centuries (Riegl & Luke, 1999). Recovery of blasted reefs is highly variable and depends on reef type, degree of shelteredness, level of initial destruction and the degree to which it is protected following blasting or other disturbances. Other fishing gears such as bottom trawling nets also devastate benthic communities and disturb marine life, are far more widely used and could therefore be argued to have a broader net negative impact. However, for some coral and coral-dependent species, blasting has arguably the more devastating effect on the immediate local level and is viewed as a particularly destructive fishing gear (FAO & UNEP, 2010; Tudela, 2004). In addition to directly destroying coral reefs and associated species, blast fishing indirectly affects apex predators by reducing available food resources and breeding grounds (Tudela, 2004).

Compounding the problems with natural recovery following extensive blasting disturbances are the difficulties faced in reef restoration. Although there has been substantial research on restoring reefs damaged by blast fishing, they mostly rely on the manual transfer of hard coral recruits to blasted areas (Gomez, Yap, Cabaitan, & Dizon, 2011), or the installation of frames to stabilise the rubble (costing approx. $US25/m^2$) (Williams et al., 2018). Although these costs may seem trivial for developed countries, blasting occurs almost exclusively in developing nations. These techniques do show some success, but are time-consuming, cost-intensive and have yet to develop into widespread large-scale operations (de la Cruz, Villanueva, & Baria, 2014; Fox, Mous, Pet, Muljadi, & Caldwell, 2005), with some isolated exceptions (Williams et al., 2018).

As for the effect on coral reef fish, a single blast will kill virtually all organisms at the epicentre of the blast and rupture the swim bladders of fish within the lethal zone of the explosion pressure wave, a diameter of approximately 10 metres around the blast, depending on local topography and bomb strength (Alcala, 2000). Organisms without swim bladders - such as crustaceans - are more resistent to the pressure changes, as are cylindrical fish with open, thicker-walled swim bladders, but these may still be killed or injured (Calud et al., 1989). Moreover, habitat quality (as measured by coral diversity and rugosity) is positively linked to species richness and abundance (Tyler, Manica, Jiddawi, & Speight, 2011), as well as biomass (Ainsworth et al., 2008) and mean length, particularly of herbivores (Rogers, Blanchard, & Mumby, 2018). Although not all studies have directly studied the impacts of blasting on biological markers such as abundance and diversity (e.g. Friedlander & Parrish, 1998; Knudby, LeDrew, & Brenning, 2010), the degradation to the reef habitat from blasting has been well established (e.g. Fox et al., 2003), and therefore these studies that focus on rugosity and its impact on various markers remain relevant despite not focusing on blasting per se.

Therefore, blast fishing is a threat to coral reef ecosystem biodiversity and resilience, especially when considered in combination with other threats such as ocean acidification, pollution, sea-level rise, rising water temperatures and coastal development. Reef Check survey data showed blasting damage reduced from its maximum recorded level in 1998 to its lowest point in 2010. However, between 2010 and 2015 the level of damage nearly tripled (Reef Check 2018). Although there was considerable among-country and among-reef variation, these data highlight a worrying trend when viewed in the light of the limited recovery possibilities for damaged reefs and climactic impacts. Climate change, as a whole, presents a formidable threat to coral reefs, and this threat is intensified when reefs experience significant disruptions through destructive fishing (Cinner et al., 2013; Hoegh-Guldberg et al., 2007).

2.5.2.2 Economic

Papers focusing on economic implications of blast fishing comprised 5.6% of the literature (Figure 1), and a further 26.4% included economic implications as part of their discussion. Of the 11 papers focusing primarily on economic considerations, three analysed tourism development as a means to combat blasting (Cushnahan, 2001; Steenbergen, 2013; Teh & Cabanban, 2007), three the net benefits and losses associated with blasting (Cesar, 1996; Cesar et al., 1997; Pet-Soede et al., 1999), and one compared the costs of deterrence measures and rehabilitation (Haisfield et al., 2010). The literature generally concentrated on Indonesia, with a further two studies carried out in Malaysia and Papua New Guinea. The most frequently cited paper on economic impacts found that in Indonesia, blast fishing provides short-term financial benefits to blast fishers. However, this paper also argued that society as a whole incurs significantly higher costs than benefits over a 20-year period, in the form of foregone income from sustainable fisheries and coastal tourism and the loss of coral reef coastal protection. (Pet-Soede et al., 1999). The paper assessed small-, medium- and large-scale operations and found that blasting incomes were comparable to the highest incomes amongst fishers using conventional legal methods. Their description of the gear used by these blasting operations and their scope was echoed by a more recent assessment of blasting across Southeast Asia (Chan & Hodgson, 2017). An earlier analysis, also conducted in Indonesia, concluded that the projected foregone income over 25 years from sustainable fisheries production alone was approximately six times higher than the net private benefits accrued from blasting (Cesar, Lundin, Bettencourt, & Dixon, 1997). The disparity between private benefits and societal losses was particularly wide in areas where coral reefs had the potential to contribute income through tourism. However, in addition to blasting there remain significant challenges to ecotourism including lack of infrastructure and capital, and it did not emerge as a viable broad-scale solution to blasting.

A more nuanced picture of the economic aspects of blasting is offered by distinguishing between the profits produced by targeted versus random blasting, as well as among small-, medium- and large-scale blasting operations. While there has been little research conducted on the ecological impacts of blasting schooling fish, the economic impacts are somewhat clearer. Targeted blasts on schooling fish have the potential to generate substantial profits, well above those gained using traditional methods, whereas random blasts (particularly those conducted on already damaged reefs) can leave fishers with a net loss (Fox & Erdmann, 2000; Pet-Soede & Erdmann, 1998). Small-scale blast fishers are usually restricted to nearshore reefs which are likely already damaged, and may work alone or in pairs, leading to less targeted blasting and less efficient catch retrieval, and therefore lower incomes relative to middle- and large-scale operations. It should be noted that the available data are sparse and overwhelmingly concentrated on Indonesia, and therefore cannot be extrapolated to other countries without caution. However, the literature concurs that in the absence of adequate enforcement, blasting is generally more profitable than legal methods (Bailey & Sumaila, 2015). There remain significant gaps as regards other blast fishing epicentres such as Malaysia, the Philippines and Tanzania. Blast fishing seems to have decreased in Tanzania in the past five years (Rubens, 2019), but media reports point to blasting as an ongoing problem in Malaysia, Indonesia and the Philippines, as well in South American nations (Almendral, 2018; Carrere, 2020; Geraldine, 2017; Khan, 2019; Morse, 2018).

Recent studies have revealed the effect of disturbances on coral reef fishery productivity. One model showed that production is a quadratic function of structural complexity, whereby productivity initially increases as the reef shifts from coral to algal turf and becomes dominated by invertebrates, and then further increases as branching corals are lost. However, as standing dead coral disintegrates and rugosity declines to zero, productivity drops, at which point the absolute difference in productivity between a healthy and destroyed reef is 35% (Rogers et al., 2018). The model therefore shows that reef fisheries have an initial robustness in the face of reef degradation, mainly due to the increased biomass of herbivores. However, this robustness is likely short-lived, as standing dead coral is much more vulnerable to further disturbances than intact; precipitous drops in both biomass and productivity are then likely. This is an interesting parallel to the inverse quadratic association found between fish biomass and socioeconomic development (Cinner et al., 2009), and further investigation may shed light on the complex relationships between development and fishery sustainability.

Another social-ecological study modelled the interactions in a reef fishery between fish stocks and fishing intensity, and found that when social and ecological components are subject to strong feedbacks, their responses (in the form of available fish biomass and fishing intensity) become increasingly unstable and non-linear (Hughes et al., 2017). The authors argued that while degraded fisheries may recover if fishing intensity drops, in the near future a more likely scenario is that even as fish biomass decreases, fishing intensity will remain high, leading to faster rates of fish stock degradation. It seems that although blasting may offer short-term benefits to fishers when reefs are intact or only slightly degraded, these profits will quickly decline as reef complexity and health decreases. The long-term economic impact of extensive blasting can therefore be catastrophic to communities dependent on marine resources, albeit offering short-term individual benefits.

2.5.3 Solutions

2.5.3.1 Deterrence measures

Deterrence measures or enforcement are an essential part of any program to prevent blasting and other destructive fishing. There were 37 papers that discussed deterrence measures in some capacity, and of these 12 directly assessed the effectiveness of deterrence measures in five countries. Seven papers found the deterrence measures under review to be effective, two found the measures to be effective under specific or limited circumstances, and the remaining three the measures to be ineffective (Table 2). These mixed results highlight the complexities faced in coastal fisheries management, which often takes place in developing countries with limited funding and capacity for resource management. Although directly comparing deterrence measures across fisheries is difficult due to a lack of data on density of blasting versus density of deterrence measures, common themes among the papers reporting successful deterrence include regular patrols and strictly enforced penalties. In contrast, papers that found deterrence measures to be unsuccessful reported inconsistent enforcement efforts and a lack of infrastructure and funding (Table 2).

Although measures that encourage compliance with regulations are important to ensure long-lasting sustainable fisheries management, enforcement is a crucial element in managing and preventing blasting, as it creates a disincentive to engage in destructive fishing. This disincentive is necessary precisely because of the ease and profitability of blasting: without enforcement of some kind, blasters are unlikely to shift voluntarily to legal methods (Pet-Soede et al., 1999). Bioeconomic modelling provides a starting point to understanding how monitoring efforts and punishment levels should be calibrated to maximise the often limited resources in coastal reef fisheries while also producing the desired results. Because it is assumed that fines are costless while monitoring is costly, deterrence models often recommend that fines be set as high as possible and monitoring minimised to achieve an efficient response. This ignores the realities of coastal fisheries, many of which are in developing countries. The application of fines is not "costless", particularly where judiciary systems are weak and avoidance activities are common and exacerbated by corruption (Katikiro & Mahenge, 2016). In contrast with the assumption that illegal fishers are rational economic agents who aim to maximise profit, perceptions of regulation legitimacy also influence compliance (Akpalu, 2008). Monitoring is therefore an important component in enforcement, particularly as fishers are more sensitive to the risk of detection than the severity of punishment (Akpalu, 2008).

An Indonesian model also found that the probability of detection is more important than the fine, and that fines must not exceed what fishers can reasonably pay (Bailey & Sumaila, 2015). Other real-life examples of the effectiveness of patrolling abound: in Komodo National Park in Indonesia, weekly government-NGO patrols reduced the incidence of blasting by 75% in one year (Fox et al., 2005); in northern Tanzania, 6 patrol bases staffed by community members and navy personnel virtually eliminated dynamiting over eight years (Verheij, Makoloweka, & Kalombo, 2004); and more recently in Tanzania, regular government patrols, sporadic naval enforcement actions and political pressure have also reduced blasting to almost non-existent levels over a four year period (Rubens 2019; Tanzania Blast-Fishing Monitoring Network, 2018). In general, countries with higher levels of monitoring, surveillance and enforcement experience less destructive fishing (Petrossian, 2015). The cessation of enforcement also leads to reinvigorated blasting activities, for example in Hong-Kong (Chan & Hodgson, 2017). Finally, although society undoubtedly incurs higher costs through conducting patrols and monitoring activities than in simply legislating for higher fines, reef rehabilitation has been found in Indonesia to be between five and 70 times more costly than preventing reef destruction through enforcement (Haisfield et al., 2010).

The difficulties lie in determining what level of ongoing enforcement and monitoring is needed, and which parties are best suited to carry out these activities. Enforcement schemes must be seen as equitable and fair in order to be successful (Akpalu, 2008; Pomeroy et al., 2015). However, equity and fairness are culturally and socially defined, and so solutions that work for one fishery may be inappropriate for another. Consistency is also key: a survey of Tanzanian fishers' perceptions of recurring blast fishing found that 48% agreed that enforcement does lead to a reduction in blasting, but that inconsistency in enforcement efforts and variable motivation and interests of the enforcers and government has led to only partial success and ongoing blasting (Katikiro & Mahenge, 2016).

The final component is to determine whether community-based or national monitoring will be most effective for a given fishery. Community-based monitoring can be an effective part of enforcement programs, but is likely to work best in small-scale fishery settings where offenders run small operations (Cesar et al., 1997). Where blasting operates on a medium- or large-scale and particularly where offenders may originate from other regions or countries, a nationally coordinated approach is necessary, as demonstrated most recently in Tanzania (Rubens 2019). Communities also require adequate resources such as appropriate vessels and communication devices if they are to contribute in a meaningful way to enforcement. Effective enforcement is essential; however enforcement methods tend to be location-specific, making it difficult to generalise about the most successful approaches due to the complex social, economic, cultural and political factors at play.

2.5.3.2 Economic incentives

If enforcement is the stick of a blasting prevention system, economic incentives are the carrot: they encourage compliance with regulations and are vital to ensuring long-term success in combating blasting. The literature focused on alternative income generating activities (AIGA), which are predicated on developing alternatives to destructive or intensive fishing in order to change fisher behaviour and thereby reduce pressure on the fishery and increase sustainability (Niesten, Gjertsen, & Fong, 2013). Three criteria are essential for the success of AIGA: i) clearly defined property rights; ii) equitable distribution of benefits; and iii) sustainable financing mechanisms (Mohammed & Wahab, 2013). The literature includes numerous small-scale studies and grey literature and has produced mixed results, suggesting that the success or failure of alternative livelihood programs is dependent on localised environmental, social, economic and cultural factors. A total of six papers discussed AIGA, of which two found direct support that AIGA reduce use of destructive fishing gear (Chan & Hodgeson, 2017; Silva, 2006), one found tangential support (Pollnac, Crawford, & Gorospe, 2001), one found AIGA to be ineffective (Slade & Kalangahe, 2015), and two the success of AIGA to be context dependent (Cesar et al., 1997; Ireland 2004). A regional analysis of countries in the Western Indian Ocean identified capital accessibility, economic vulnerability, institutional frameworks and governance as being crucial in understanding household livelihood strategies (Ireland, 2004). A study in the Philippines found that integrating local livelihood priorities with conservation objectives is a significant predictor for the success of MPAs (Pollnac et al., 2001). The degree of dependence on marine resources is negatively correlated with standing fish biomass in protected areas, providing theoretical support for AIGA as part of the strategy to increase fishery sustainability (Cinner et al., 2012).

However, alternative livelihood programs usually focus on local fishers, and as blasters are often outsiders, these programs are effectively rendered ineffectual. Additionally, the challenges facing AIGA implementation are considerable: data on household livelihoods are often limited, target communities are often reluctant to adopt risky livelihoods requiring capital or specialised knowledge and AIGA programs typically require years of investment and support before they are self-sustaining (Ireland, 2004). Successful case studies do exist (Mohammed & Wahab, 2013), but reports of long-term successful AIGA are rare. Moreover, longitudinal analyses or BACIP evaluation designs which would greatly contribute to evaluations of AIGA are also rare (McClanahan et al., 2015). We therefore argue that although AIGA can undoubtedly succeed given the right conditions, the complex nature of these programs means that other solutions may offer a more direct route to combat blasting and conserve marine resources.

2.5.3.3 CBM and MPAs

The third broad solution to blasting is the designation of MPAs with a CBM component, which can regulate resource extraction, promote conservation and protect local livelihoods in an equitable and sustainable fashion. About one-third of the literature focused on the socio-political structures surrounding blasting, specifically governance structures for fishing communities and marine resources (Figure 1). Of these papers, 30 addressed CBM and MPAs as a means of marine resource management, and ten specifically assessed the effectiveness of MPAs in reducing blasting. Five papers found that MPAs, often in conjunction with enforcement efforts and CBM, were effective, four papers concluded that the MPAs under review were either ineffective or even had a net negative effect on communities and ecosystems, and one had mixed results (Table 3).

MPAs have become a prominent tool for the management and preservation of marine resources, and their number and scope have expanded significantly in recent years (Hargreaves-Allen, Mourato, & Milner-Gulland, 2017). There is substantial research to suggest that indicators of reef health such as coral and fish biodiversity, density and abundance are better within regulated or no-take zones than outside them (Daw, Cinner, McClanahan, Graham, & Wilson, 2011; Kamukuru, Mgaya, & Öhman, 2004; McClure et al., 2020; Tyler et al., 2011). However, criticisms of MPAs are numerous, ranging from accusations of ineffective protection of marine resources and inconsistent management to allegations of post-colonial forms of control that fail to include local priorities and perspectives (Elliott, Mitchell, Wiltshire, Manan, & Wismer, 2001; Glaser et al., 2015; Kamat, 2014). Some MPAs with CBM do incorporate traditional access rights and gear restrictions; however, issues with communication, equitable access and long-term adherence to marine resource rules have plagued many programs (Campbell, Cinner, et al., 2012; Campbell, Hoey, et al., 2012).

Broadly speaking, a successful MPA will also mean the success of anti-blasting initiatives, and so we focused on the aspects of MPAs that encouraged compliance with regulations and discouraged destructive behaviours. Compliance was positively associated with graduated sanctions, whereby areas are zoned variously as no-take, restricted and open (Cinner et al., 2012). Fish biomass was also strongly influenced by the distance to markets, suggesting that as the potential for commercial benefit decreases, so does resource extraction. Surprisingly, endogenous factors such as permanent community organisations, clearly defined access rights, higher budget and increased research activity did not lead to improved socioeconomic or ecological indicators (Cinner et al., 2012; Hargreaves-Allen et al., 2017; McClanahan & Abunge, 2018). These findings seem to suggest that management does not impact conservation outcomes, and that geographical and market driven factors have greater influence on the status of marine ecosystems. However, other studies show that human elements within these social-ecological systems are relevant to conservation outcomes. Global studies have found that fish biomass in MPAs is positively related to the perceived legitimacy of management processes, effectiveness of monitoring, and clearly defined boundaries (Pollnac et al., 2010), as well as enforcement and consistency of monitoring (Daw et al., 2011). Conversely, adherence to rules declines when immediate benefits are not seen by fishing communities (Gorris, 2016), an important factor to consider when implementing and monitoring CBM programs in MPAs. The level of formal education within a community may have a small positive effect on perceived benefits (Baticados & Agbayani, 2000; Cinner & Pollnac, 2004), but targeting education without addressing ongoing conflicts over resource use and the influence of market-driven factors is unlikely to lead to success (McClanahan, Cinner, Kamukuru, Abunge, & Ndagala, 2009).

As for the environmental awareness training offered in many CBM programs, their influence is difficult to measure due to haphazard implementation (McClanahan et al., 2015). Positive reports citing the increased involvement of fishers in combating blast fishing following awareness training are matched with criticisms of the inaccessibility, irrelevance and ineffectiveness of such programs. Given their ubiquity, further research is needed in this field. In east Africa, factors such as wealth, occupation, geographic isolation, distance to markets and level of dependence on marine resources increase the among-community and within-community variation in perceptions of MPAs, even when communities fall under the same management umbrellas (McClanahan & Abunge, 2018). Positive perceptions of spatial, catch and gear restrictions create an environment that is conducive to compliance. In contrast, a small number of individuals practising destructive fishing can cause disproportionate damage to coral reef ecosystems and ultimately undermine the long-term success of MPAs if not prevented or penalised, even if the majority of inhabitants agree and comply with restrictions. Therefore, policies and structures that encourage positive perceptions of MPA benefits across the community are important, and the goal of reducing variability of perceptions within and among communities should be taken into account when implementing management and deterrence programs against blasting. Seen in this light, context-specific MPA frameworks emerge not as an optional extra but as an essential ingredient for MPA success. MPAs and CBM programs are vital tools to control and prevent blasting, but are strongly influenced by a multitude of localised factors that lead them to flourish or fail.

2.6 CONCLUSION

Our review of blast fishing identified its historical and current dispersion, and found that it remains a threat to coral reef ecosystems and the sustainability of local fishing livelihoods. We analysed poverty as a driver for both the uptake of and ongoing nature of blasting, and found that although poverty may be a contributing factor, it is unlikely to be the sole or dominant predictor. Conversely, effective enforcement and appropriate governance structures are positively related to a reduction in blasting, as effective monitoring and sanctions lead to higher compliance with gear and spatial restrictions. There was general consensus on the destructive ecological impacts of blast fishing and the highly limited ability of coral reefs to recover naturally from blasting. Large-scale coral restoration projects are limited by the time and expense involved, and therefore preventing damage from occuring is more cost-effective than rehabilitating reefs. Economic analyses showed that while blasting initially delivers substantial private benefits to fishers, that society as a whole experiences significant costs in the form of foregone income from tourism and legal fishing, as well as lost ecosystem services. Fisheries may be initially robust in the face of blasting, but productivity is predicted to drop precipitously as structural complexity is lost, thus also eroding lucrative private benefits from blasting. We conclude therefore that blasting has a net negative economic impact on fishers and the broader community.

We assessed the three most common solutions to blasting in the literature: i) increased or improved deterrence measures; ii) economic incentives; and iii) CBM and MPAs. Whether deterrence efforts are conducted by governments, communities or a combination thereof, equity, consistency and perceived legitimacy of the processes emerged as key components. The primary economic incentive used in blast fishing areas is AIGA; we found that despite the good intentions of such programs, the significant challenges in implementing appropriate and long-lived AIGA render this solution less effective than others. The success of MPAs and CBM is dependent on the perceived legitimacy of the development and implementation process, clearly defined reserve boundaries, consistent and effective monitoring and characteristics of resource user characteristics such as wealth. Incorporating traditional or customary management programs show varying degrees of success, and is again highly dependent on implementation methods for their ongoing effectiveness in conserving reefs and ensuring livelihood sustainability. The best approach to long-term management of blasting is therefore a combination of enforcement and MPAs developed in accordance with local users, as the ability of management systems to safeguard local livelihoods leads to better compliance and, ultimately, to better conservation outcomes. This should provide the consistency needed in enforcement as well as the context-dependent modifications to programs that are necessary for sustainable fisheries and conservation. In conclusion, blast fishing does not occur in a vacuum: centred on areas with an abundance of easily accessible coral reefs, the practice is complex and is influenced by a wide variety of social, cultural and environmental factors. The solutions to blast fishing must therefore also incorporate these factors if they are to be successful. Gathering data on all aspects of blast fishing will improve our ability to conserve coral reef ecosystems, bolster food security and support human and reef resilience, and should therefore be a priority for future research.

2.7 REFERENCES

Abraham, R. K., & Kelkar, N. (2012). Do terrestrial protected areas conserve freshwater fish diversity? Results from the Western Ghats of India. Oryx, 46(4), 544-553. doi:10.1017/S0030605311000937

Ainsworth, C. H., Varkey, D. A., & Pitcher, T. J. (2008). Ecosystem simulations supporting ecosystem-based fisheries management in the Coral Triangle, Indonesia. *Ecological Modelling, 214*(2-4), 361-374. doi:10.1016/j.ecolmodel.2008.02.039

Akpalu, W. (2008). Fishing regulations, individual discount rate, and fisherman behaviour in a developing country fishery. *Environment and Development Economics*, *13*(5), 591-606.

Alcala, A. C. (2000). Blast fishing in the Philippines, with notes on two destructive fishing activities. *Silliman Journal, 41*(2), 27-47.

Almendral, A. (2018). In the Philippines, Dynamite Fishing Decimates Entire Ocean Food Chains. *The New York Times*. Retrieved from www.nytimes.com/2018/06/15/world/asia/philippines-dynamite-fishing-coral.html

Arai, T. (2015). Diversity and conservation of coral reef fishes in the Malaysian South China Sea. *Reviews in Fish Biology and Fisheries, 25*(1), 85-101. doi:10.1007/s11160-014-9371-9

Bailey, M., & Sumaila, U. R. (2015). Destructive fishing and fisheries enforcement in eastern Indonesia. *Marine Ecology Progress Series, 530*, 195-211. doi:10.3354/meps11352

Baticados, D. B., & Agbayani, R. F. (2000). Co-management in marine fisheries in Malalison Island, central Philippines. *International Journal of Sustainable Development & World Ecology, 7*(4), 343-355. doi:10.1080/13504500009470053

Benson, C. (2012). Conservation NGOs in Madang, Papua New Guinea: Understanding Community and Donor Expectations. Society & Natural Resources, 25(1), 71-86. doi:10.1080/08941920.2011.603141

Booth, A. (2019). Measuring poverty and income distribution in Southeast Asia. *Asian-Pacific Economic Literature, 33*(1), 3-20. doi:10.1111/apel.12250

Burke, L., Reytar, K., Spalding, M., & Perry, A. (2011). *Reefs at Risk Revisited*. Washington, DC.

Calud, A., Rodriguez, G., Aruelo, R., Aguilar, G., Cinco, E., Armada, N., & Silvestre, G. (1989). Preliminary Results of a Study of the Municipal Fisheries in Lingayen Gulf. In G. Silvestre, E. Miclat, & T. E. Chua (Eds.), *Towards Sustainable Development of the Coastal Resources of Lingayen Gulf, Philippines* (Vol. 17, pp. 43-62).

Campbell, S. J., Cinner, J. E., Ardiwijaya, R. L., Pardede, S., Kartawijaya, T., Mukmunin, A., . . . Baird, A. H. (2012). Avoiding conflicts and protecting coral reefs: customary management benefits marine habitats and fish biomass. *Oryx, 46*(04), 486-494. doi:10.1017/s0030605312000348

Campbell, S. J., Hoey, A. S., Maynard, J., Kartawijaya, T., Cinner, J., Graham, N. A. J., & Baird, A. H. (2012). Weak Compliance Undermines the Success of No-Take Zones in a Large Government-Controlled Marine Protected Area. *PLoS ONE, 7*(11). doi:10.1371/journal.pone.0050074

Carrere, M. (2020). Bringing rocks to a dynamite fight: Fishers take on blast fishing in Peru. Retrieved from www.news.mongabay.com/2020/01/bringing-rocks-to-a-dynamite-fight-fishers-take-on-blast-fishing-in-peru/

Cesar, H. (1996). Economic Analysis Of Indonesian Coral Reefs, World Bank. 103 pp.
Cesar, H., Lundin, C. G., Bettencourt, S., & Dixon, J. (1997). Indonesian coral reefs - an economic analysis of a precious but threatened resource. *Ambio, 26*(6), 345-350.
Chan, A., & Hodgson, P. A. (2017). *A systematic analysis of blast fishing in South-East Asia and possible solutions.* Paper presented at the 2017 IEEE OES International Symposium on Underwater Technology, UT 2017.
Chou, L. M., Tuan, V. S., Yeemin, T., Cabanban, A., Suharsono, & Kessna , I. (2002). Status of Southeast Asia Coral Reefs. In *Status of Coral Reefs of the World: 2002*, ed. Clive Wilkinson, Australian Institute of Marine Science. Townsville, Queensland. Chapter 7, pp 123-152.
Cinner, J., McClanahan, T., Wamukota, A., Darling, E., Humphries, A., Hicks, C., . . . Allison, E. (2013). *Social-ecological vulnerability of coral reef fisheries to climatic shocks* Rome, Italy.
Cinner, J. E. (2010). Poverty and the use of destructive fishing gear near east African marine protected areas. *Environmental Conservation, 36*(04), 321-326. doi:10.1017/s0376892910000123
Cinner, J. E., McClanahan, T. R., Daw, T. M., Graham, N. A. J., Maina, J., Wilson, S. K., & Hughes, T. P. (2009). Linking Social and Ecological Systems to Sustain Coral Reef Fisheries. *Current Biology, 19*(3), 206-212. doi:10.1016/j.cub.2008.11.055
Cinner, J. E., McClanahan, T. R., MacNeil, M. A., Graham, N. A., Daw, T. M., Mukminin, A., . . . Jiddawi, N. (2012). Comanagement of coral reef social-ecological systems. *Proceedings of the National Academy of Sciences, 109*(14), 5219-5222. doi:10.1073/pnas.1121215109
Cinner, J. E., & Pollnac, R. B. (2004). Poverty, perceptions and planning: why socioeconomics matter in the management of Mexican reefs. *Ocean & Coastal Management, 47*(9), 479-493. doi:10.1016/j.ocecoaman.2004.09.002
Costanza, R., de Groot, R., Sutton, P., van der Ploeg, S., Anderson, S. J., Kubiszewski, I., . . . Turner, R. K. (2014). Changes in the global value of ecosystem services. *Global Environmental Change, 26*, 152-158. doi:10.1016/j.gloenvcha.2014.04.002
Cushnahan, G. (2001). Resource use and tourism on a small Indonesian island. *Tourism Recreation Research, 26*(3), 25-31.
Daw, T. M., Cinner, J. E., McClanahan, T. R., Graham, N. A. J., & Wilson, S. K. (2011). Design Factors and Socioeconomic Variables Associated with Ecological Responses to Fishery Closures in the Western Indian Ocean. *Coastal Management, 39*(4), 412-424. doi:10.1080/08920753.2011.589224
de la Cruz, D. W., Villanueva, R. D., & Baria, M. V. B. (2014). Community-based, low-tech method of restoring a lost thicket of Acropora corals. *ICES Journal of Marine Science / Journal du Conseil, 71*(7), 1866-1875.
Dietz, T., Ostrom, E., & Stern, P. C. (2003). The struggle to govern the commons. *science, 302*(5652), 1907-1912.
Dunning, K. H. (2015). Ecosystem services and community based coral reef management institutions in post blast-fishing Indonesia. Ecosystem Services, 16, 319-332. doi:10.1016/j.ecoser.2014.11.010
Elliott, G., Mitchell, B., Wiltshire, B., Manan, I. A., & Wismer, S. (2001). Community participation in marine protected area management Wakatobi National Park, Sulawesi, Indonesia. *Coastal Management, 29*(4), 295-316. doi:10.1080/089207501750475118

Fauzi, A., & Buchary, E. A. (2002). A Socioeconomic Perspective of Environmental Degradation at Kepulauan Seribu Marine National Park, Indonesia. *Coastal Management, 30*(2), 167-181. doi:10.1080/089207502753504698
Fisheries and Agriculture Organisation (FAO) & United Nations Environmntal Programme (UNEP). (2010). *Report of the FAO/UNEP expert meeting on impacts of destructive fishing practices, unsustainable fishing, and illegal, unreported and unregulated (IUU) fishing on marine biodiversity and habitats.* 23–25 September 2009. FAO Fisheries and Aquaculture Report. Rome. 32 pp.
Flores, E., & Silvestre, G. (1987). Community-based coral reef fishery resource management in the Philippines: the Balicasag Island experience. Paper presented at the Proceedings of the Symposium on the Exploitation and Management of Marine Fishery Resource in Southeast Asia, Sess. 16. FAO.
Fox, H. E., & Caldwell, R. L. (2006). Recovery from blast fishing on coral reefs: a tale of two scales. *Ecological Applications, 16*(5), 1631-1635.
Fox, H. E., & Erdmann, M. V. (2000). Fish yields from blast fishing in Indonesia. *Coral Reefs, 19*(2), 114. doi:10.1007/s003380000094
Fox, H. E., Mous, P. J., Pet, J. S., Muljadi, A. H., & Caldwell, R. L. (2005). Experimental Assessment of Coral Reef Rehabilitation Following Blast Fishing. *Conservation Biology, 19*(1), 98-107. doi:10.1111/j.1523-1739.2005.00261.x
Fox, H. E., Pet, J. S., Dahuri, R., & Caldwell, R. L. (2003). Recovery in rubble fields: long-term impacts of blast fishing. *Marine Pollution Bulletin, 46*(8), 1024-1031. doi:10.1016/s0025-326x(03)00246-7
Francis, J., Wagner, G. M., Mvungi, A., Ngwale, J., & Salema, R. (2002). *Tanzania National Report – Phase 1: Integrated Problem Analysis* www.researchgate.net/publication/268054477_Tanzania_National_Report_-_Phase_1_Integrated_Problem_Analysis
Friedlander, A. M., & Parrish, J. D. (1998). Habitat characteristics affecting fish assemblages on a Hawaiian coral reef. *Journal of Experimental Marine Biology and Ecology, 224*(1), 1-30. doi:10.1016/S0022-0981(97)00164-0
Galvez, R., Hingco, T. G., Bautista, C., & Tungpalan, M. T. (1989). Sociocultural Dynamics of Blast Fishing and Sodium-Cyanide Fishing in Two Fishing Villages in the Lingayen Gulf Area. In G. Silvestre, E. Miclat, & T. E. Chua (Eds.), *Towards Sustainable Development of the Coastal Resources of Lingayen Gulf, Philippines* (Vol. 17, pp. 43-62).
Geraldine, A. (2017). Illegal foreign commercial fisherman resorting to fish bombing in Sabah waters. *New Straits Times*. Retrieved from www.nst.com.my/news/nation/2017/09/278886/illegal-foreign-commercial-fisherman-resorting-fish-bombing-sabah-waters
Glaser, M., Breckwoldt, A., Deswandi, R., Radjawali, I., Baitoningsih, W., & Ferse, S. C. A. (2015). Of exploited reefs and fishers - A holistic view on participatory coastal and marine management in an Indonesian archipelago. *Ocean & Coastal Management, 116*, 193-213. doi:10.1016/j.ocecoaman.2015.07.022
Gomez, E. D., Yap, H. T., Cabaitan, P. C., & Dizon, R. M. (2011). Successful Transplantation of a Fragmenting Coral, Montipora digitata, for Reef Rehabilitation. *Coastal Management, 39*(5), 556-574. doi:10.1080/08920753.2011.600240
Gorris, P. (2016). Deconstructing the Reality of Community-Based Management of Marine Resources in a Small Island Context in Indonesia. *Frontiers in Marine Science, 3*(120). doi:10.3389/fmars.2016.00120
Fisheries Act, (2003).

Guard, M., & Masaiganah, M. (1997). Dynamite fishing in southern Tanzania, geographical variation, intensity of use and possible solutions. *Marine Pollution Bulletin, 34*(10), 758-762.

Gurney, G. G., & Darling, E. S. (2017). *A Global Social-Ecological Systems Monitoring Framework for Coastal Fisheries Management: A Practical Monitoring Handbook* New York, USA.

Haisfield, K. M., Fox, H. E., Yen, S., Mangubhai, S., & Mous, P. J. (2010). An ounce of prevention: cost-effectiveness of coral reef rehabilitation relative to enforcement. *Conservation Letters, 3*(4), 243-250. doi:10.1111/j.1755-263X.2010.00104.x

Hargreaves-Allen, V. A., Mourato, S., & Milner-Gulland, E. J. (2017). Drivers of coral reef marine protected area performance. *PLoS ONE, 12*(6), e0179394. doi:10.1371/journal.pone.0179394

Hill, J., & Wilkinson, C. (2004). *Methods for Ecological Monitoring of Coral Reefs: A Resource For Managers* Townsville, Australia.

Hoegh-Guldberg, O., Mumby, P. J., Hooten, A. J., Steneck, R. S., Greenfield, P., Gomez, E., . . . Caldeira, K. (2007). Coral reefs under rapid climate change and ocean acidification. *science, 318*(5857), 1737-1742.

Hoegh-Guldberg, O., Kennedy, E. V., Beyer, H. L., McClennen, C., & Possingham, H. P. (2018). Securing a Long-term Future for Coral Reefs. Trends in Ecology & Evolution, 33(12), 936-944. doi:https://doi.org/10.1016/j.tree.2018.09.006.

Huber, M. E. (1994). An assessment of the status of the coral reefs of Papua New Guinea. *Marine Pollution Bulletin, 29*(1-3), 69-73. doi:10.1016/0025-326X(94)90428-6

Hughes, T. P., Barnes, M. L., Bellwood, D. R., Cinner, J. E., Cumming, G. S., Jackson, J. B., . . . Morrison, T. H. (2017). Coral reefs in the Anthropocene. *Nature, 546*(7656), 82-90.

Hughes, T. P., Huang, H., & Young, M. A. L. (2013). The Wicked Problem of China's Disappearing Coral Reefs. *Conservation Biology, 27*(2), 261-269. doi:10.1111/j.1523-1739.2012.01957.x

Hulsen, T., de Vlieg, J., & Alkema, W. (2008). BioVenn – a web application for the comparison and visualization of biological lists using area-proportional Venn diagrams. *BMC Genomics, 9*(1), 488. doi:10.1186/1471-2164-9-488

Hussain, S. M., Debashish, S., Toge, R., Mahesh, P., & Singh, R. K. (2016). Fishing in the Siang belt of Arunachal Pradesh, India: learning traditional ecological knowledge of Adi and Galo communities. *Indian Journal of Traditional Knowledge, 15*(4), 685-692.

Ireland, C. (2004). *Alternative Sustainable Livelihoods for Coastal Communities—A Review of Experience and Guide to Best Practice* Somerset.

Kamat, V. (2014). " The Ocean is our Farm": Marine Conservation, Food Insecurity, and Social Suffering in Southeastern Tanzania. *Human Organization, 73*(3), 289-298.

Kamukuru, A. T., Mgaya, Y. D., & Öhman, M. C. (2004). Evaluating a marine protected area in a developing country: Mafia Island Marine Park, Tanzania. *Ocean & Coastal Management, 47*(7-8), 321-337. doi:10.1016/j.ocecoaman.2004.07.003

Katikiro, R. E., & Mahenge, J. J. (2016). Fishers' Perceptions of the Recurrence of Dynamite-Fishing Practices on the Coast of Tanzania. *Frontiers in Marine Science, 3*. doi:10.3389/fmars.2016.00233

Khan, H. (2019). Fish Bombing: These fishermen use dynamite to put food on the table. Retrieved from www.sbs.com.au/news/dateline/fish-bombing-these-fishermen-use-dynamite-to-put-food-on-the-table

Knudby, A., LeDrew, E., & Brenning, A. (2010). Predictive mapping of reef fish species richness, diversity and biomass in Zanzibar using IKONOS imagery and machine-learning techniques. *Remote Sensing of Environment, 114*(6), 1230-1241. doi:10.1016/j.rse.2010.01.007

Levine, A. (2004). Local Responses to Marine Conservation in Zanzibar, Tanzania. Journal of International Wildlife Law & Policy, 7(3-4), 183-202. doi:10.1080/13880290490883241

Licuanan, W. Y., & Gomez, E. D. (2000). Philippine Coral Reefs, Reef Fishes, and Associated Fisheries: Status and Recommendations to Improve Their Management. Australian Institute of Marine Science. 51 pp.

Liquete, C., Piroddi, C., Drakou, E. G., Gurney, L., Katsanevakis, S., Charef, A., & Egoh, B. (2013). Current Status and Future Prospects for the Assessment of Marine and Coastal Ecosystem Services: A Systematic Review. *PLoS ONE, 8*(7), e67737. doi:10.1371/journal.pone.0067737

Marcus, J. E., Samoilys, M. A., Meeuwig, J. J., Villongco, Z. A. D., & Vincent, A. C. J. (2007). Benthic status of near-shore fishing grounds in the central Philippines and associated seahorse densities. *Marine Pollution Bulletin, 54*(9), 1483-1494. doi:10.1016/j.marpolbul.2007.04.011

McClanahan, T. R., & Abunge, C. A. (2018). Demographic variability and scales of agreement and disagreement over resource management restrictions. *Ecology and Society, 23*(4). doi:10.5751/ES-10544-230433

McClanahan, T. R., Cinner, J., Kamukuru, A. T., Abunge, C., & Ndagala, J. (2009). Management preferences, perceived benefits and conflicts among resource users and managers in the Mafia Island Marine Park, Tanzania. *Environmental Conservation, 35*(04). doi:10.1017/s0376892908005250

McClanahan, T. R., Donner, S. D., Maynard, J. A., MacNeil, M. A., Graham, N. A., Maina, J., . . . Darling, E. S. (2012). Prioritizing key resilience indicators to support coral reef management in a changing climate. *PLoS ONE, 7*(8), e42884.

McClanahan, T. R., Glaesel, H., Rubens, J., & Kiambo, R. (1997). The effects of traditional fisheries management on fisheries yields and the coral-reef ecosystems of southern Kenya. *Environmental Conservation, 24*(2), 105-120. doi:10.1017/S0376892997000179

McClanahan, T. R., Muthiga, N. A., Abunge, C., Kamukuru, A. T., Mwakalapa, E., & Kalombo, H. (2015). What happens after conservation and management donors leave? A before and after study of coral reef ecology and stakeholder perceptions of management benefits. *PLoS ONE, 10*(10). doi:10.1371/journal.pone.0138769

McClure, E. C., Sievers, K. T., Abesamis, R. A., Hoey, A. S., Alcala, A. C., & Russ, G. R. (2020). Higher fish biomass inside than outside marine protected areas despite typhoon impacts in a complex reefscape. *Biological Conservation, 241*, 108354. doi:10.1016/j.biocon.2019.108354

McManus, J. W. (1997). Tropical marine fisheries and the future of coral reefs: a brief review with emphasis on Southeast Asia. *Coral Reefs, 16*(1), S121-S127. doi:10.1007/s003380050248

McManus, J. W., Reyes Jr, R. B., & Nanola Jr, C. L. (1997). Effects of Some Destructive Fishing Methods on Coral Cover and Potential Rates of Recovery. *An International Journal for Decision Makers, Scientists and Environmental Auditors, 21*(1), 69-78. doi:10.1007/s002679900006

Mohammed, E. Y., & Wahab, A. (2013). *Direct economic incentives for sustainable fisheries management: the case of Hilsa conservation in Bangladesh.* London, UK.
Morse, I. (2018). Amid lack of enforcement, fishermen take the fight to blast fishing. *Mongabay*. Retrieved from www.news.mongabay.com/2018/10/amid-uneven-enforcement-fishermen-take-the-fight-to-blast-fishing/
Nafees, M., Ahmed, T., & Arshad, M. (2011). A Review of Kabul River Uses and Its Impact on Fish and Fishermen. *The Journal of Humanities and Social Sciences, 19*(2), 73-84.
Neumann, B., Vafeidis, A. T., Zimmermann, J., & Nicholls, R. J. (2015). Future Coastal Population Growth and Exposure to Sea-Level Rise and Coastal Flooding - A Global Assessment. *PLoS ONE, 10*(3), e0118571. doi:10.1371/journal.pone.0118571
Niesten, E., Gjertsen, H., & Fong, P. S. (2013). Incentives for marine conservation: options for small island developing states. *Environment and Development Economics, 18*(4), 440-458. doi:10.1017/S1355770X12000484
Norton-Kyshe, J. W. (1971 [1898]). *The History of the Laws and Courts of Hong Kong from the Earliest Period to 1898*. Michigan: Vetch and Lee (Noronha and Company, Hongkong).
Ostrom, E. (2009). A General Framework for Analyzing Sustainability of Social-Ecological Systems. *science, 325*(5939), 419-422.
Pauly, D., Silvestre, G., & Smith, I. R. (1989). On Development, Fisheries and Dynamite: A Brief Review of Tropical Fisheries Management. *Natural Resource Modeling, 3*(3), 307-329. doi:10.1111/j.1939-7445.1989.tb00084.x
Pet-Soede, C., Cesar, H. S. J., & Pet, J. S. (1999). An economic analysis of blast fishing on Indonesian coral reefs. *Environmental Conservation, 26*(2), 83-93. doi:10.1017/s0376892999000132
Pet-Soede, L., & Erdmann, M. (1998). An overview and comparison of destructive fishing practices in Indonesia. *SPC Live Reef Fish Information Bulletin, 4*, 28-36.
Petrossian, G. A. (2015). Preventing illegal, unreported and unregulated (IUU) fishing: A situational approach. *Biological Conservation, 189*, 39-48. doi:10.1016/j.biocon.2014.09.005
Pollnac, R., Christie, P., Cinner, J. E., Dalton, T., Daw, T. M., Forrester, G. E., . . . McClanahan, T. R. (2010). Marine reserves as linked social–ecological systems. *Proceedings of the National Academy of Sciences, 107*(43), 18262. doi:10.1073/pnas.0908266107
Pollnac, R., Crawford, B., & Gorospe, M. (2001). Discovering Factors that Influence the Success of Community-based Marine Protected Areas in the Visayas, Philippines. *Ocean and Coastal Management, 44*, 683-710.
Pomeroy, R., Parks, J., Reaugh-Flower, K., Guidote, M., Govan, H., & Atkinson, S. (2015). Status and Priority Capacity Needs for Local Compliance and Community-Supported Enforcement of Marine Resource Rules and Regulations in the Coral Triangle Region. *Coastal Management, 43*(3), 301-328. doi:10.1080/08920753.2015.1030330
Pullin, A. S., & Stewart, G. B. (2006). Guidelines for Systematic Review in Conservation and Environmental Management. *Conservation Biology, 20*(6), 1647-1656. doi:10.1111/j.1523-1739.2006.00485.x
R Core Team. (2017). R: A language and environment for statistical computing. Vienna, Austria.

Raymundo, L. J., Maypa, A. P., Gomez, E. D., & Cadiz, P. (2007). Can dynamite-blasted reefs recover? A novel, low-tech approach to stimulating natural recovery in fish and coral populations. *Mar Pollut Bull*, *54*(7), 1009-1019. doi:10.1016/j.marpolbul.2007.02.006

Reef Check. (2018). *Reef Check survey data on dynamite fishing 1997-2018*.

Riegl, B., & Luke, K. E. (1999). Ecological Parameters of Dynamited Reefs in the Northern Red Sea and their Relevance to Reef Rehabilitation. *Marine Pollution Bulletin*, *37*(8), 488-498. doi:10.1016/S0025-326X(99)00104-6

Rocliffe, S., Peabody, S., Samoilys, M., & Hawkins, J. P. (2014). Towards A Network of Locally Managed Marine Areas (LMMAs) in the Western Indian Ocean. *PLoS ONE*, *9*(7). doi:10.1371/journal.pone.0103000

Rogers, A., Blanchard, J. L., & Mumby, P. J. (2018). Fisheries productivity under progressive coral reef degradation. *Journal of Applied Ecology, 55*(3), 1041-1049. doi:10.1111/1365-2664.13051

Rubens, J. (2019). *Combating blast-fishing in Tanzanian marine waters: Progress, achievements & lessons 2016-2018* Dar es Salaam, Tanzania.

Short, R., Gurung, R., Rowcliffe, M., Hill, N., & Milner-Gulland, E. J. (2018). The use of mosquito nets in fisheries: A global perspective. *PLoS ONE, 13*(1). doi:10.1371/journal.pone.0191519

Silva, P. (2006). *Exploring the linkages between poverty, marine protected area management, and the use of destructive fishing gear in Tanzania*. The World Bank. 43 pp. Retrieved from http://econ.worldbank.org

Sudara, S. (1996). Marine fisheries and environment in the ASEAN region. Paper presented at the Asia-Pacific Fishery Commission. Sess. 25, Seoul (Korea Republic), 15-24 Oct 1996. FAO.

Sulu, R. J., Eriksson, H., Schwarz, A.-M., Andrew, N. L., Orirana, G., Sukulu, M., . . . Beare, D. (2015). Livelihoods and Fisheries Governance in a Contemporary Pacific Island Setting. *PLoS ONE, 10*(11). doi:10.1371/journal.pone.0143516

Steenbergen, D. J. (2013). The Role of Tourism in Addressing Illegal Fishing: The Case of a Dive Operator in Indonesia. Contemporary Southeast Asia, 35(2), 188-214. doi:http://dx.doi.org/10.1355/cs35-2c

Tanzania Blast-Fishing Monitoring Network. (2018). *Blast records*. Retrieved from: www.tz-blast-monitoring.net/

Teh, L. S. L., Teh, L. C. L., & Sumaila, U. R. (2013). A Global Estimate of the Number of Coral Reef Fishers. *PLoS ONE, 8*(6), e65397. doi:10.1371/journal.pone.0065397

Tudela, S. (2004). *Ecosystem effects of fishing in the Mediterranean: an analysis of the major threats of fishing gear and practices to biodiversity and marine habitats.* General Fisheries Commision for the Mediterranean. Rome: FAO. 58 pp.

Tyler, E. H. M., Manica, A., Jiddawi, N., & Speight, M. R. (2011). A role for partially protected areas on coral reefs: maintaining fish diversity? *Aquatic Conservation: Marine and Freshwater Ecosystems, 21*(3), 231-238. doi:10.1002/aqc.1182

Verheij, E., Makoloweka, S., & Kalombo, H. (2004). Collaborative coastal management improves coral reefs and fisheries in Tanga, Tanzania. *Ocean & Coastal Management, 47*(7-8), 309-320. doi:10.1016/j.ocecoaman.2004.07.002

Wagner, G. M. (2004). Coral reefs and their management in Tanzania. *Western Indian Ocean Journal of Marine Science, 3*(2), 227-243.

Waheed, Z., Van Mil, H. G. J., Hussein, M. A. S., Jumin, R., Ahad, B. G., & Hoeksema, B. W. (2015). Coral reefs at the northernmost tip of borneo: An assessment of scleractinian species richness patterns and benthic reef assemblages. *PLoS ONE*, *10*(12). doi:10.1371/journal.pone.0146006

Wells, S. (2009). Dynamite fishing in northern Tanzania--pervasive, problematic and yet preventable. *Marine Pollution Bulletin, 58*(1), 20-23. doi:10.1016/j.marpolbul.2008.09.019

Wickham, H. (2009). *ggplot2: Elegant Graphics for Data Analysis.* New York: Springer-Verlag.

Wilcox, C., Mann, V., Cannard, T., Ford, J., Hoshino, E., & Pascoe, S. (2021). A review of illegal, unreported and unregulated fishing issues and progress in the Asia-Pacific Fishery Commission region. Bangkok: FAO and Hobart: CSIRO. 149 pp. doi:10.4060/cb2640en

Wilkinson, C. R., & Buddemeier, R. W. (1994). *Global Climate Change and Coral Reefs: Implications for People and Reefs.* Gland, Switzerland.

Willoughby, N., Nikijuluw, V., & Suradisastra, K. (1996). The Effects of Human Population Pressure on Fishing Methods: from nets to dynamite to cyanide. Paper presented at the Asia-Pacific Fishery Commission. Sess. 25, Seoul (Korea Republic), 15-24 Oct 1996. FAO.

Williams, S. L., Sur, C., Janetski, N., Hollarsmith, J. A., Rapi, S., Barron, L., . . . Mars, F. (2018). Large-scale coral reef rehabilitation after blast fishing in Indonesia. *Restoration Ecology*. doi:10.1111/rec.12866

Yates, B. F. (1994). Implementing coastal zone management policy: Kepulauan Seribu Marine Park, Indonesia. Coastal Management, 22(3), 235-249. doi:10.1080/08920759409362234

2.8 TABLES

Table 1. Literature search results by country and region.

Continent/Area	*Region*	*Percentage*	*Country*	*Percentage*
Africa	Central Africa	1.42	Congo	0.47
			Ghana	0.94
	East Africa	22.17	Comoros	0.94
			Tanzania	21.22
	North Africa	3.30	Egypt	2.35
			Libya	0.47
			Morocco	0.47
	West Africa	1.42	Nigeria	0.47
			São Tomé & Príncipe Islands	0.47
			Senegal	0.47
Americas	Central America	1.42	El Salvador	1.42
	South America	4.25	Brazil	0.47
			Colombia	2.35
			Peru	1.42
Asia	Central Asia	0.94	Afghanistan	0.47
			Pakistan	0.47
	East Asia	3.30	China	3.30
	South Asia	5.66	India	3.30
			Sri Lanka	2.35
	Southeast Asia	50.47	Cambodia	0.47
			Indonesia	21.22
			Malaysia	6.13
			Myanmar	0.94
			Philippines	13.68
			Southeast Asia (Regional)	5.66
			Timor-Leste	0.47

Continent/Area	*Region*	*Percentage*	*Country*	*Percentage*
			Vietnam	1.89
Europe	East Europe	0.47	Ukraine	0.47
	Mediterranean	0.94	Greece	0.47
			Mediterranean (Regional)	0.47
Oceania	Oceania	2.83	Papua New Guinea	1.89
			Solomon Islands	0.47
			Wallis & Futuna	0.47
Pacific	Pacific	0.47	Pacific (Regional)	0.47
Global	Global	1.42	Global	1.42
Total	*14*	*100*	*31*	*100*

Table 2. Papers assessing the effectiveness of deterrence measures against blasting by country.

Paper	*Location*	*Deterrence Effective?*	*Findings*
Baticados & Agbayani (2004)	Philippines	Yes	Co-management between resource users and the government is perceived to be successful by resource users. Strict enforcement by the government is an essential part of the management strategy.
Dunning (2015)	Indonesia	Yes	Blasting has practically ceased due to severe legal penalties, increased local awareness, enforcement, and graduated sanctions. Isolated incidents can be attributed to outsiders.
Fox et al. (2005)	Indonesia	Yes	Weekly patrols reduced blasting by 75%, in conjunction with programs designed to raise community awareness thereof.
Haisfield et al. (2010)	Indonesia	Yes	Patrols effectively reduce blasting, e.g. in Komodo National Park, 50-70 10-day patrols are conducted per year over an 1 100 km^2 area.Moreover, due to high profits obtained from blasting, fishers are unlikely to adopt legal methods without strong enforcement.
Katikiro & Mahenge (2015)	Tanzania	Yes	Strict enforcement has proven to be effective. Without government support, community based management has not been successful in preventing blasting.

Paper	*Location*	*Deterrence Effective?*	*Findings*
Levine (2004)	Tanzania	Yes	Police patrols using two boats over a 470 km^2 area as well as community monitoring resulted in a reduction of blasting. However, prosecution of offenders has been rare.
Licuanan & Gomez (2000)	Philippines	Yes, in conjunction with other aspects.	Blast fishing decreased due to educational campaigns, strong deterrence measures by the government and depletion of target fish species.
Cesar et al. (1997)	Indonesia	Yes, under certain conditions. Additional measures usually needed.	Enforcement is necessary when offenders are outsiders and/or with large stakeholders. With internal offenders, whether they be large or small stakeholders, a combination of government coastal zone management, community based management and government effforcement will be the most effective.
Chan & Hodgeson (2017)	China	Only in limited cases, additional measures usually needed.	An enforcement-only approach is usually ineffective and unsustainable, e.g. in Hong Kong blasting ceased following rigorous enforcement efforts but resumed when enforcement ended. A mixture of enforcement, making fishers aware of monitoring and enforcement efforts, education programs and alternative income schemes is recommended.
Gorris (2016)	Indonesia	No	Enforcement efforts are ineffective due to lack of infrastructure and equipment, rare prosection and lack of funding. This is particularly true for remote areas, in which many fisheries are located. Patrols occurred rarely due to high costs.
Guard & Masaiganah (1997)	Tanzania	No	Enforcement efforts are ineffective due to corruption and leniency in sentencing. This leads to apathy and lack of support among the fishing communities. Patrols are effective, but are only conducted sporadically and are therefore ineffective.
Huber (1994)	Papua New Guinea	No	Enforcement efforts are ineffective due to a lack of enforcement capacity and issues with inter-agency coordination. Enforcement efforts occur rarely if at all.

Table 3. Papers assessing the effectiveness of MPAs and CBM against blasting by country.

Paper	***Location***	***MPAs and CBM Effective?***	***Findings***
Abraham & Kelkar (2012)	India	Yes	Blast fishing intensity was higher in unprotected than in protected areas. *N.b. This article refers to freshwater ghats and rivers.*
Rocliffe et al. (2014)	Tanzania	Yes	Blast fishing decreased within the MPAs, and resource users perceived an increase in fish abundance. At the time of writing, MPAs covered 13% and MPAs and CBM areas together covered 58.7% of the marine territory.
Silva (2006)	Tanzania	Yes, indirectly through AIGA schemes that are implemented concurrently with the MPA	Households inside MPAs are less likely to target reef species, but MPAs have no direct impact on choice of fishing gear. MPAs may influence gear choice and target species indirectly through AIGA programs, which do directly reduce te probability of selecting destructive gears such as explosives. At the time of writing, MPAs covered 1 380 km^2 or 4% of the marine territory.
Tyler et al. (2011)	Tanzania	Yes, but more restrictions means better outcomes	Increased species richness was found in regulated over unregulated reefs, however abundance, biomass and length were unaffected. Therefore stricter regulations, such as reducing fishing overall in conjunction with enforcing bans on blasting, may be required to increase biomass of target species. Protected area covered 470 km^2.
Verheij et al. (2004)	Tanzania	Yes, in conjunction with enforcement	Joint patrols between police and communities and reef closures stabilised or increased the biomass of commercial reef fish on open and closed reefs. Higher densities were observed on closed reefs. The 6 CBM areas covered 1 604 km^2.
Chou et al. (2002)	Vietnam	Mixed results	In one area within an MPA, blast fishing was virtually eliminated through a combination of strategic reef closures, awareness raising in communities, police monitoring and community development initiatives. However, other reefs within the same MPA continue to be affected by blasting. Reasons for this disparity were attributed to inappropriate zoning and a lack of enforcement. The MPA covered 160 km^2.
Campbell, Cinner, et al. (2012)	Indonesia	No	Continued blast fishing within the CBM area was attributed to inadequate enforcement, and resulted in reduced coral cover and fish biomass. However, biomass was greater in areas with gear restrictions, despite ongoing blasting. Total area covered was 7.14 km^2.

Paper	*Location*	*MPAs and CBM Effective?*	*Findings*
Benson (2012)	Papua New Guinea	No	Blast fishing within the Wildlife Management Areas (WMA) (very similar to CBM areas) was attributed to inadequate enforcement and poorly implemented community management schemes. Total area covered was 10.85 km^2.
Hughes et al. (2013)	China	No	MPAs have failed to protect nearshore reefs from decline due to inadequate size and poor monitoring. Blasting severely reduced coral cover in some areas.
Yates (1994)	Indonesia	No	Blast fishing continued within MPA borders due to poor zoning implementation, inter-agency conflict and a lack of stakeholder input. Total area covered was 1080 km^2.

2.9 FIGURES

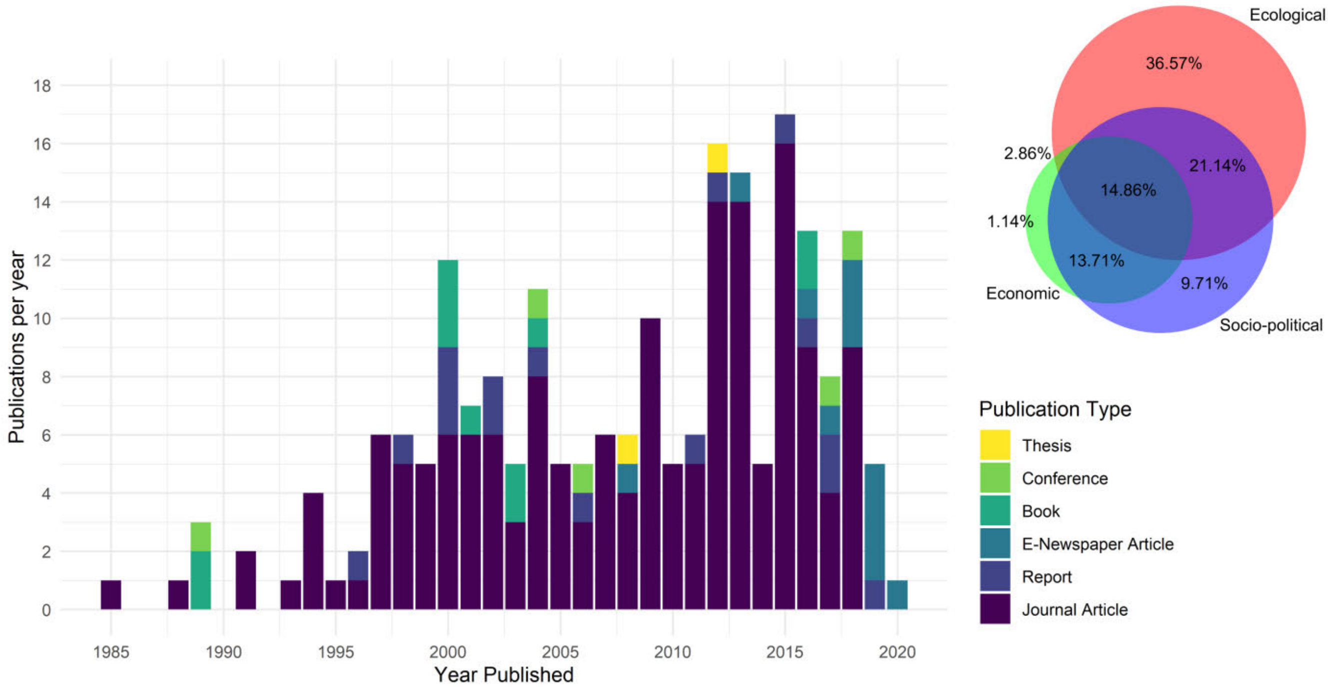

Figure 1. Left: Literature search results, shown by year of publication, type of publication and frequency. Top-right: Literature search results separated by their primary, secondary and tertiary focus on ecological, socio-political and economic aspects of blasting. Generated using BioVenn software (Hulsen, de Vlieg, & Alkema, 2008).

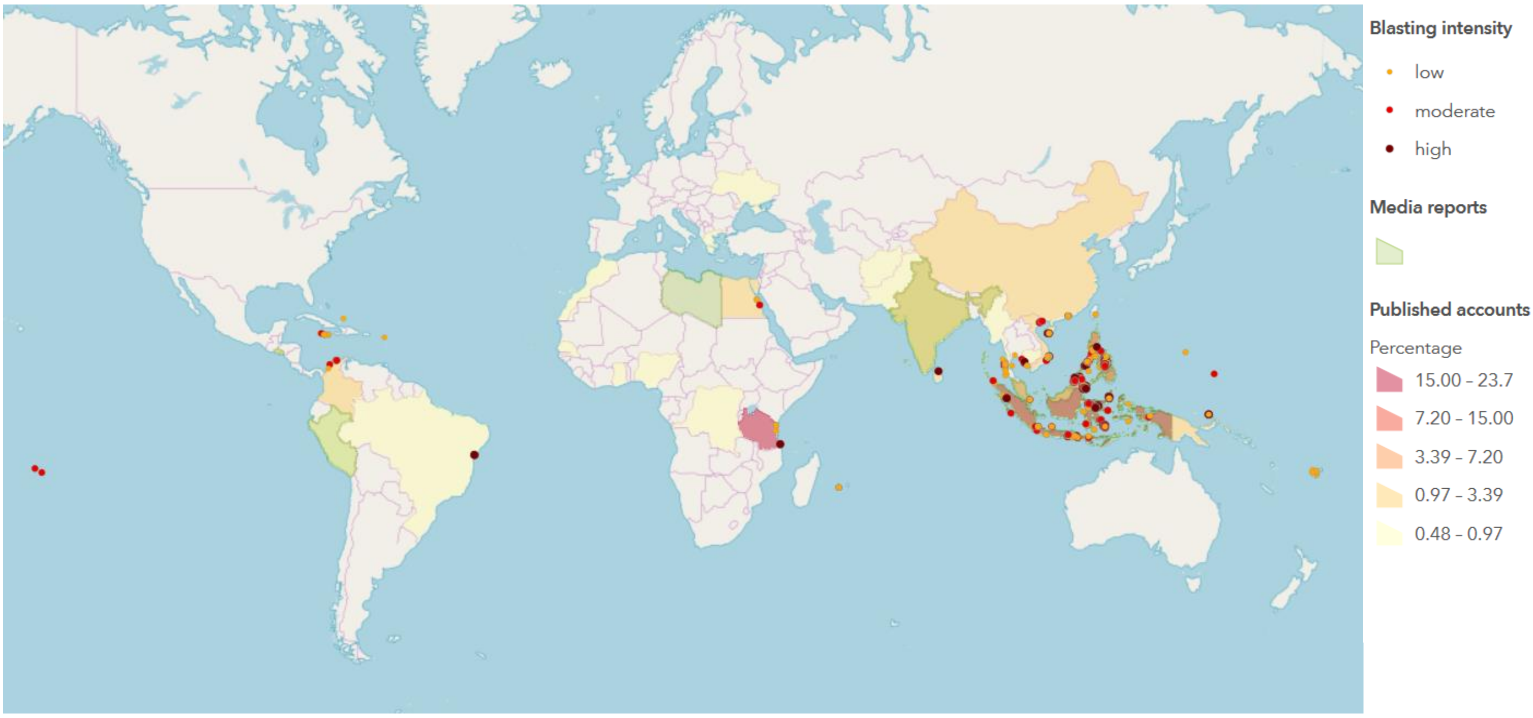

Figure 2. Literature search results showing blast fishing intensity from 1997-2018, media reports of blasting, and the percentage of published articles with empirical evidence of blast fishing. Blast fishing intensity data obtained from Reef Check (2018) and used with permission.

Statement of Originality

Higher Degree Research Thesis by Publication
University of New England

We, the Research Master/PhD candidate and the candidate's Principal Supervisor, certify that the following text, figures and diagrams are the candidate's original work.

Type of work	Page number/s
Text	15 – 50
Figures 1 and 2	49 and 50, respectively

Name of Candidate: Melissa Hampton-Smith

Name/title of Principal Supervisor: Sarah Mika

[redacted]

5th August 2021

Candidate   Date

[redacted]

5th August 2021

Principal Supervisor   Date

Statement of Authors' Contribution

Higher Degree Research Thesis by Publication
University of New England

STATEMENT OF AUTHORS' CONTRIBUTION

We, the Research Master/PhD candidate and the candidate's Principal Supervisor, certify that all co-authors have consented to their work being included in the thesis and they have accepted the candidate's contribution as indicated in the *Statement of Originality*.

	Author's Name (please print clearly)	**% of contribution**
Candidate	Melissa Hampton-Smith	80
Other Authors	Deborah Bower	10
	Sarah Mika	10

Name of Candidate: Melissa Hampton-Smith

Name/title of Principal Supervisor: Sarah Mika

[redacted]

5[th] August 2021

Candidate

Date

[redacted]

5[th] August 2021

Principal Supervisor

Date

Chapter 3: Drivers of blast fishing and reduction in Tanzania

3.1 INTRODUCTION

Destructive fishing methods such as blast fishing were first reported in Tanzania in the 1960s, and have been a pervasive and recurring concern along the Tanzanian coastline over the last six decades (Jiddawi & Öhman, 2002). Blast fishing has long been regarded as a fundamentally unsustainable and destructive fishing practice that is largely unsupported by local fishing communities (Darwall & Guard, 2000). Extensive blast fishing leads to partial or complete destruction of reef structures, and the resulting drop in rugosity results in sharply declining fish abundance and species richness (Fox, Pet, Dahuri, & Caldwell, 2003; Rogers, Blanchard, & Mumby, 2018). Although there is a dearth of data on the direct impacts of blasting on markers such as abundance and diversity, the degradation to the reef habitat from blasting has been well established (e.g. Fox et al., 2003). Therefore studies that focus on rugosity degradation and its impact on various markers remain relevant (e.g. Friedlander & Parrish, 1998; Knudby, LeDrew, & Brenning, 2010; Rogers, Blanchard, & Mumby, 2018), despite not focusing on blasting per se. Reef regeneration is limited and highly dependent on environmental conditions (Fox & Caldwell, 2006). Despite being made illegal in 1970 and attracting significant fines and incarceration periods, blasting has persisted along the majority of the Tanzanian coastline (Braulik et al., 2017; *Fisheries Act 1970*; *Fisheries Act 2003*). In the 1980s and early 1990s, the intensity of blast fishing led to widespread damage and degradation of the majority of coral reef ecosystems (Muhando & Mohammed, 2002; Nzali, Johnstone, & Mgaya, 1998). There has been intermittent success in addressing the issue since then, but blast fishing and its associated negative impacts on catch sizes and key fish populations has continued (McClanahan et al., 2015). This is of especial concern in poorer regions, where a significant proportion of the population relies directly or indirectly on fishing as their primary source of income, as well as an important food source (Kamat, 2014; Silva, 2006).

Previous attempts to control blast fishing include action taken in the mid 1990s, which resulted in a five-year lull in blasting between 1998 and 2002 (Rubens, 2016). These actions included community-based programs along with naval intervention and had a significant impact on community behaviour with a considerable reduction in blast fishing. However, anecdotal evidence, community feedback, and underwater sound recorder data showed that from the mid 2000s until very recently, blast fishing once again became a regular activity along Tanzania's coastline, threatening the livelihoods of thousands of families (Braulik et al., 2017; Slade & Kalangahe, 2015). This situation continued until October 2016, in which a marked reduction was observed in the frequency of blast fishing. The decline in blasting in all recorded regions in Tanzania has been attributed to a well-coordinated and externally funded response under the Magufuli government, entailing public political pressure by senior government members and raids conducted by the navy in blast fishing hotspots (Rubens, 2019).

Over the past two decades, several reports and surveys have linked destructive fishing techniques in Tanzania to various causes, including poverty and poor marine resource management (Cinner, 2010; Silva, 2006). Globally, poverty is among the predominant assumed causes of blast fishing, in which limited access to education, alternative employment opportunities and resources leads fishers to engage in destructive fishing in order to increase personal or household incomes (Galvez, Hingco, Bautista, & Tungpalan, 1989; McManus, 1997; Wagner, 2004). However, for some, blast fishing is preferred to traditional methods due to its ease and profitability (Pet-Soede & Erdmann, 1998). In the absence of enforcement, there is a clear financial incentive for fishers to begin and continue blasting, until such time as fish stocks drastically decline or deterrents are introduced (Hughes et al., 2017; Pet-Soede, Cesar, & Pet, 1999). Moreover, an increase in socioeconomic development from a low to a moderate standard has been associated with deceased fish biomass in western Indian Ocean coastal fisheries (Cinner et al., 2009). Although socioeconomic factors are likely linked to blast fishing, assuming a linear relationship between poverty reduction and a decrease in blasting is problematic and not clearly supported in the literature. Alternative theories on destructive fishing causation include inadequate or ineffective enforcement (Arai, 2015), and inappropriate or ineffective marine resource governance (Gorris, 2016; McClanahan, Glaesel, Rubens, & Kiambo, 1997). In Tanzania, blast fishing has been variously attributed to poverty (Silva, 2006), lack of enforcement

(Katikiro & Mahenge, 2016; Wells, 2009) and inappropriate marine resource management (Slade & Kalangahe, 2015). However, there is insufficient empirical evidence to substantiate any one of these potential causes as a dominant or even significant driver of blasting. There is also a lack of data on the causes of the reported recent reduction of blasting in Tanzania. A network of organisations conducting community monitoring reported a reduction in blasting between 2016 and 2018, which coincided with the above-mentioned government campaign (Rubens, 2019; Tanzania Blast-Fishing Monitoring Network, 2018). However, the effect of this reduction on the views and actions of Tanzanian fishing communities remains unknown.

My study therefore aimed to address these gaps in understanding, and provide knowledge that will enable policy makers to better understand the recent reduction of blast fishing in Tanzania, as well as its original widespread use. Increased understanding of the mechanism behind the decline in blasting could help deter blast fishing in future by helping to create workable, sustainable, and cost-effective marine resource management solutions. My objectives were to (1) determine indicators associated with a previous engagement in blast fishing, with a focus on economic predictors; and (2) assess which factors caused previous blast fishers to cease, focusing primarily on economic factors. Section 3.2 outlines the methods, section 3.3 discusses the ethical considerations of the research and its limitations, and sections 3.4 and 3.5 detail the results and discuss these results, respectively.

3.2 METHODS

3.2.1 Research Design

In order to ascertain drivers of blast fishing and reduction in its practice, my study used an observational retrospective design, in which participants were selected in areas with low and high blast fishing histories. This approach was chosen because the outcome had already occurred, and an experimental approach where illegal blasting would be measured would be unethical, as well as logistically challenging. Because of the difficulties in selecting true control sites, a quasi-experimental design where causation could be established was also rejected. Purposive sampling was used to ensure variation in independent variables. Although purposive sampling has precedence in similar exploratory studies (Agrawal, 2001; Cinner et al., 2012), caution should be used when interpreting results because the villages were not selected randomly. The data were collected in two phases, in May-June and October 2019. In Phase 1, data were collected in the Kigamboni, Kinondoni, Lindi Rural and Mtwara Rural districts (Kigamboni and Kinondoni are represented as one district, Dar es Salaam, in all charts due to the low number of respondents from Kigamboni). Phase 2 data were collected in Kilwa, Pangani, Mkinga and Kinondoni districts. In total, 19 villages were purposively selected based on their blast fishing histories, of which 13 were located in former blast fishing hotspots (Figure 3). The remaining six villages were selected as controls in areas with low or negligible blasting (Figure 4).

Governance arrangements varied among villages; there were active Beach Management Units (BMU) in 10 of the villages, one village had a municipal group comprising fishers and local government members, six villages were covered by Collaborative Management Area Plans (CMAP), and the remaining two villages had no formal resource management arrangements in place. BMUs were established in Kilwa district in 2005 under the RUMAKI Seascape Program, and then expanded to Mtwara and Kigamboni districts in 2013 under the EU-WWF Fisheries Co-Management Program (Mahongo 2017). BMUs comprise local fishers and represent the local fishing communities. Their responsibilities include collecting catch data, maintaining landing sites, arbitrating disputes and providing input to develop and improve fishery management plans (Mahongo 2017). CMAs cover three northern districts in Tanzania and were implemented in 1994 under the Tanga Coastal Zone Conservation and Development Program. In each participating village covered by CMAPs, groups representing local fishers have similar responsibilities as BMUs and are also often called as such (Wells et al. 2007).

The focus was to survey villages along the length of Tanzania's coastline in order to ascertain variability; therefore smaller sample sizes in each village were taken to enable more villages to be surveyed. This type of surveying is known as mini surveying, and is appropriate when large-scale surveys cannot be conducted due to time or budget restraints, or where quantitative data is sought to corroborate qualitative findings (Kumar, 2006). Mini surveys typically have a smaller number of participants and use closed-question surveys that can be completed in half an hour or less. They can provide valuable information about trends and tendencies, and when representative sampling techniques are used, can also be springboards for broader consequent studies (Béné, Chijere, Allison, Snyder, & Crissman, 2012). Despite the constraints imposed by the small sample sizes in each village, my study generated statistical data to aid in an understanding of the specific local contexts, which can potentially be used for inferring information about the entire coastline, or as a starting point for future studies.

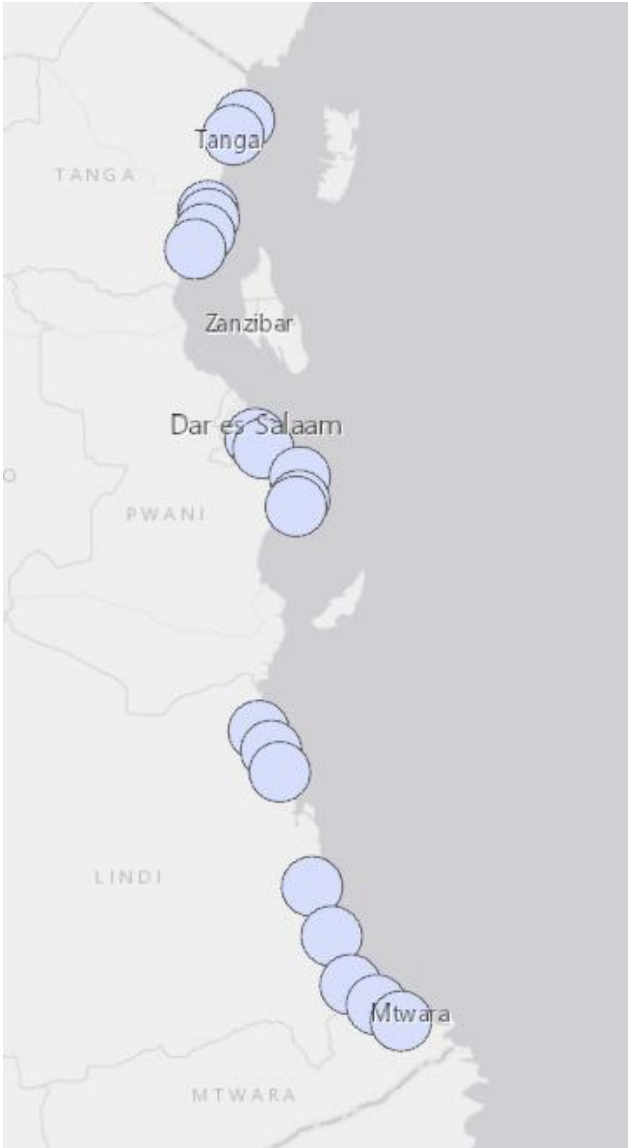

Figure 3. Survey sites (n = 19) used to ascertain drivers behind blast fishing and reduction in its practice in Tanzania in 2019.

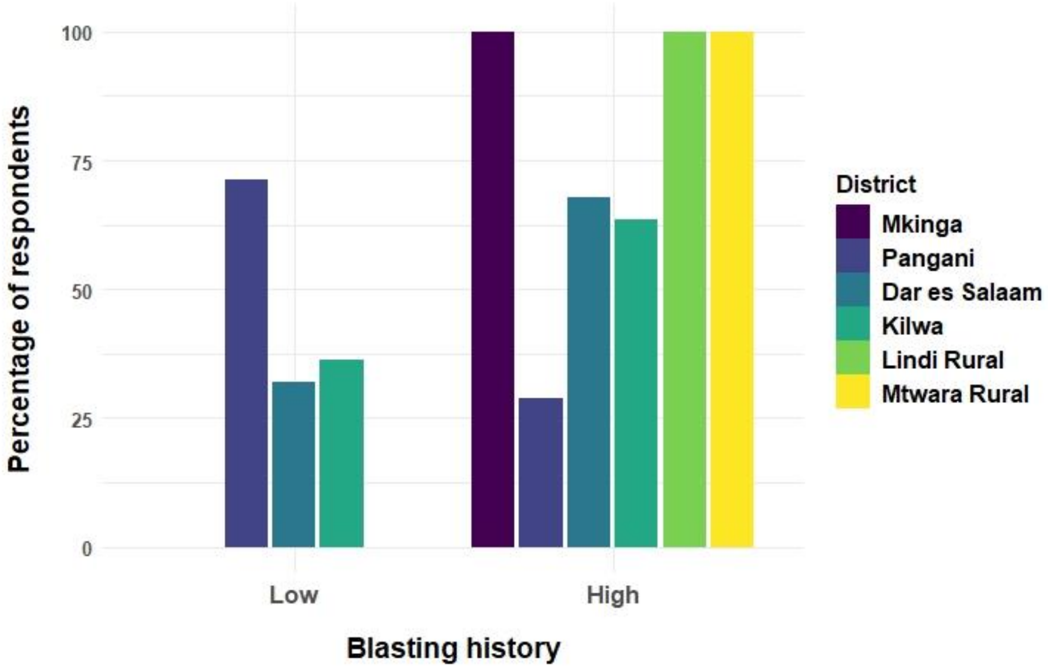

Figure 4. Blasting history distribution by district and percentage of respondents (n = 341) in 19 coastal villages in Tanzania in 2019.

3.2.2 Participants

A systematic sample of households from the target villages was taken by dividing the most recent population estimate by the target number of households and then surveying every *n*th house. The target number of households in each village varied depending on logistical constraints and village size. Household heads or representatives thereof were surveyed about their perceptions of blasting and the reduction of the blast fishing. The household sample (n = 101) comprised a total of 495 participants (including minors) in 18 villages and seven districts. All adults in each household were surveyed, and income data were amalgamated to give a total household income. The final household sample (n = 98) excluded 3 households from the analysis due to incomplete data collection and comprised 86 households with male and 12 with female household heads. Of these households, 50 sourced their primary income from fishing. Fisher groups were purposively surveyed by contacting village heads and Beach Management Unit leaders, who organised groups of fishers for interviews. The final sample of fishers (n = 243) was taken from 19 villages in seven districts, of which 239 were male and 4 were female. These respondents' data were combined into the final dataset (n = 341), upon which all analyses were conducted (Table 4).

Table 4. Number of villages, household respondents and fisher respondents by district.

District	*No. villages*	*No. households*	*No. fisher respondents*
Mkinga	2	10	25
Pangani	4	12	57
Kinondoni (Dar es Salaam)	1	3	10
Kigamboni (Dar es Salaam)	4	29	61
Kilwa	4	25	48
Lindi Rural	2	12	25
Mtwara Rural	2	7	17
Total	*19*	*98*	*243*

3.2.3 Instruments and implementation

My study used two instruments to collect quantitative data: a household survey and fisher group survey. The household and fisher surveys were composed of several modules and comprised structured questions with pre-defined possible answers. Household surveys are a common method used to generate current and detailed data on households and individuals in developing countries such as Tanzania. Such data have become central to policy analysis, development planning, assessment of interventions and government decision-making at all levels. Face to face surveys continue to be widely used in the developing world, as internet and phone interviews are limited by poor internet and phone penetration or incomplete telephone sampling frames.

Both surveys were based on guidelines and survey items developed by the World Bank and the Tanzanian National Bureau of Statistics for the Living Standards Measurement surveys (Deaton & Grosh, 2000; Tanzanian NBS, 2015). In addition, specific items for fisher group surveys focusing on fishing expenses and income were based on guidelines from the Food and Agriculture Organisation of the United Nations (FAO) (Stamatopoulos, 2002). Surveys were translated and cross-checked by two Tanzanian translators with knowledge of marine resource terms. Data were recorded on the translated surveys in Kiswahili. Some minor modifications were made between data collection phases to address errors in the original surveys. The household and fisher surveys can be found in English and Kiswahili in Appendix A. In addition to the quantitative data gathered, qualitative notes on the participants, their environment and the survey sites were taken throughout data collection to contextualise, supplement and enhance the quantitative data.

Before the commencement of household surveys, participants were informed about the research project by the local village guide accompanying the research team to each household. The average total time for each household survey was 60 minutes. Fishers were informed about the research project by village leaders or Beach Management Unit leaders. Average survey duration ranged from 90 to 120 minutes. All efforts were made to ensure the reliability of results by using the same survey items and survey team for every survey, which were conducted in Kiswahili.

3.2.4 Model building and variable selection

3.2.4.1 Operationalisation of objectives

Three response variables were assigned to the two objectives (Table 5).

Table 5. Aim, objectives and response variables. Response variable codes correspond to household survey items shown in Appendix A, marked with #, or with operationalised variables shown in Appendix B, marked with *.

Aim: investigate involvement in blast fishing and reduction thereof	
Objective	*Response variable*
1. determine indicators associated with previous blasting engagement	- Village blast fishing history – low or high (1.00b*) - Reported reasons for blasting (5.17#)
2. assess which factors caused blasting reduction	- Reported reasons for reduction (5.18#)

The first objective of my study was to determine indicators associated with a previous engagement in blast fishing. This objective was operationalised into two response variables: low or high blasting history of a survey site, and the primary reasons for blasting. Blasting history was analysed using a generalised linear mixed regression model with a binomial distribution and survey site as a random factor. Additionally, Kruskal-Wallis tests with a Holm-Bonferroni correction were performed to determine whether there were significant differences between villages with low and high blasting for catch species, gear, fishing transport mode, fishing grounds, household economic indicators and attitudes towards marine resource management (see Table 8, Table 9, Table 11, Table 12 and Table 10 for details on explanatory variables). The blast fishing history of an area was determined through information obtained from local experts, as well as two surveys that recorded blasting incidences (Braulik et al., 2017; Tanzania Blast-Fishing Monitoring Network, 2018). Survey sites were coded as having a low or high blasting history; 66% of respondents came from villages with a high blasting history (Figure 5). However, it should be noted that the binary classification of blasting as low or high is problematic due to the complex nature of blasting. In the absence of empirical data on the village level, the classification system used is an approximation. The determination of a village's blasting history took into account blasting in the immediate vicinity, as well as blasting in nearby fishing grounds that were reportedly used by fishers from that village. This classification is therefore by necessity based on an amalgamation of local expert advice and anecdotal evidence from respondents and should be treated with caution.

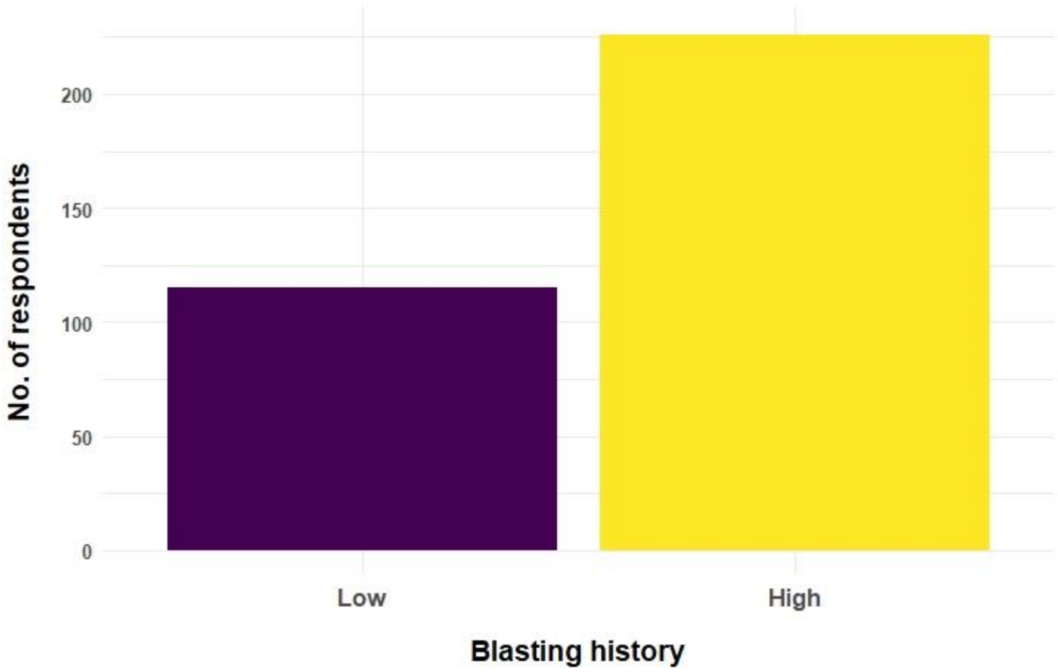

Figure 5. Blasting history distribution (n = 341) in 19 coastal villages in Tanzania in 2019.

The model predicting primary reasons for blasting used a multinomial logistic regression and compared four possible reasons: blasting is easier, more profitable, traditional methods are ineffective and an absence of punishment. The response variable data were obtained from the household and fisher surveys. In the original data, the item for the primary reason for blasting and blasting reduction was ranked with four levels, but due to a large number of incomplete cases only the primary reasons for blasting were analysed (Figure 6).

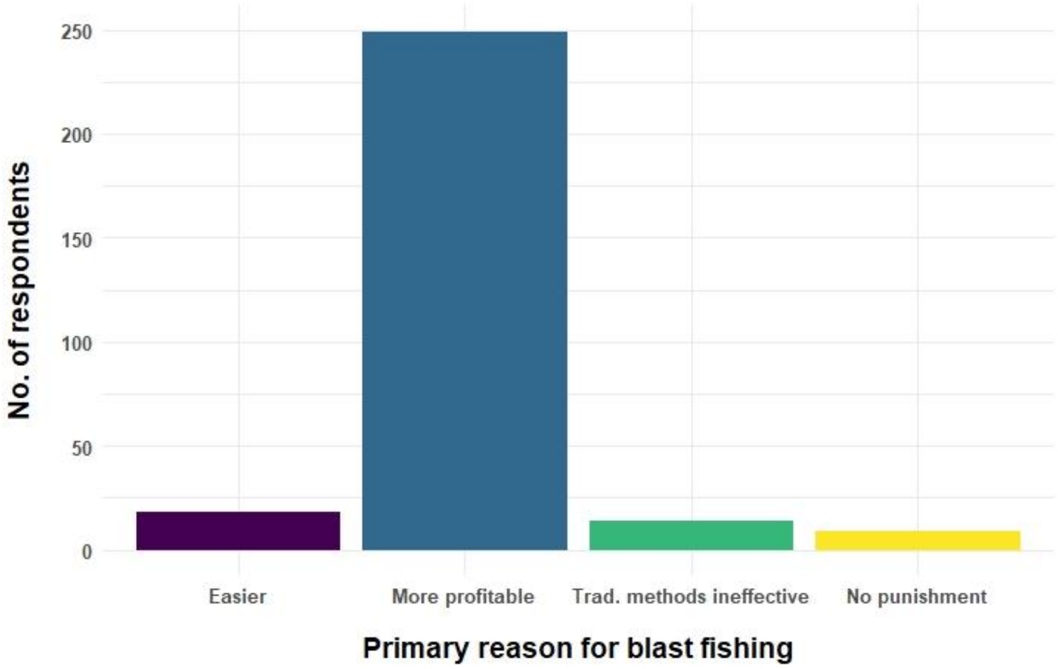

Figure 6. Distribution of primary reasons for blasting (n = 290) in 19 coastal villages in Tanzania in 2019.

My second objective was to assess which factors caused previous blast fishers to cease. This objective was operationalised into a response variable showing the primary reasons for ceasing blast fishing. Respondents were asked to choose between the government campaign, community groups, reduced fish availability and that alternative methods to blasting were more attractive. Community groups were defined as NGO organisations such as World Wildlife Fund (WWF) and SeaSense that established village-level groups to promote sustainable fishing methods and marine resource use. The forth option, "alternative methods to blasting are more attractive" was not chosen by any respondents and was therefore eliminated from the analysis. The third option "reduced fish availability", was only selected by one respondent and was therefore also removed. As with the primary reasons for blasting, the response variable was obtained from the household and fisher surveys and only the primary reasons for blasting reduction were analysed (Figure 7). As this was in effect a binary response, a generalised linear mixed regression model with a binomial distribution and survey site as a random factor was used.

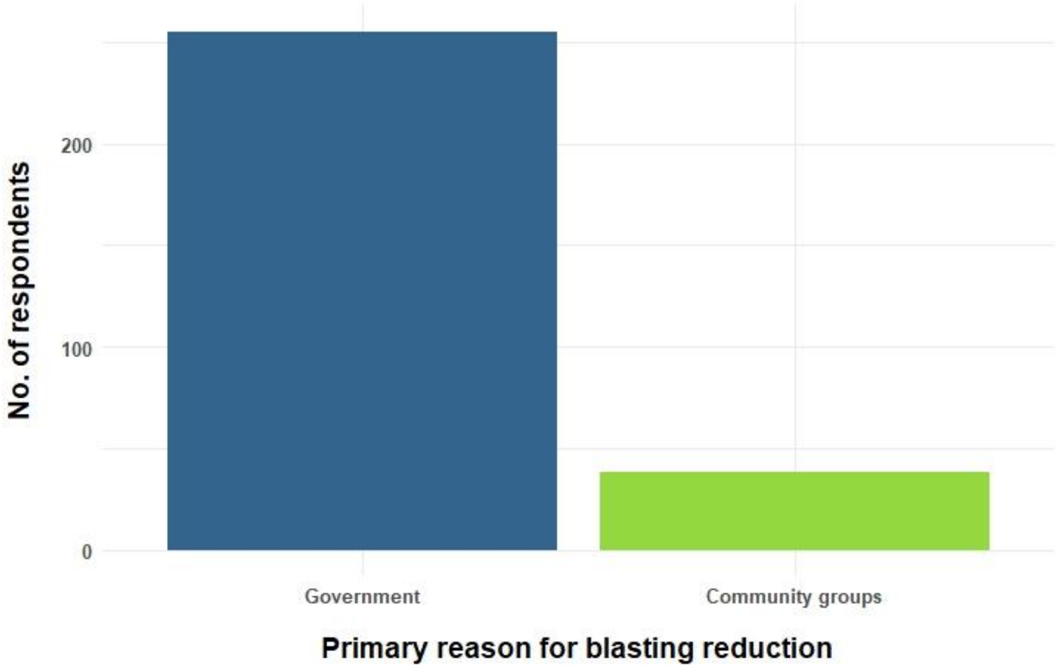

Figure 7. Primary reasons for stopping blasting distribution (n = 293) in 19 coastal villages in Tanzania in 2019.

3.2.4.2 Explanatory variables

The selection of predictor variables was based on previous socio-economic and ecological surveys conducted in the region (Cinner et al., 2012; Tanzanian NBS, 2015), and were grouped according to Ostrom's (2009) framework for analysing social-ecological systems (Figure 8).

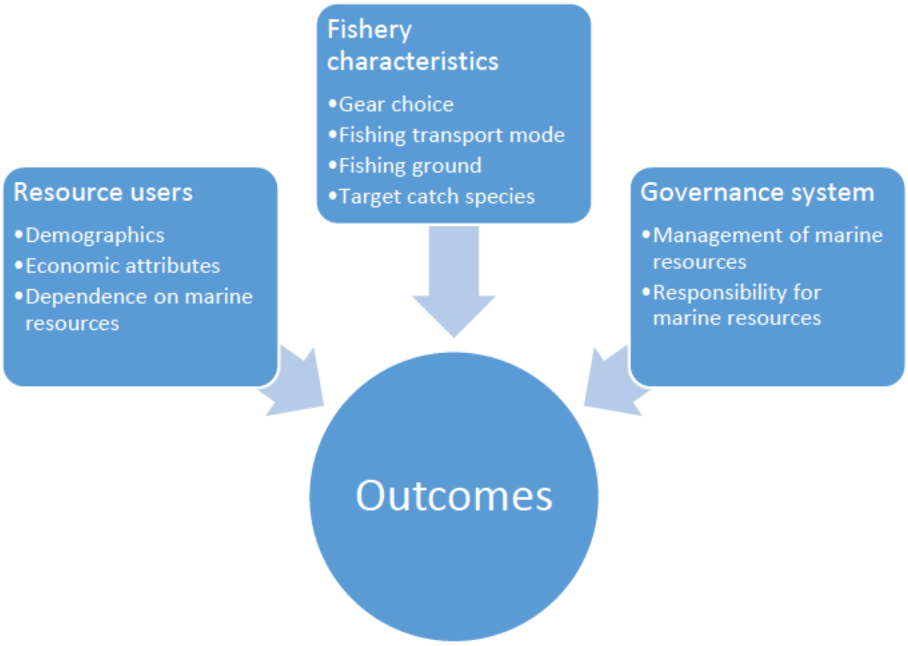

Figure 8. Response variables derived from Tanzanian NBS (2015) and Cinner (2012) and grouped according to Ostrom (2009).

As the primary focus was on the effect of economic factors on participation in blasting and its cessation, a model was created with economic predictor variables (Table 6). Although not strictly an indicator of financial status, the use of housing standard through the assessment of household attributes to establish economic status in developing countries has precedence in recent large-scale Tanzanian studies, and is commonly used in developing countries where incomes are highly variable (The World Bank 2015). Variables that were highly correlated with each other were removed ($R \geq 0.5$), leaving housing standard and total weekly household fishing income in the final model (Table 7). Models with both variables and with only fishing income were compared for each response variable.

Table 6. Initial economic model explanatory variables. Variable codes correspond to household survey items shown in Appendix A, marked with #, or with operationalised variables shown in Appendix B, marked with *.

Explanatory variable	Description	
Housing standard (3.13*)	Index of housing standard incorporating variables 3.01-3.12#, z-score standardised	
Total fishing income (4.1e*)	Average household fishing income over 7 days	
Total household income (2.13d*)	Sum of all household income averaged over 7 days	
Access to credit (2.14#)	Household access to credit	Dummy variable
Ease of access to credit (2.15#)	Household ease in accessing credit	5-point Likert scale
Household economic status trends (2.17#)	Household economic status compared to 12 months before	5-point Likert scale
Change in fishing income over 5 years (4.11#)	Current fishing income compared to 5 years before	5-point Likert scale

Table 7. Final economic model explanatory variables. Variable codes correspond to household survey items shown in Appendix A, marked with #, or with operationalised variables shown in Appendix B, marked with *.

Explanatory variable	Description
Housing standard (3.13*)	Aggregated index incorporating variables 3.01-3.12#, higher score showed higher housing standard. Z-score standardised.
Total fishing income (4.1e*)	Average household fishing income over 7 days

In order to explore the possibility that alternative factors were influential on blasting and the reduction, a series of additional candidate models were created to represent resource user demographics, dependence on marine resources, gear choice, preferred catch species, management of marine resources and responsibility for marine resources. Fishing transport mode and fishing ground choice were not included as candidate models due to discrepancies in data collection which led to distorted model output, but were included in Kruskal-Wallis tests. Firstly, significant associations between gears, fishing transport modes and target catch species were established using χ^2 tests and Cramer's V tests; variables that were significantly correlated with one another were removed (Cramer's V ≥ 0.1). Secondly, lasso regression was performed where relevant on each model to select the most important variables (Table 8). The variables for gears (Table 9), target catch species (Table 10), fishing transport modes (Table 11) and fishing grounds (Table 12) were described following previous surveys in Tanzania, see respective tables for details. Variables were scaled where necessary to reduce over- or underdispersion and convergence problems. All variables with 5-point Likert scales were collapsed to three levels to simplify interpretation and reduce issues with non-convergence of models.

Table 8. Candidate model explanatory variables. Variable codes correspond to household survey items shown in Appendix A, marked with #, or with operationalised variables shown in Appendix B, marked with *.

Explanatory variable	**Description**	
MODEL: RESOURCE USER DEMOGRAPHICS		
- Education level (1.12#)	Highest completed education level	
- Age (1.05#)		
MODEL: DEPENDENCE ON MARINE RESOURCES		
- Household use of marine resources (2.04#)	Relationship to marine resources	
- Consumption of marine food resources (5.06#)	Frequency of seafood consumption	
- Availability of alternative income sources (5.07#)	Ease of finding alternative income to fishing	5-point Likert scale
MODEL: GEARS		
Variables (4.15a – 4.15j*)	Gear choices based on previous surveys conducted in Tanzania	Transformed into dummy variables
MODEL: TARGET CATCH SPECIES		
Variables (5.01a – 5.01q*)	Target species choices based on previous surveys conducted in Tanzania	Transformed into dummy variables

Explanatory variable	Description	
MODEL: GOVERNANCE OF MARINE RESOURCES		
- Impact of campaign (5.08[#])	Impact of government campaign against blasting on fishing	5-point Likert scale
- Fishing regulations (5.09[#])	Fairness of local fishing regulations	5-point Likert scale
- Adherence to rules (5.1 – 5.12[#])	Level of adherence to local fishing regulations	5-point Likert scale
- Fish availability trends (5.13[#])	Trends in fish availability over a 5-year period	5-point Likert scale
MODEL: RESPONSIBILITY FOR MARINE RESOURCES		
- Responsibility for marine resources (5.16[#])	Allocation of responsibility to manage marine resources	Ranked variable, only primary ranking used
- Responsibility to stop blasting (5.16[#])	Allocation of responsibility to control blasting	Ranked variable, only primary ranking used

Table 9. Final selection of gears used for candidate model and Kruskal-Wallis analysis following variable selection. Based on Tanzanian NBS (2015) and Wells et al. (2007).

Gear	Description	Kiswahili
Gill net	Mono-filament nets with 5-10 cm mesh size, deployed from boats on fringing and offshore reefs, and open sea	Nyavu
Shark net	Mono-filament net with 12-20 cm mesh size, deployed from boats on mainly offshore reefs and open sea	Jarife
Long line	Multiple hooks and line, deployed from boats	Longline / Kaputi
Hand line	Single hook and line, deployed from the shore and boats	Mshipi
Fish trap	Usually deployed from smaller boats on fringing reefs	Madema
Octopus stick	Hooked stick used by divers to extract octopus from reefs	Mdeke
Fins and mask	Used by divers to extract octopus, lobster and squid from reefs	Pelepele

Table 10. Final selection of common catch species used for candidate model and Kruskal-Wallis analysis following variable selection. Based on field observations and Hempson (2008), Jiddawi and Öhman (2002) and Moshy and Bryceson (2016).

Family		**Species**	**Common name**	**Kiswahili**
CARCHARHINIDAE	Requiem sharks	e.g. *Carcharhinus amblyrhynchos*	e.g. Grey reef	Papa
SCOMBRIDAE	Mackerels	e.g. *Scomberomorus plurilineatus*	e.g. Kanadi kingfish	Nguru
	Tuna	e.g. *Thunnus albacares*	e.g. Yellowfin tuna	Jodari
LUTJANIDAE	Snappers	e.g. *Lutjanus argentimaculatus*	e.g. Mangrove red snapper	Red snapper
CARANGIDAE	Trevallys	e.g. *Caranx tille*	e.g. Tille trevally	Kolekole
	Jacks			
ENGRAULIDAE	Anchovies	e.g. *Stolephorus commersonnii*	e.g. Commerson's anchovy	Dagaa mcheli
DASYATIDAE	Rays	e.g. *Pastinachus sephen;*	e.g. Feathertail stringray;	Taa
		Taeniura lymma	Bluespotted stringray	Taa (Bocho)
SERRANIDAE	Groupers	*Cephalopholis argus*	Bluespotted grouper	Chewa
LETHRINIDAE	Emperors	e.g. *Lethrinus harak*	e.g. Thumbprint emperor	Changu
MULLIDAE	Goatfish	e.g. *Upeneus tragula*	e.g. Freckled goatfish	Mkundaji
SIGANIDAE	Rabbitfish	*e.g. Siganus canaliculatus*	e.g. Whitespotted spine foot	Tasi / Chafi
SCARIDAE	Parrotfish	*e.g. Calotomus carolinus; Calotomus spinidens*	e.g. Carolines parrotfish; Spinytooth parrotfish	Pono / Kangu
CAESIONIDAE	Fusiliers	*Caesio xanthonota*	Yellowfin fusilier	Kibua mbono

Family		Species	Common name	Kiswahili
OCTOPODIDAE	Octopus	*Octopus cyanea*	Day octopus	Pweza
LOLIGINIDAE	Squid	e.g. *Loligo duvauceli*	e.g. Indian squid	Ngisi
PALINURIDAE	Spiny lobsters	*e.g. Panulirus ornatus*	e.g. Ornate spiny lobster	Kambakoche / kamba

Table 11. Final selection of fishing transport modes used for candidate model and Kruskal-Wallis analysis following variable selection. Based on Tanzanian NBS (2015) and Wells et al. (2007).

Fishing transport	Description	Kiswahili
Fibreglass boat	Used with an engine, straight stern, 3 – 10 m long	Fibre / Boti
Dhow boat	Used with sail, wooden planked boat with pointed stern and prow, 3 – 6 m long	Dau
Dugout canoe	Used with sail, paddle or poles, 2 – 4.5 m long	Mtumbwi
Foot fisher	Use of fins, masks, octopus sticks and nets is common	Miguu

Table 12. Fishing grounds used for candidate model and Kruskal-Wallis analysis. Based on field observations.

Fishing ground	Description
Open sea	Reachable only by boat that was not in the vicinity of reefs
Offshore reef	Reachable only by boat in the vicinity of coral reefs
Fringing reef	Coral reef reachable by boat or swimming in the vicinity of the shore
Shore	Area accessible from the shore or by swimming

3.2.5 Analysis

The data were analysed using R v4.0.2 (R Core Team, 2017) with the mlogit v1.1.0 (Croissant, 2020), glmmTMB v1.0.2.1 (Brooks et al., 2017), lme4 v1.1-23 (Bates, Maechler, Bolker, & Walker, 2015), glmnet v4.0-2 (Friedman, Hastie, & Tibshirani, 2010) and DHARMa v0.3.2 (Hartig, 2020) packages. Figures were produced using the ggplot2 (Wickham, 2009) and ggeffects (Lüdecke, 2018) packages. The full reproducible code is available in Appendix C.

3.3 ETHICS AND LIMITATIONS

Ethical concerns related to my study included risk for participants and obtaining informed consent. When taking part in the household or fisher group survey, the immediate risk for the participants was low. Information that could identify the participants, such as full names and GPS locations of houses was retained only by myself, and digitalised daily. All paper records of sensitive information were erased following each day's fieldwork, and no audio or video taping took place. Efforts were made to ensure that participants were informed before granting consent by having the village guide and translator provide oral and written information about the study and its impacts.

There are several limitations of my study. Firstly, in the research design process, two large datasets, one on socioeconomic conditions in Tanzania and one with empirical blast fishing data were assumed to be available and suitable for analysis. These datasets were not used in the analysis due to unsuitability and access issues, which required the analysis to take a substantially different path to the one planned. The survey methods and specific survey items had been designed to build upon these two longitudinal datasets, and because their unavailability only became apparent at the end of data collection, data collection could not be altered or adjusted to fit the revised research questions. This resulted in large parts of the collected data being unusable for the project. Retrospectively revising research questions and modelling approaches meant relying on collected data as response variables that were not originally intended for such purposes, leading to a limited array of analysis options.

Secondly, my sample was overwhelmingly dominated by male respondents: 1.65% of the fisher respondents were female, and 12.24% of household heads. This can be justified due to the reality that the majority of households are headed by men and that artisanal fishing in Tanzania is dominated by male fishers. Additionally, the majority of female fishers are shore fishers who target sessile invertebrates and anchovies and therefore do not use explosives. However, excluding them from data collection is problematic because women play an active and vital role in the Tanzanian fishery sector as whole through the collection of the species mentioned above, as well as processing, marketing and distributing fishery products (Kleiber, Harris, & Vincent, 2015; Moshy, Bryceson, & Mwaipopo, 2015). Within the limits of my time and budget, I attempted to address this issue by surveying all adults in each household, thereby allowing women to also contribute their perspectives. However, the lack of female respondents, particularly in the fisher focus groups, undoubtedly biased the results and this bias should be taken into account when interpreting the results.

Finally, the experimental design contains bias and is somewhat unbalanced due to the non-random site selection. Challenges to the validity of the results may arise due to the purposive selection of villages based on their blasting histories, as opposed to a truly random selection. However, prior information on village characteristics was gathered so as to ensure a sample that was as representative as possible. In addition, although all attempts were made to randomly select households, logistical constraints and outdated or inaccurate population records resulted in a sample that was not truly random and therefore biased. The results should therefore be treated with caution and interpreted with this limitation in mind.

3.4 RESULTS

3.4.1 Objective 1: Indicators associated with a previous engagement in blasting

3.4.1.1 Blasting history

No model significantly predicted blasting history. Kruskal-Wallis tests revealed significant differences between villages with low and high blasting for attitudes towards marine resource management and a number of target catch species, gears and fishing transport modes. The analysis of household economic indicators and fishing grounds showed no significant differences between low and high blasting histories.

Table 13. Kruskal-Wallis test results for blasting history with adjusted p-values using Holm-Bonferroni correction. Variables in *italics* and adjusted p-values with * indicate ≤ α 0.05

Variable	**Kruskal-Wallis test statistic**	**P-value**	**Adj. p-value**
HOUSEHOLD ECONOMIC INDICATORS			
Access to credit	0.86	0.35	1.00
Ease of access to credit	7.74	0.10	1.00
HH economic status change over 12 months	2.67	0.61	1.00
5-year HH fishing income trends	5.40	0.25	1.00
GEARS			
Gill net	3.83	0.05	0.96
Shark net	9.59	<0.01	0.05*
Long line	43.06	<0.01	<0.01*
Hand line	17.31	<0.01	<0.01*
Fish trap	1.99	0.16	1.00
Octopus stick	6.95	0.01	0.18
Fins and mask	6.07	0.01	0.29
FISHING TRANSPORT MODES			
Foot fisher	6.00	0.01	0.29
Dhow	14.46	<0.01	<0.01*
Dugout	3.67	0.06	1.00
Fibreglass boat	2.34	0.17	1.00

Variable	Kruskal-Wallis test statistic	P-value	Adj. p-value
FISHING GROUNDS			
Open sea fishing ground	2.48	0.12	1.00
Offshore reef fishing ground	1.30	0.25	1.00
Fringing reef fishing ground	0.23	0.63	1.00
Shore fishing ground	7.85	0.01	0.12
TARGET CATCH SPECIES			
Groupers	23.81	<0.01	<0.01*
Snappers	0.16	0.69	1.00
Sharks	8.70	<0.01	0.08
Lobsters	79.19	<0.01	<0.01*
Emperors	0.05	0.82	1.00
Goatfish	0.02	0.88	1.00
Rabbitfish	1.10	0.29	1.00
Trevallys	2.81	0.09	1.00
Octopus	22.63	<0.01	<0.01*
Squid	32.55	<0.01	<0.01*
Mackerels	40.05	<0.01	<0.01*
Parrotfish	8.54	<0.01	0.08
Rays	0.19	0.66	1.00
Anchovies	15.86	<0.01	<0.01*
Tuna	0.31	0.58	1.00
Fusiliers	0.61	0.43	1.00
RESPONSIBILITY FOR MARINE RESOURCES			
Responsible to manage marine resources	30.97	<0.01	<0.01*
Responsible to stop blasting	51.32	<0.01	<0.01*

Examining gears by blasting history revealed that long lines were exclusively used by high blasting history villages (Figure 11). Shark nets and octopus sticks were used mainly by respondents in high blasting history villages, whereas the usage of gill nets, hand lines and fins and masks was more evenly distributed (Figure 11). Anchovies and squid were targeted in the large majority by high blasting history villages, far more low blasting history villages targeted lobsters than their high blasting history counterparts (Figure 14). The great majority of respondents who identified the government as responsible to manage marine resources came from high blasting villages; conversely, high blasting villages comprised less than half of those believing the government responsible to stop blasting (Figure 16). Far more respondents from high blasting villages allocated the primary responsibility to stop blasting to fishers and community groups than their low blasting counterparts (Figure 16). Economic variables, fishing transport modes and fishing grounds displayed no discernible pattern.

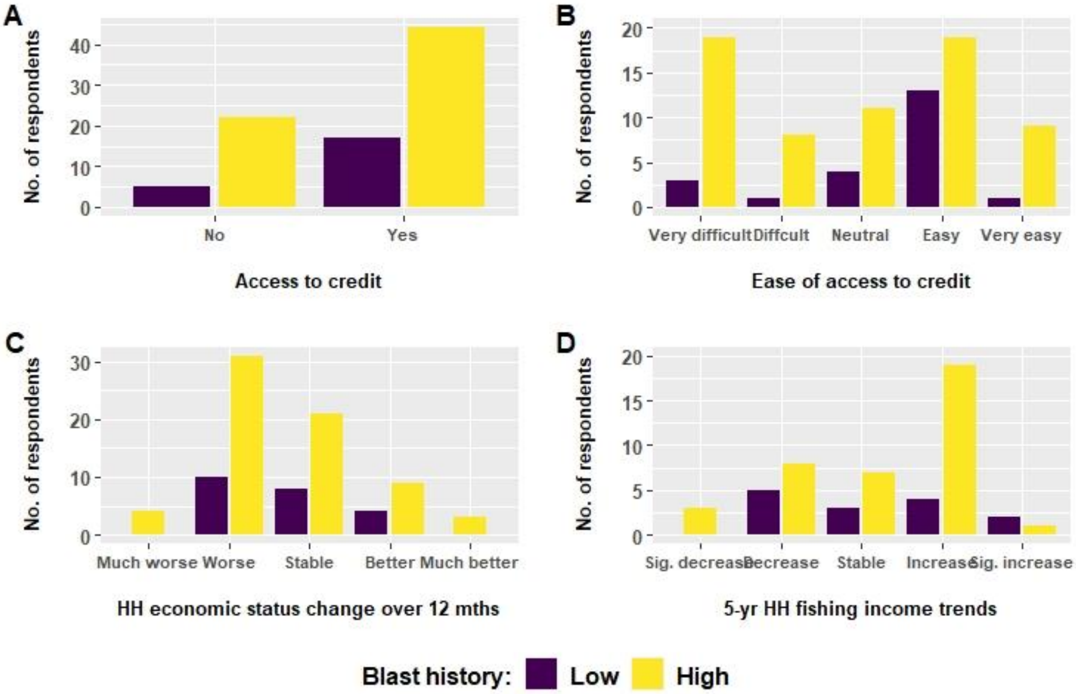

Figure 9. Household economic variables showing current status and temporal trends by blasting history and number of respondents in 18 coastal villages in Tanzania in 2019.

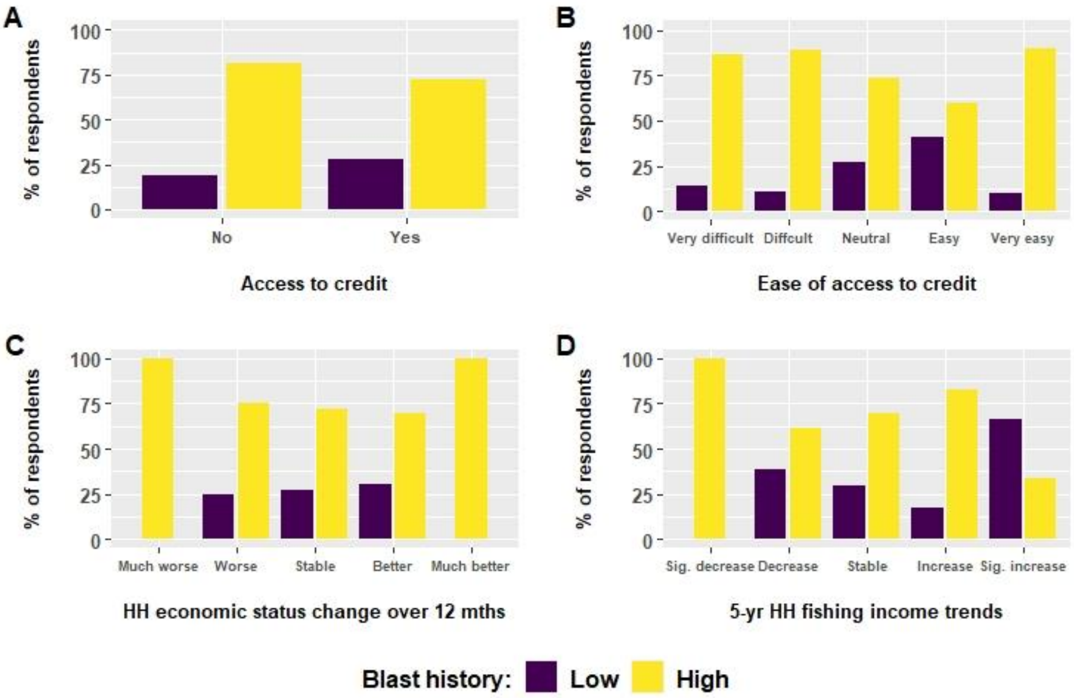

Figure 10. Household economic variables showing current status and temporal trends by blasting history and percentage of respondents in 18 coastal villages in Tanzania in 2019.

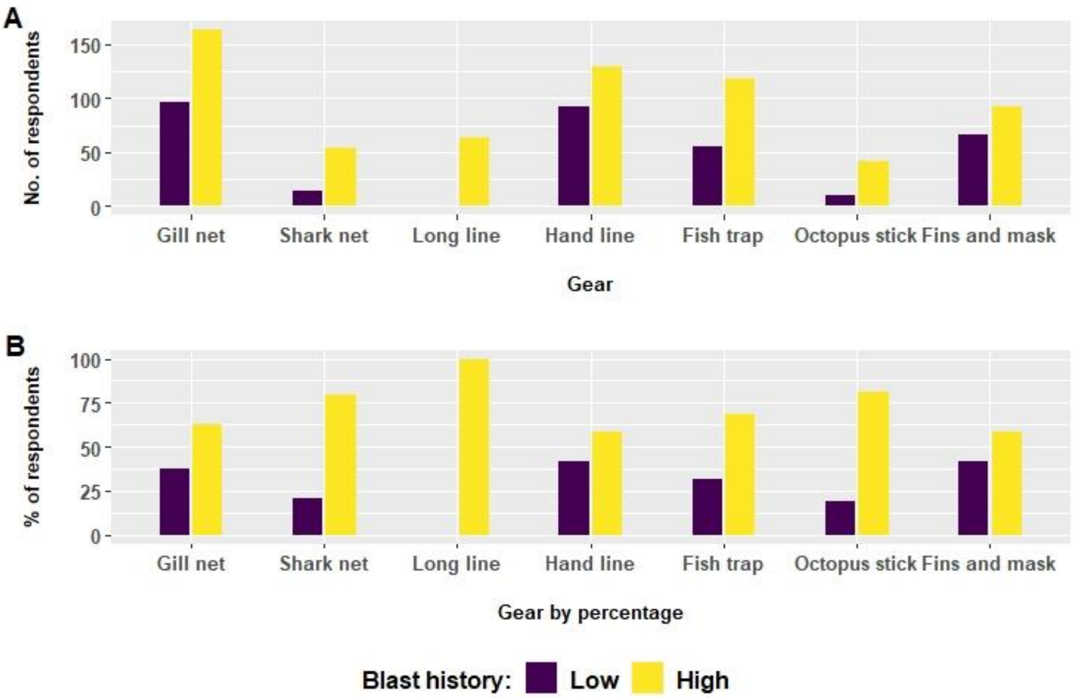

Figure 11. Gears by blasting history, number of respondents and percentage of respondents in 19 coastal villages in Tanzania in 2019.

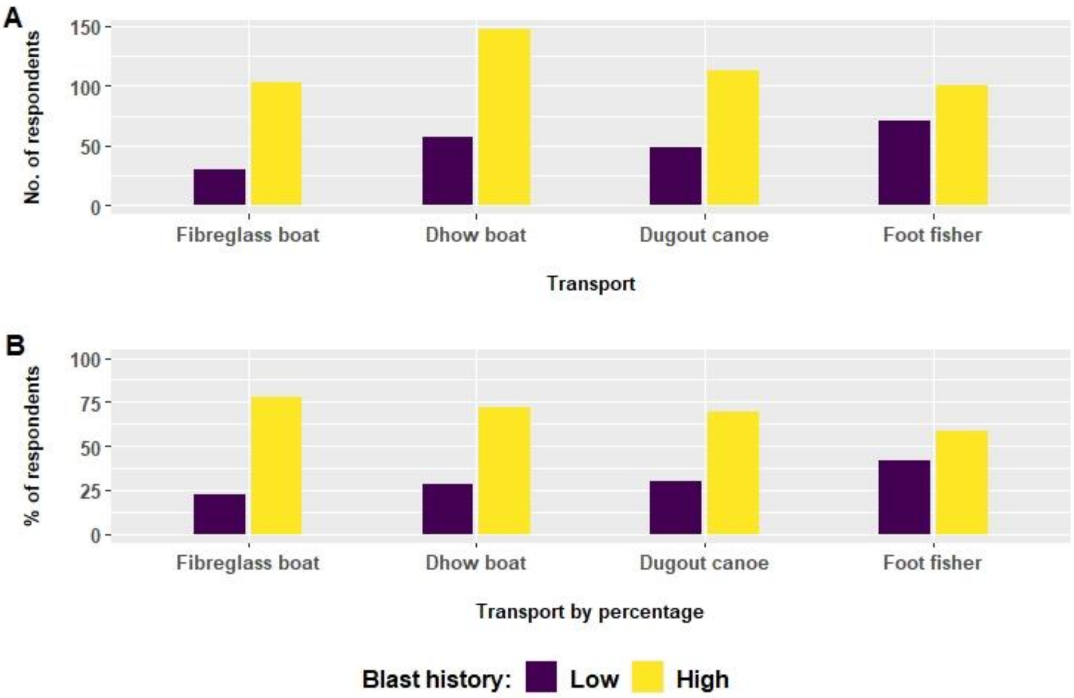

Figure 12. Fishing transport modes by blasting history, number of respondents and percentage of respondents in 19 coastal villages in Tanzania in 2019.

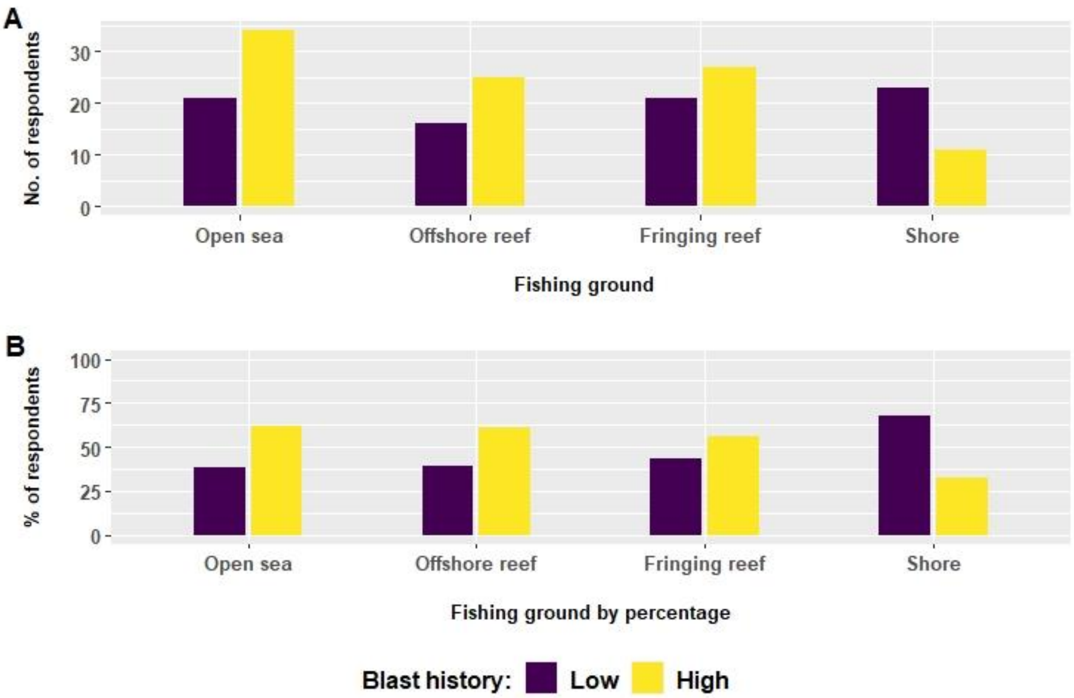

Figure 13. Fishing grounds by blasting history, number of respondents and percentage of respondents in 19 coastal villages in Tanzania in 2019.

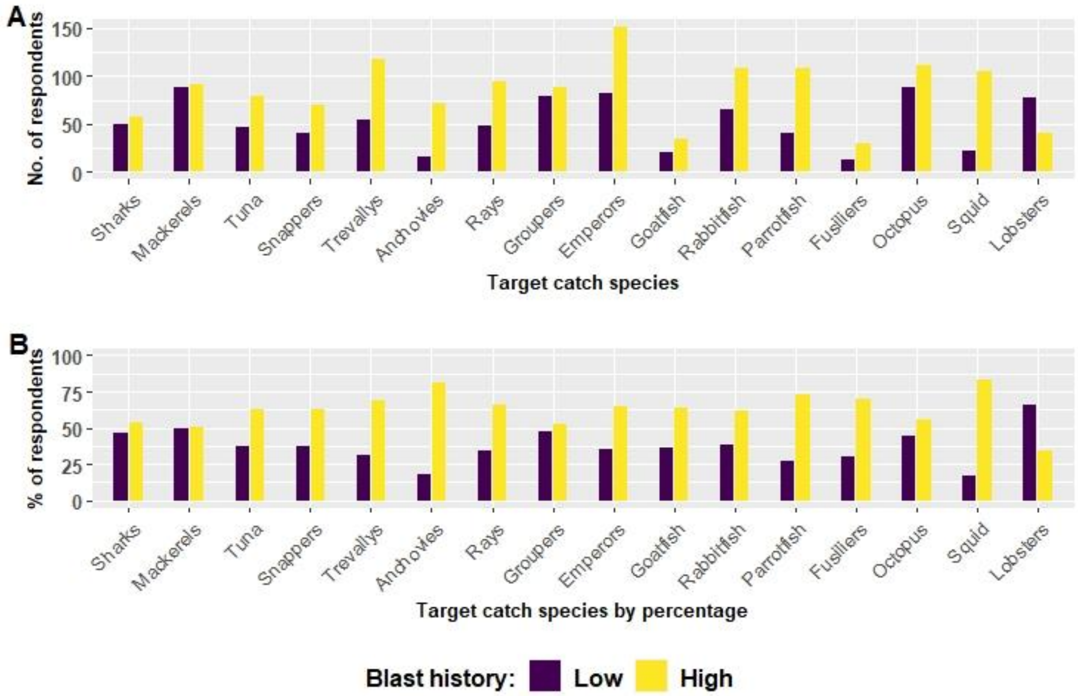

Figure 14. Target catch species by blasting history, number of respondents and percentage of respondents in 19 coastal villages in Tanzania in 2019.

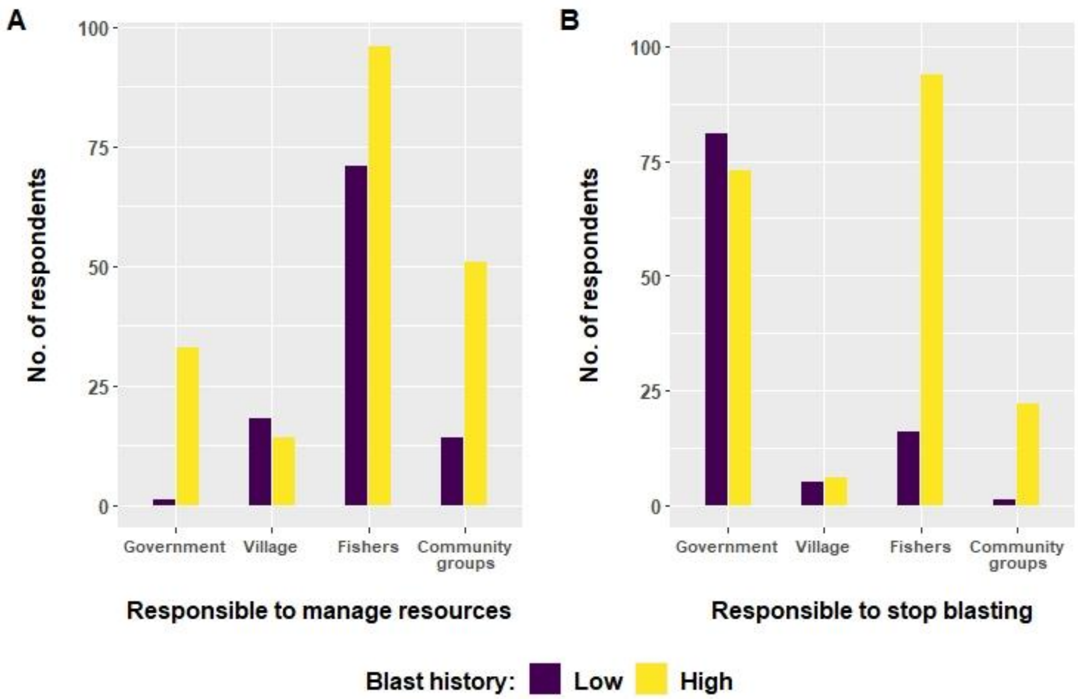

Figure 15. Feelings of responsibility towards marine resources by blasting history and number of respondents in 19 coastal villages in Tanzania in 2019.

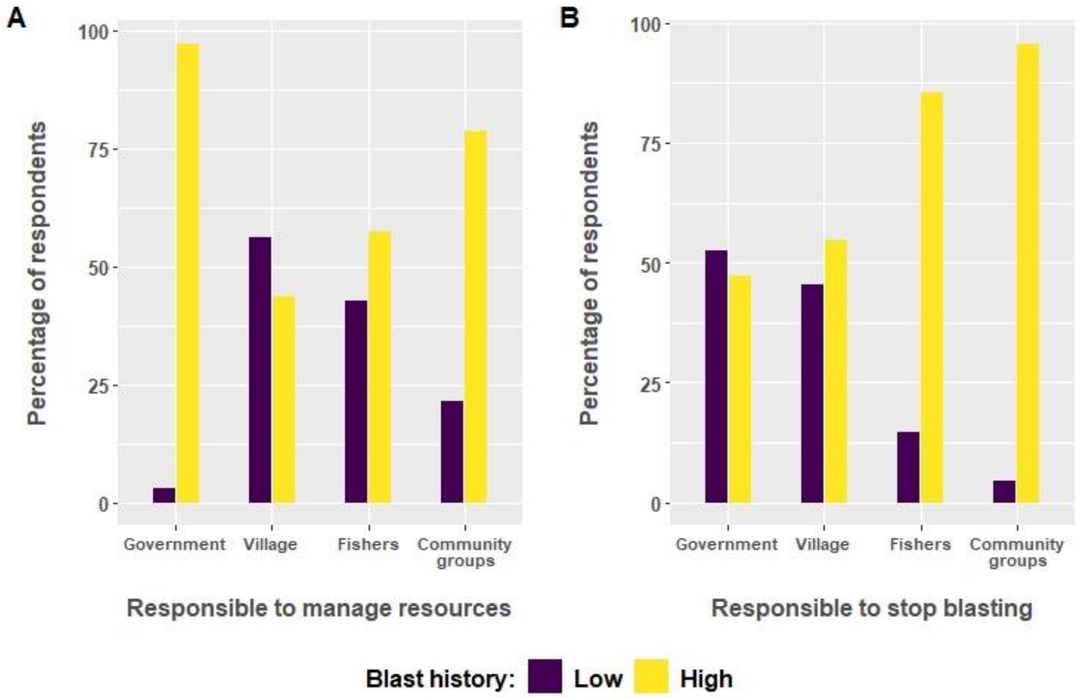

Figure 16. Feelings of responsibility towards marine resources by blasting history and percentage of respondents in 19 coastal villages in Tanzania in 2019.

3.4.1.2 Primary reasons for blasting

Fishing income significantly predicted the primary reasons for blasting. As fishing income increased, respondents were 2.55 times more likely to select the reason that blasting is profitable in comparison to the reference category that blasting is easier (P = 0.009) (Table 14). In comparison to the reason that traditional methods are ineffective, an increase in fishing income led to a 3.16 greater chance than respondents would select the profitability of blasting as the primary cause of blasting (P = 0.003) (Table 15). When this topic was explored further during household surveys and focus groups, participants cited poverty, lack of awareness, blast fishing being an easier method, and a lack of enforcement as contributing to the widespread use of blasting. All other candidate models did not significantly predict respondents' selection of primary blasting cause. Mtwara Rural district had the highest percentage of respondents for the category "No punishment", Kilwa district for "Traditional methods ineffective" and Pangani for "Easier" (Figure 18).

Table 14. Multinomial regression summary for primary causes of blasting, reference category "Easier". P-values with * indicate ≤ α 0.05.

	Primary reason for blasting (ref = Easier)			
Coefficient	*Odds Ratios*	*std. Error*	*Conf. Int (95%)*	*P-Value*
log(Fishing income) : More profitable	2.55	0.36	1.27 – 5.13	0.009*
log(Fishing income) : Trad. methods ineffective	0.81	0.49	0.31 – 2.12	0.666
log(Fishing income) : No enforcement	1.83	0.57	0.60 – 5.60	0.292
R^2 McFadden	0.055			

Table 15. Multinomial regression summary for primary causes of blasting reference category "Traditional methods ineffective". P-values with * indicate ≤ α 0.05.

	Primary reason for blasting (ref = Trad. methods ineffective)			
Coefficient	*Odds Ratios*	*std. Error*	*Conf. Int (95%)*	*P-Value*
log(Fishing income) : Easier	1.24	0.49	0.47 – 3.25	0.666
log(Fishing income) : More profitable	3.16	0.39	1.47 – 6.75	0.003*
log(Fishing income) : No enforcement)	2.26	0.59	0.71 – 7.19	0.168
R^2 McFadden	0.055			

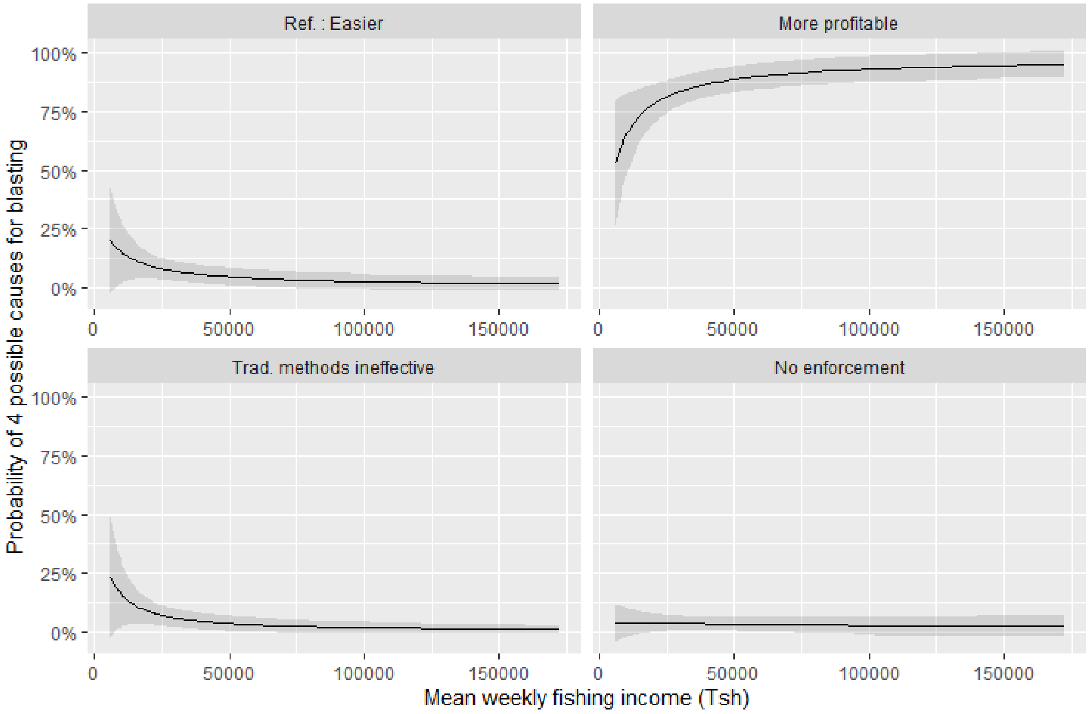

Figure 17. Probability of respondents' choosing one of four possible blast fishing drivers, plotted by mean weekly fishing income with predicted model values. Bands show 95% confidence intervals.

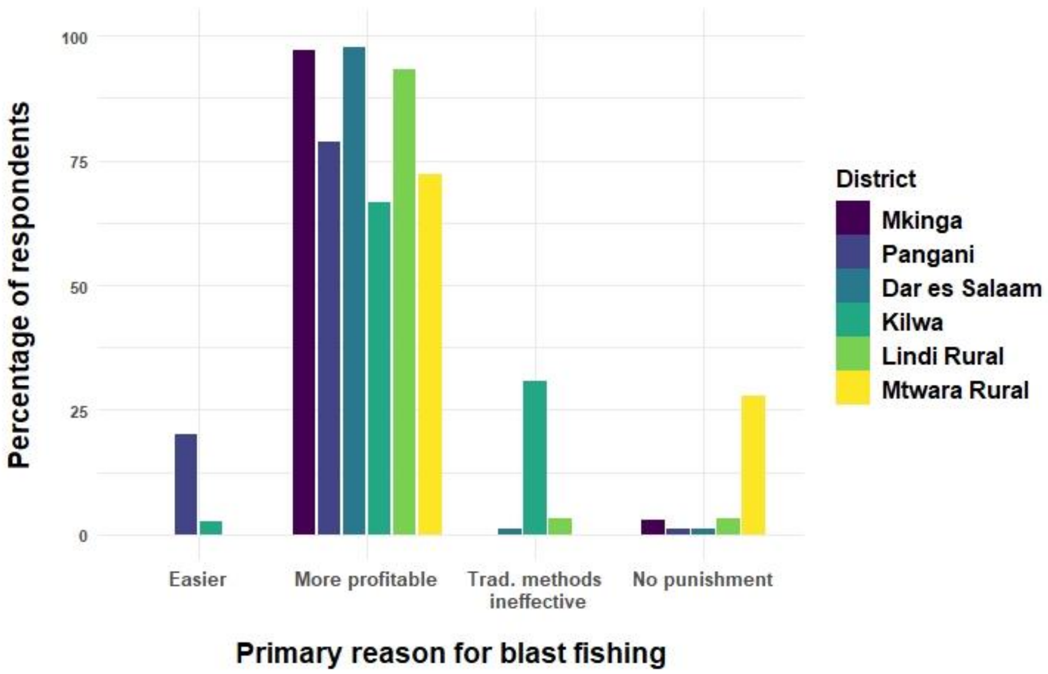

Figure 18. Distribution of primary reasons for blasting by district and percentage of respondents (n = 290) in 19 coastal villages in Tanzania in 2019.

3.4.2 Objective 2: Indicators associated with reduction of blasting

Fishing income significantly predicted the primary reasons for reduction in blasting. As income from fishing increased, respondents were 85% less likely to select community groups as being the reason for blasting cessation, as opposed to the government (P = 0.050) (Table 16) (Figure 19). All other models did not significantly predict respondents' selection of primary blasting cessation cause. The model displayed nearly perfect interdependence of residuals (ICC = 0.98) with only slight within-cluster variation. However, the combined adjusted quantile test on the expected versus predicted residuals was significant, indicating a possible problem with model fit. Tests for dispersion and zero-inflation were nonetheless insignificant.

Table 16. Binomial regression model summary for blasting reduction reasons. P-values with * indicate ≤ α 0.05.

	Primary reasons for blast reduction (ref = Government)			
Coefficient	*Odds Ratios*	*std. Error*	*Conf. Int (95%)*	*P-Value*
log(Fishing income) : Community groups	0.15	0.95	0.02 – 1.00	0.050*
Random Effects				
σ^2	3.29			
$\tau_{00\ village\ 1\ 01c}$	147.20			
ICC	0.98			
$N_{village\ 1\ 01c}$	19			
Marginal R^2 / Conditional R^2	0.015 / 0.978			

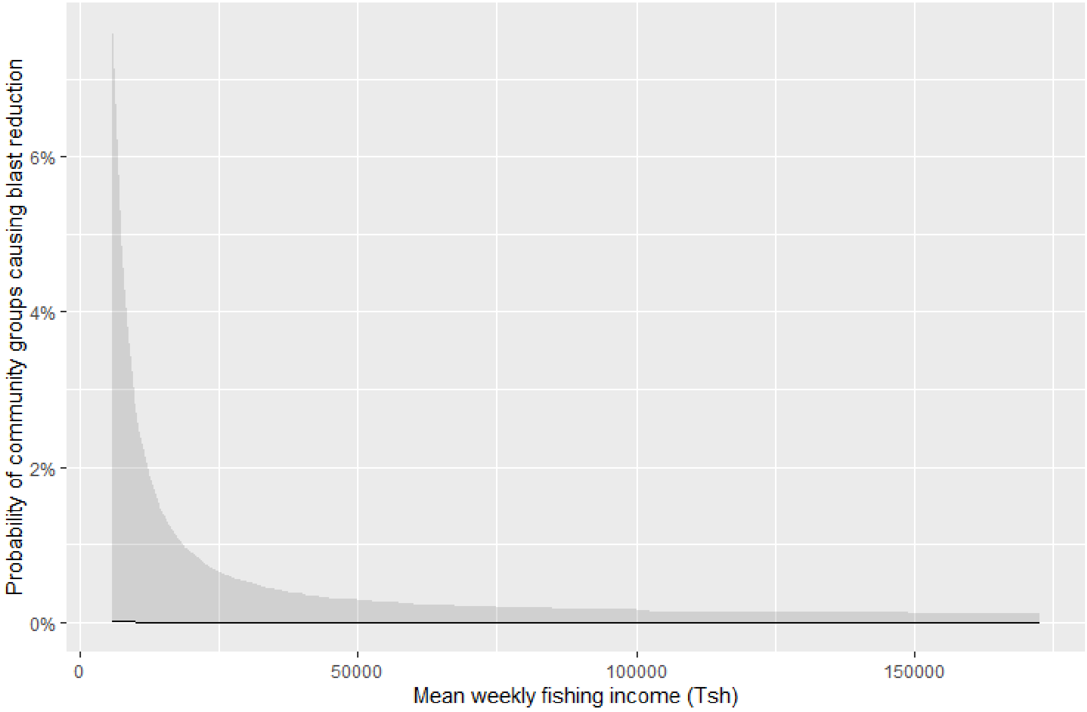

Figure 19. Probability of community groups being the primary driver of blasting reduction as opposed to the government, plotted by mean weekly fishing income with predicted model values. Bands show 95% confidence intervals.

However, despite increased fishing income decreasing the odds that community groups would be chosen over the government as the primary blast cessation cause, mean income was lower for those who chose the government than community groups (Figure 20). Only participants from northern and central districts (Mkinga, Pangani and Dar es Salaam) selected community groups as the primary reason for blasting reduction (Figure 21).

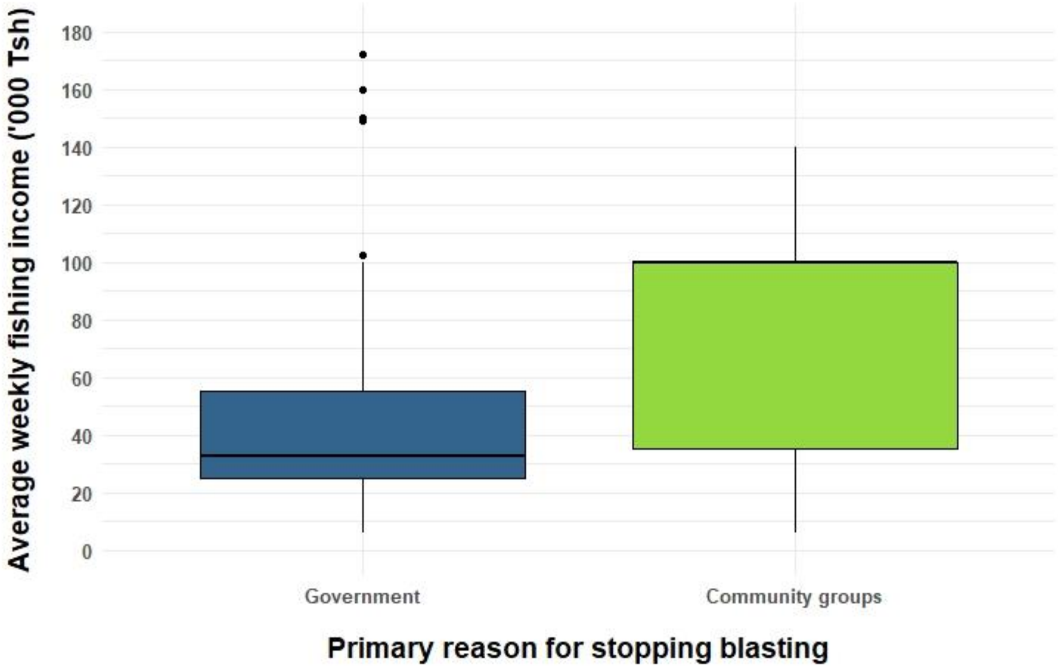

Figure 20. Respondents who chose the government over community groups as their primary reason for blasting cessation had a lower average weekly fishing income.

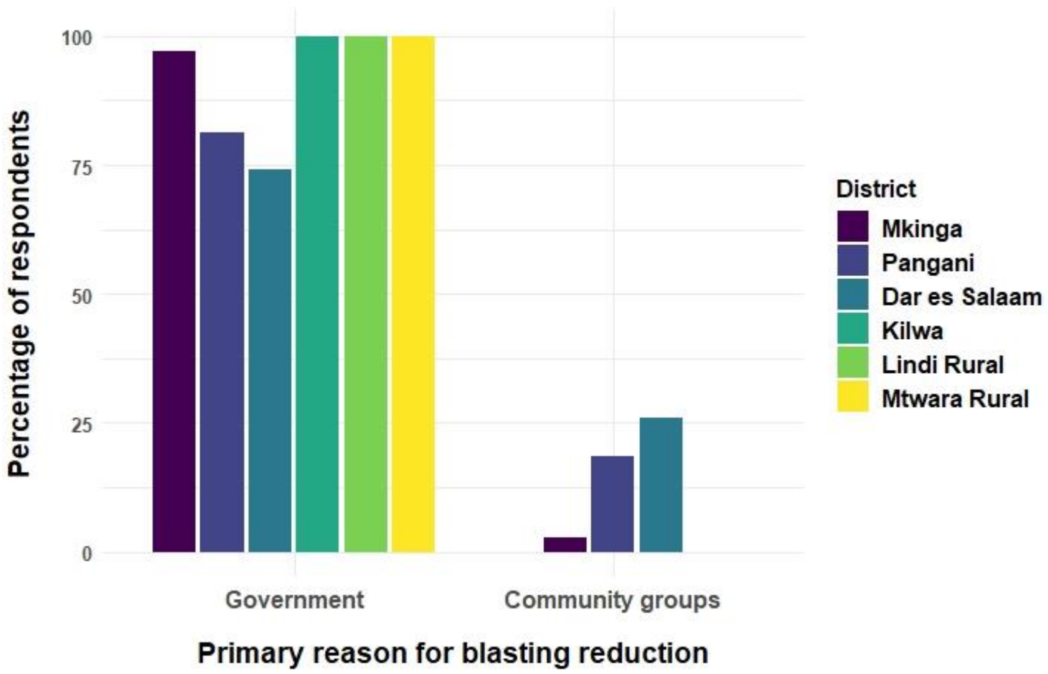

Figure 21. Primary reasons for stopping blasting distribution by district and percentage of respondents (n = 293) in 19 coastal villages in Tanzania in 2019.

3.5 DISCUSSION

The first objective was to identify predictors for blasting history; however, no model produced significant results. This may be due to inaccuracies in the classification of blasting history. Several local experts were consulted during the development of the classification system, and when using one system, the probability of a high blasting history was significantly increased by increased fishing income and housing standards. However, the final and most accurate system used for the analysis revealed that no factors significantly predicted blasting. This should not be interpreted to mean that blasting behaviour cannot be predicted, rather that classifying blasting history with a simplistic binary system is problematic and possibly unreliable. Although empirical data on blasting frequency and location was not available for this analysis, the inclusion thereof would undoubtedly improve the accuracy of the analysis. The problem could also lie with sampling bias: out of the seven districts, only three included control sites with a low blasting history.

Complicating matters further is the complex economic dynamic between blast fishers and their sponsors: blasting operations in Tanzania are allegedly influenced by wealthier middlemen, as they are in Indonesia (Ammarell, 2014). Fishers are enticed by promised profits and are established by patrons with necessary equipment to carry out blasting operations. However, they are then trapped into continuing to blast to repay their debts. While there is no concrete evidence in Tanzania to verify this phenomenon, data collection being complicated by the illegal and politicised nature of the practice, anecdotal evidence from local community organisations working to combat blasting suggests that this dynamic between fishers and patrons was widespread before the government campaign began in 2016 (Rubens, 2019; Slade & Kalangahe, 2015). This could explain the failure of economic indicators focusing solely on fishers and not on other members of the blast fishing profit chain to predict blasting history. Finally, extreme weather events including flooding and storms affected fishing and other income generating activities during the period of data collection, which may have distorted participants' perceptions of fish availability and income trends and therefore also distorted the analysis.

Kruskal-Wallis tests revealed significant differences between low and high blast history villages for a number of target catch species, however there was no discernible pattern among reef-based, demersal, semi-demersal and pelagic species to be seen, and neither could an obvious pattern be identified for associated gears and fishing transport modes. Interestingly, low and high blasting villages displayed significant differences in feelings of responsibility towards managing marine resources, with high blasting history villages overwhelmingly selecting fishers and community groups as having the primary responsibility to stop blasting. Although the model using these two predictors produced insignificant results, this could be an avenue for fruitful further research, as community attitudes towards marine resource management are crucial factors in long-term management plans (e.g. Pollnac et al., 2010). This study was therefore unable to demonstrate a clear causal effect for blasting, and neither directly supported nor detracted from the three dominant causes of blasting identified in the literature: poverty (e.g. McManus, 1997; Pauly, Silvestre, & Smith, 1989; Wagner, 2004), lack of deterrence (e.g. Haisfield, Fox, Yen, Mangubhai, & Mous, 2010) or ineffective governance (e.g. Hughes, Huang, & Young, 2013).

Profitability was cited as the primary reason for blasting, demonstrating a clear financial motivation for this illegal activity. However, the increased chance of selecting profitability with increased fishing income suggests that respondents in lower economic brackets were not driven as strongly by financial motivation. These results suggest that as income increases, the profitability of blasting becomes more attractive, which could be attributed to the fisher-middleman dynamic described above, or to the need to maintain higher living standards. Therefore, in contrast to participants' assertion that poverty contributed to their blasting, our results do not unambiguously support poverty as a driving factor. It should be noted that the multinomial logistic model used did not allow survey site to be used as a random factor, so it may be that cases within villages were too highly correlated, thus distorting the results. Nonetheless, these findings are consistent with previous studies in both Tanzania and elsewhere that drew a link between higher fishing incomes and blasting (e.g. Pet-Soede et al., 1999; Pet-Soede & Erdmann, 1998, Silva, 2006). Interestingly, despite Mtwara having been heavily targeted during previous naval raids on blast fishing hotspots during the 1997 Operation Pono (Rubens, 2016), a higher percentage of respondents cited a lack of punishment as a primary reason for blasting than in any other region.

This could be attributed to the fact that in intervening years, there has been a marked reluctance by the government to initiate military operations and risk further allegations of human rights abuses, as happened in Mtwara during the operation.

The government was selected as the primary reason for ceasing blast fishing by an overwhelming majority of participants, which supported the theory that enforcement by the Ministry of Fisheries and Livestock, the Tanzanian navy, and the police force was responsible for the reduction. An increase in fishing income decreased the probability that respondents would choose community groups over the government as the primary reason for blasting reduction, although the effect size was small. One possible explanation is that blasting was practised by fishers in higher income brackets. Given the lucrative nature of blasting, blasters earning high incomes required stronger deterrents to cease. Moreover, blast fishers sponsored by middlemen would be locked economically into continuing to blast, and would therefore be less deterred by "soft" enforcement such as community programs and education campaign drives. Several outliers with substantially higher incomes skewed the results towards higher income predicting the primary reason as the government, rather than community groups. It is likely that blast fishers received considerably higher incomes than fishers using traditional methods, and so this result is not surprising.

As with the analysis of the primary reasons for blasting, these results accord with studies that point to the profitability of blasting as its primary cause (Bailey & Sumaila, 2015), and to the necessity of deterrence measures to halt blasting (e.g. Chan & Hodgson, 2017; Fox et al., 2005). These findings, while preliminary, may help us to understand why blast fishing has continually reoccurred in Tanzania – enforcement efforts have historically been inconsistent and plagued by lack of political will and funding, as well as corruption (Katikiro & Mahenge, 2015; Rubens, 2016). Among-district variation pointed to a divide between northern and southern districts in the reasons for stopping blasting. The strong and long-standing presence of fisher community groups in Mkinga, Pangani and Dar es Salaam districts may have contributed to the differences observed between these and southern districts, in which no respondent cited community groups as the primary reason for blasting reduction. This observation provides encouraging if tentative support for previous studies in which CBM within MPAs was found to reduce blasting when applied correctly and appropriately to the local context (e.g. Rocliffe et al., 2014).

In conclusion, these results point to a complex relationship between socioeconomic factors and blasting causation. They provide tentative support for the importance of enforcement in managing destructive fishing, and do not support the theory that poverty causes blasting. However, there are undoubtedly other factors influencing Tanzanian fishers' decisions to blast or cease blasting, including economical and geographical factors such as distance from fishing ground to urban markets and the changing taxation on fish sales since 2015, as well as political factors such as the influence of political pressure on wealthy (and historically well-connected) blasting middlemen. This analysis focused on primary data gathered from fishing communities in areas with low and high blast fishing histories, and sheds light on the drivers for blast fishing and blasting reduction in Tanzania. Further avenues for research include a focus on blasting causality in the Tanzanian context, including the influence of governance structures on blasting frequency. Given the problems faced in this study with blasting history classification, the inclusion of empirical blasting data is recommended. An analysis incorporating secondary data on geo-spatial and political factors with the primary data gathered for this study could provide a more accurate and comprehensive picture of blast fishing drivers, and should therefore be considered for future research.

3.6 REFERENCES

Agrawal, A. (2001). Common property institutions and sustainable governance of resources. *World development, 29*(10), 1649-1672. doi:10.1016/S0305-750X(01)00063-8

Ammarell, G. (2014). Shared Space, Conflicting Perceptions, and the Degradation of an Indonesian Fishery. *Ethos, 42*(3), 352-375. doi:10.1111/etho.12053

Arai, T. (2015). Diversity and conservation of coral reef fishes in the Malaysian South China Sea. *Reviews in Fish Biology and Fisheries, 25*(1), 85-101. doi:10.1007/s11160-014-9371-9

Bailey, M., & Sumaila, U. R. (2015). Destructive fishing and fisheries enforcement in eastern Indonesia. *Marine Ecology Progress Series, 530*, 195-211. doi:10.3354/meps11352

Bates, D., Maechler, M., Bolker, B., & Walker, S. (2015). Fitting Linear Mixed-Effects Models Using lme4. Journal of Statistical Software, 67(1), 1-48. doi:10.18637/jss.v067.i01

Béné, C., Chijere, A. D., Allison, E. H., Snyder, K., & Crissman, C. (2012). *Design and implementation of fishery modules in integrated household surveys in developing countries. Living Standards Measurement Study – Integrated Surveys on Agriculture*. Penang, Malaysia: The WorldFish Center. 83 pp.

Braulik, G., Wittich, A., Macaulay, J., Kasuga, M., Gordon, J., Davenport, T. R. B., & Gillespie, D. (2017). Acoustic monitoring to document the spatial distribution and hotspots of blast fishing in Tanzania. *Marine Pollution Bulletin, 125*(1-2), 360-366. doi:10.1016/j.marpolbul.2017.09.036

Brooks, M. E., Kristensen, K., van Benthem, K. J., Magnusson, A., Berg, C. W., Nielsen, A., . . . Bolker, B. M. (2017). glmmTMB Balances Speed and Flexibility Among Packages for Zero-inflated Generalized Linear Mixed Modeling. *The R Journal, 9*(2), 378-400.

Chan, A., & Hodgson, P. A. (2017). *A systematic analysis of blast fishing in South-East Asia and possible solutions.* Paper presented at the 2017 IEEE OES International Symposium on Underwater Technology, UT 2017.

Cinner, J. E. (2010). Poverty and the use of destructive fishing gear near east African marine protected areas. *Environmental Conservation, 36*(04), 321-326. doi:10.1017/s0376892910000123

Cinner, J. E., McClanahan, T. R., Daw, T. M., Graham, N. A. J., Maina, J., Wilson, S. K., & Hughes, T. P. (2009). Linking Social and Ecological Systems to Sustain Coral Reef Fisheries. *Current Biology, 19*(3), 206-212. doi:10.1016/j.cub.2008.11.055

Cinner, J. E., McClanahan, T. R., MacNeil, M. A., Graham, N. A., Daw, T. M., Mukminin, A., . . . Jiddawi, N. (2012). Comanagement of coral reef social-ecological systems. *Proceedings of the National Academy of Sciences, 109*(14), 5219-5222. doi:10.1073/pnas.1121215109

Croissant, Y. (2020). mlogit: Multinomial Logit Models (Version version 1.1-0): R package. Retrieved from https://CRAN.R-project.org/package=mlogit

Darwall, W. R. T., & Guard, M. (2000). Southern Tanzania. In T. R. McClanahan, C. R. C. Sheppard, & D. O. Obura (Eds.), *Coral Reefs of the Indian Ocean: Their Ecology and Conservation* (pp. 131-165). Oxford: Oxford University Press.

Fisheries Act 1970. Tanzania

Fisheries Act 2003. Tanzania

Fox, H. E., & Caldwell, R. L. (2006). Recovery from blast fishing on coral reefs: a tale of two scales. *Ecological Applications, 16*(5), 1631-1635.

Fox, H. E., Mous, P. J., Pet, J. S., Muljadi, A. H., & Caldwell, R. L. (2005). Experimental Assessment of Coral Reef Rehabilitation Following Blast Fishing. *Conservation Biology, 19*(1), 98-107. doi:10.1111/j.1523-1739.2005.00261.x

Fox, H. E., Pet, J. S., Dahuri, R., & Caldwell, R. L. (2003). Recovery in rubble fields: long-term impacts of blast fishing. *Marine Pollution Bulletin, 46*(8), 1024-1031. doi:10.1016/s0025-326x(03)00246-7

Friedlander, A. M., & Parrish, J. D. (1998). Habitat characteristics affecting fish assemblages on a Hawaiian coral reef. *Journal of Experimental Marine Biology and Ecology, 224*(1), 1-30. doi:10.1016/S0022-0981(97)00164-0

Friedman, J., Hastie, T., & Tibshirani, R. (2010). Regularization Paths for Generalized Linear Models via Coordinate Descent. *Journal of Statistical Software, 33*(1), 1-22.

Galvez, R., Hingco, T. G., Bautista, C., & Tungpalan, M. T. (1989). Sociocultural Dynamics of Blast Fishing and Sodium-Cyanide Fishing in Two Fishing Villages in the Lingayen Gulf Area. In G. Silvestre, E. Miclat, & T. E. Chua (Eds.), *Towards Sustainable Development of the Coastal Resources of Lingayen Gulf, Philippines* (Vol. 17, pp. 43-62).

Gorris, P. (2016). Deconstructing the Reality of Community-Based Management of Marine Resources in a Small Island Context in Indonesia. *Frontiers in Marine Science, 3*(120), 1-15. doi:10.3389/fmars.2016.00120

Grosh, M., & Glewwe, P. (2000). *Designing Household Survey Questionnaires for Developing Countries. Lessons from 15 Years of the Living Standards Measurement Study*. Washington DC, USA: The World Bank. 365 pp.

Haisfield, K. M., Fox, H. E., Yen, S., Mangubhai, S., & Mous, P. J. (2010). An ounce of prevention: cost-effectiveness of coral reef rehabilitation relative to enforcement. *Conservation Letters, 3*(4), 243-250. doi:10.1111/j.1755-263X.2010.00104.x

Hartig, F. (2020). DHARMa: Residual Diagnostics for Hierarchical (Multi-Level / Mixed) Regression Models. R Package. (Version 0.3.2). Retrieved from https://CRAN.R-project.org/package=DHARMa.

Hempson, T. N. (2008). *Impacts of Dynamite Fishing on Coral Reef Communities in the Tanga Region, Tanzania.* (MSc). University of Cape Town, Cape Town.

Hughes, T. P., Barnes, M. L., Bellwood, D. R., Cinner, J. E., Cumming, G. S., Jackson, J. B., . . . Morrison, T. H. (2017). Coral reefs in the Anthropocene. *Nature, 546*(7656), 82-90. doi:10.1038/nature22901

Hughes, T. P., Huang, H., & Young, M. A. L. (2013). The Wicked Problem of China's Disappearing Coral Reefs. *Conservation Biology, 27*(2), 261-269. doi:10.1111/j.1523-1739.2012.01957.x

Jiddawi, N. S., & Öhman, M. C. (2002). Marine fisheries in Tanzania. *Ambio, 31*(7), 518-527.

Kamat, V. (2014). " The Ocean is our Farm": Marine Conservation, Food Insecurity, and Social Suffering in Southeastern Tanzania. *Human Organization, 73*(3), 289-298.

Katikiro, R. E., & Mahenge, J. J. (2016). Fishers' Perceptions of the Recurrence of Dynamite-Fishing Practices on the Coast of Tanzania. *Frontiers in Marine Science, 3*, 1-14. doi:10.3389/fmars.2016.00233

Kleiber, D., Harris, L. M., & Vincent, A. C. (2015). Gender and small-scale fisheries: a case for counting women and beyond. Fish and Fisheries, 16(4), 547-562. doi:10.1111/faf.12075

Knudby, A., LeDrew, E., & Brenning, A. (2010). Predictive mapping of reef fish species richness, diversity and biomass in Zanzibar using IKONOS imagery and machine-learning techniques. *Remote Sensing of Environment, 114*(6), 1230-1241. doi:10.1016/j.rse.2010.01.007

Kumar, K. (2006). *Conducting Mini Surveys in Developing Countries (PN-ADG-566).* USAID Bureau for Policy and Program Coordination. https://dec.usaid.gov/dec/content/Detail.aspx?vID=47&ctID=ODVhZjk4NWQtM2YyMi00YjRmLTkxNjktZTcxMjM2NDBmY2Uy&rID=MTMzNTk2. 40 pp.

Lüdecke, D. (2018). ggeffects: Tidy Data Frames of Marginal Effects from Regression Models. Journal of Open Source Software, 3(26), 772-777. doi:10.21105/joss.00772

Mahongo, S. (2017). Capturing and documenting lessons and experiences of EU-WWF Fisheries Co-Management Programme Final Report. Dar es Salaam, Tanzania: WWF Tanzania. 25 pp. doi:10.13140/RG.2.2.26964.55685

McClanahan, T. R., Glaesel, H., Rubens, J., & Kiambo, R. (1997). The effects of traditional fisheries management on fisheries yields and the coral-reef ecosystems of southern Kenya. *Environmental Conservation, 24*(2), 105-120. doi:10.1017/S0376892997000179

McClanahan, T. R., Muthiga, N. A., Abunge, C., Kamukuru, A. T., Mwakalapa, E., & Kalombo, H. (2015). What happens after conservation and management donors leave? A before and after study of coral reef ecology and stakeholder perceptions of management benefits. *PLoS ONE, 10*(10), 1-24. doi:10.1371/journal.pone.0138769

McManus, J. W. (1997). Tropical marine fisheries and the future of coral reefs: a brief review with emphasis on Southeast Asia. *Coral Reefs, 16*(1), S121-S127. doi:10.1007/s003380050248

Moshy, V. H., Bryceson, I., & Mwaipopo, R. (2015). Social-ecological Changes, Livelihoods and Resilience Among Fishing Communities in Mafia Island Marine Park, Tanzania. Forum for Development Studies, 42(3), 529-553. doi:10.1080/08039410.2015.1065906

Moshy, V. H., & Bryceson, I. (2016). Seeing Through Fishers' Lenses: Exploring Marine Ecological Changes Within Mafia Island Marine Park, Tanzania. *SAGE Open, 6*(2). doi:10.1177/2158244016641716

Muhando, C. A., & Mohammed, M. S. (2002). Coral reef benthos and fisheries in Tanzania before and after the 1998 bleaching and mortality event. *Western Indian Ocean Journal of Marine Science, 1*(1), 43-52.

Nzali, L. M., Johnstone, R. W., & Mgaya, Y. (1998). Factors affecting scleractinian coral recruitment on a nearshore reef in Tanzania. *Ambio*, 717-722.

Ostrom, E. (2009). A General Framework for Analyzing Sustainability of Social-Ecological Systems. *science, 325*(5939), 419-422.

Pauly, D., Silvestre, G., & Smith, I. R. (1989). On Development, Fisheries and Dynamite: A Brief Review of Tropical Fisheries Management. *Natural Resource Modeling, 3*(3), 307-329. doi:10.1111/j.1939-7445.1989.tb00084.x

Pet-Soede, C., Cesar, H. S. J., & Pet, J. S. (1999). An economic analysis of blast fishing on Indonesian coral reefs. *Environmental Conservation, 26*(2), 83-93. doi:10.1017/s0376892999000132

Pet-Soede, L., & Erdmann, M. (1998). An overview and comparison of destructive fishing practices in Indonesia. *SPC Live Reef Fish Information Bulletin, 4*, 28-36.
Pollnac, R., Christie, P., Cinner, J. E., Dalton, T., Daw, T. M., Forrester, G. E., . . . McClanahan, T. R. (2010). Marine reserves as linked social–ecological systems. *Proceedings of the National Academy of Sciences, 107*(43), 18262. doi:10.1073/pnas.0908266107
R Core Team. (2017). R: A language and environment for statistical computing. Vienna, Austria.
Rocliffe, S., Peabody, S., Samoilys, M., & Hawkins, J. P. (2014). Towards A Network of Locally Managed Marine Areas (LMMAs) in the Western Indian Ocean. *PLoS ONE, 9*(7). doi:10.1371/journal.pone.0103000
Rogers, A., Blanchard, J. L., & Mumby, P. J. (2018). Fisheries productivity under progressive coral reef degradation. *Journal of Applied Ecology, 55*(3), 1041-1049. doi:10.1111/1365-2664.13051
Rubens, J. (2016). *Review of the status of blast fishing in Tanzanian marine waters: with recommendations for priority interventions*. Dar es Salaam, Tanzania: Hotel Association of Tanzania (HAT) & BEST Dialogue. 61 pp.
Rubens, J. (2019). *Combating blast-fishing in Tanzanian marine waters: Progress, achievements & lessons 2016-2018*. Dar es Salaam, Tanzania: Hotel Association of Tanzania (HAT) & BEST Dialogue. 38 pp.
Silva, P. (2006). *Exploring the linkages between poverty, marine protected area management, and the use of destructive fishing gear in Tanzania*. The World Bank. http://econ.worldbank.org. 43 pp.
Slade, L. M., & Kalangahe, B. (2015). Dynamite fishing in Tanzania. *Marine Pollution Bulletin, 101*(2), 491-496. doi:10.1016/j.marpolbul.2015.08.025
Stamatopoulos, C. (2002). *Sample-based fishery surveys. A technical handbook.* (9251046999). Rome, Italy: FAO. 144 pp.
Tanzania Blast-Fishing Monitoring Network. (2018). *Blast records*. Retrieved from: www.tz-blast-monitoring.net/
Tanzanian National Bureau of Statistics (NBS). (2015). *National Panel Survey (NPS) - Wave 4, 2014 - 2015*. Retrieved from: www.nbs.go.tz
The World Bank. *Tanzania - Measuring Living Standards within Cities, Dar es Salaam 2014-2015 (TZA_2014_DAR-LSMS_v01_M)*. Retrieved from: https://microdata.worldbank.org/index.php/catalog/3399
Wagner, G. M. (2004). Coral reefs and their management in Tanzania. *Western Indian Ocean Journal of Marine Science*, *3*(2), 227-243.
Wells, S. (2009). Dynamite fishing in northern Tanzania - pervasive, problematic and yet preventable. *Marine Pollution Bulletin, 58*(1), 20-23. doi:10.1016/j.marpolbul.2008.09.019
Wells, S., Makoloweka, S., & Samoilys, M. (2007). *Putting Adaptive Management into Practice: Collaborative Coastal Management in Tanga, Northern Tanzania*. Nairobi, Kenya: The World Conservation Union (IUCN) & Irish Aid. 197 pp.
Wickham, H. (2009). *ggplot2: Elegant Graphics for Data Analysis.* New York: Springer-Verlag.

Chapter 4: Impact of blast fishing reduction on fishing in Tanzania

4.1 INTRODUCTION

Blast fishing has been a reoccurring concern for marine fisheries and ecosystems along the Tanzanian coastline since the 1960s (Jiddawi and Öhman, 2002). Blast fishing has a direct destructive effect on coral reef ecosystems as well as on coastal fishing communities that rely on reef fisheries as a source of income and food (Burke et al., 2011, Fox et al., 2003). The use of explosives to catch fish results in partial or complete destruction of reef structures as well as the indiscriminate removal of juveniles, which over time leads to sharply declining fish abundance and species richness (Calud et al., 1989, Rogers, Blanchard and Mumby, 2018). Coral reef rugosity and diversity are also linked to fishery relevant indicators such as biomass (Ainsworth, Varkey and Pitcher, 2008). Although few studies have directly assessed the impact of blasting on markers such as abundance and diversity, the detrimental effect of blasting on the reef habitat has been thoroughly discussed in the literature (e.g. Fox et al., 2003), as has rugosity degradation and its impact on various markers. Therefore studies that assess the impact of reef degradation remain relevant, despite not focusing on blasting per se (e.g. Friedlander & Parrish, 1998; Knudby, LeDrew, & Brenning, 2010; Rogers, Blanchard, & Mumby, 2018).

Moreover, natural reef regeneration following a reduction or cessation in blast fishing is limited by the extent of the destruction, the level of legal protection during regeneration and environmental conditions such as current strength (Fox and Caldwell, 2006, McManus, Reyes Jr and Nanola Jr, 1997). Reefs and their associated populations can recover from damage created by isolated or small-scale blasting, but extensive blasting creates rubble fields of shifting coral that disturb new coral recruits and thus prevent natural regeneration (Fox et al., 2003). Blasting can reduce the growth capacity of scleractinian corals (McManus, Reyes Jr, & Nanola Jr, 1997), and the impacts of blasting on reefs are likely non-linear due to unstable coral rubble disrupting new coral recruits (Fox & Caldwell, 2006; Raymundo, Maypa, Gomez, & Cadiz, 2007). Although rapid recovery of scleractinian corals has been observed (Alcala, 2000), other blasted reefs are estimated to require decades if not centuries to naturally regenerate (Riegl & Luke, 1999). Reef regeneration schemes are time-consuming and relatively costly for developing countries such as Tanzania, largely removing them as viable methods to address blast fishing destruction (de la Cruz, Villanueva and Baria, 2014, Fox et al., 2005). Moreover, its disproportionately poor coastal population relies heavily on the extensive coral reef ecosystems as their primary protein and income source (Kamat, 2014, Silva, 2006). Coastal households typically derive their incomes from a variety of sources in order to reduce economic precarity and provide a buffer against income fluctuations; artisanal fishing plays therefore an important role, even for those households whose primary income source is not fishing ((Béné, Hersoug, & Allison, 2010; Ireland 2004). The long-term impacts of blasting on reef ecosystems and fisheries following blasting reduction are therefore highly relevant from an ecological, economic and social perspective to Tanzania.

In Tanzania, a marked reduction was observed in the frequency of blast fishing between 2016 and 2018 following decades of periodic blasting, a decline which has remained to the current time and has been attributed to a government campaign entailing public political pressure and naval raids (Rubens, 2019). However, the impacts of the reduction on fisheries and coastal fishing communities in Tanzania remain unknown. Increased knowledge of the impacts of the blasting decline could help deter blast fishing in the future by contributing to workable and sustainable marine resource management that is tailored to the Tanzanian context. Due to the importance of community engagement and rule adherence in creating successful marine management plans (e.g. Gorris, 2016; Pollnac et al., 2010), a better understanding of the perceptions and impacts of the campaign may assist current and future plans to be both beneficial and long-lasting. My objective was to determine the impact of the blasting reduction on fishing in general, fish availability and fishing derived income, with a focus on blast fishing history as a predictive indicator. Section 4.2 outlines the methods, section 4.3 discusses the ethical considerations of the research and its limitations, and sections 4.4 and 4.5 detail the results and discuss these results, respectively.

4.2 METHODS

4.2.1 Research Design

In order to ascertain the impact of the blasting reduction, my study used an observational retrospective design, in which participants were selected in areas with low and high blast fishing histories. This approach was chosen because the outcome had already occurred, and an experimental approach where illegal blasting would be measured would be unethical, as well as logistically challenging. Because of the difficulties in selecting true control sites, a quasi-experimental design where causation could be established was also rejected. Purposive sampling was used to ensure variation in independent variables. Although purposive sampling has precedence in similar exploratory studies (Agrawal, 2001; Cinner et al., 2012), caution should be used when interpreting results because the villages were not selected randomly. The data were collected in two phases, in May-June and October 2019. In Phase 1, data were collected in the Kigamboni, Kinondoni, Lindi Rural and Mtwara Rural districts (Kigamboni and Kinondoni are represented as one district, Dar es Salaam, in all charts due to the low number of respondents from Kigamboni). Phase 2 data were collected in Kilwa, Pangani, Mkinga and Kinondoni districts. In total, 19 villages were purposively selected based on their blast fishing histories, of which 13 were located in former blast fishing hotspots (Figure 3). The remaining six villages were selected as controls in areas with low or negligible blasting (Figure 4).

Governance arrangements varied among villages; there were active Beach Management Units (BMU) in 10 of the villages, one village had a municipal group comprising fishers and local government members, six villages were covered by Collaborative Management Area Plans (CMAP), and the remaining two villages had no formal resource management arrangements in place. BMUs were established in Kilwa district in 2005 under the RUMAKI Seascape Program, and then expanded to Mtwara and Kigamboni districts in 2013 under the EU-WWF Fisheries Co-Management Program (Mahongo 2017). BMUs comprise local fishers and represent the local fishing communities. Their responsibilities include collecting catch data, maintaining landing sites, arbitrating disputes and providing input to develop and improve fishery management plans (Mahongo 2017). CMAs cover three northern districts in Tanzania and were implemented in 1994 under the Tanga Coastal Zone Conservation and Development Program. In each participating village covered by

CMAPs, groups representing local fishers have similar responsibilities as BMUs and are also often called as such (Wells et al. 2007).

The focus was to survey villages along the length of Tanzania's coastline in order to ascertain variability; therefore smaller sample sizes in each village were taken to enable more villages to be surveyed. This type of surveying is known as mini surveying, and is appropriate when large-scale surveys cannot be conducted due to time or budget restraints, or where quantitative data is sought to corroborate qualitative findings (Kumar, 2006). Mini surveys typically have a smaller number of participants and use closed-question surveys that can be completed in half an hour or less. They can provide valuable information about trends and tendencies, and when representative sampling techniques are used, can also be springboards for broader consequent studies (Béné, Chijere, Allison, Snyder, & Crissman, 2012). Despite the constraints imposed by the small sample sizes in each village, my study generated statistical data to aid in an understanding of the specific local contexts, which can potentially be used for inferring information about the entire coastline, or as a starting point for future studies.

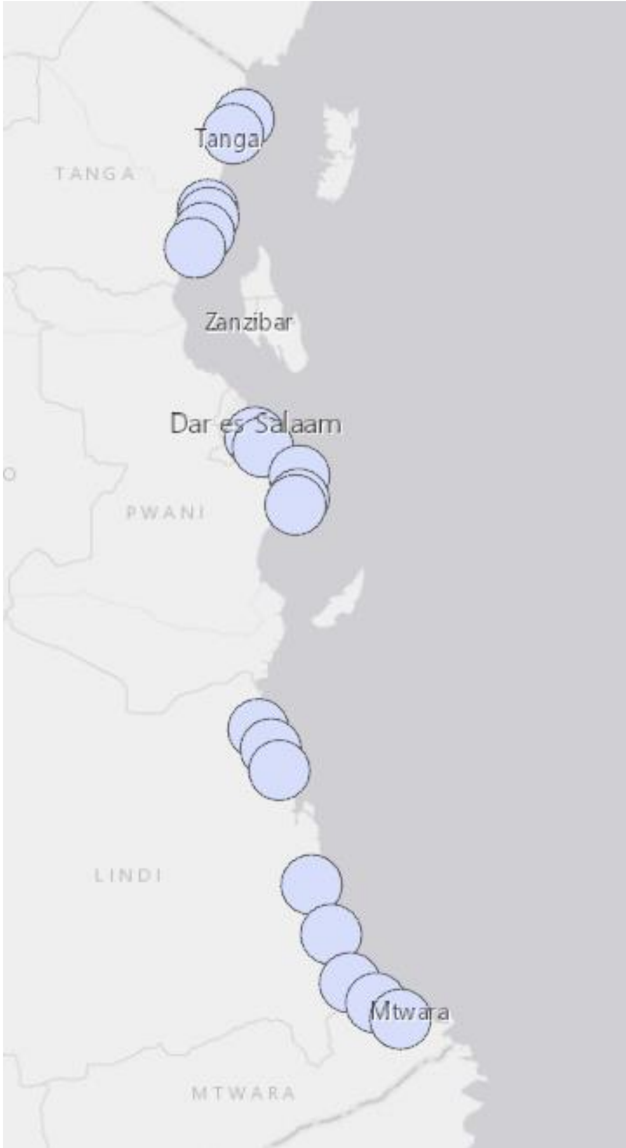

Figure 22. Survey sites (n = 19) used to ascertain drivers behind blast fishing and reduction in its practice in Tanzania in 2019.

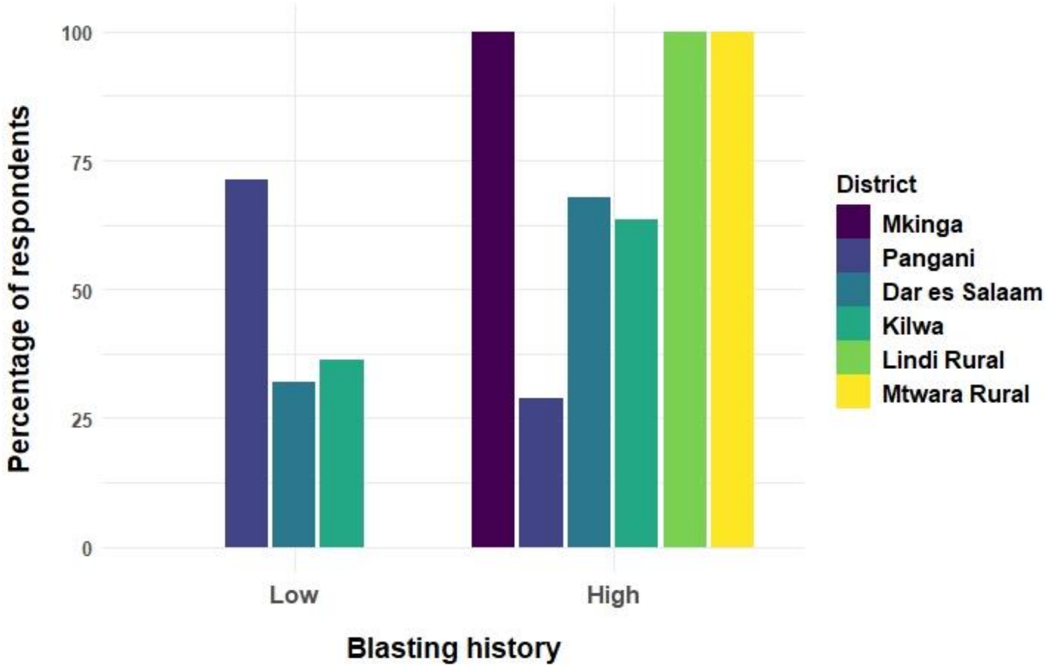

Figure 23. Blasting history distribution by district and percentage of respondents (n = 341) in 19 coastal villages in Tanzania in 2019.

4.2.2 Participants

A systematic sample of households from the target villages was taken by dividing the most recent population estimate by the target number of households and then surveying every *n*th house. The target number of households in each village varied depending on logistical constraints and village size. Household heads or representatives thereof were surveyed about their perceptions of blasting and the reduction of the blast fishing. The household sample (n = 101) comprised a total of 495 participants (including minors) in 18 villages and seven districts. All adults in each household were surveyed, and income data were amalgamated to give a total household income. The final household sample (n = 98) excluded 3 households from the analysis due to incomplete data collection and comprised 86 households with male and 12 with female household heads. Of these households, 50 sourced their primary income from fishing. Fisher groups were purposively surveyed by contacting village heads and Beach Management Unit leaders, who organised groups of fishers for interviews. The final sample of fishers (n = 243) was taken from 19 villages in seven districts, of which 239 were male and 4 were female. These respondents' data were combined into the final dataset (n = 341), upon which all analyses were conducted (Table 4).

Table 17. Number of villages, household respondents and fisher respondents by district.

District	*No. villages*	*No. households*	*No. fisher respondents*
Mkinga	2	10	25
Pangani	4	12	57
Kinondoni (Dar es Salaam)	1	3	10
Kigamboni (Dar es Salaam)	4	29	61
Kilwa	4	25	48
Lindi Rural	2	12	25
Mtwara Rural	2	7	17
Total	*19*	*98*	*243*

4.2.3 Instruments and implementation

My study used two instruments to collect quantitative data: a household survey and fisher group survey. The household and fisher surveys were composed of several modules and comprised structured questions with pre-defined possible answers. Household surveys are a common method used to generate current and detailed data on households and individuals in developing countries such as Tanzania. Such data have become central to policy analysis, development planning, assessment of interventions and government decision-making at all levels. Face to face surveys continue to be widely used in the developing world, as internet and phone interviews are limited by poor internet and phone penetration or incomplete telephone sampling frames.

Both surveys were based on guidelines and survey items developed by the World Bank and the Tanzanian National Bureau of Statistics for the Living Standards Measurement surveys (Deaton & Grosh, 2000; Tanzanian NBS, 2015). In addition, specific items for fisher group surveys focusing on fishing expenses and income were based on guidelines from the Food and Agriculture Organisation of the United Nations (FAO) (Stamatopoulos, 2002). Surveys were translated and cross-checked by two Tanzanian translators with knowledge of marine resource terms. Data were recorded on the translated surveys in Kiswahili. Some minor modifications were made between data collection phases to address errors in the original surveys. The household and fisher surveys can be found in English and Kiswahili in Appendix A. In addition to the quantitative data gathered, qualitative notes on the participants, their environment and the survey sites were taken throughout data collection to contextualise, supplement and enhance the quantitative data.

Before the commencement of household surveys, participants were informed about the research project by the local village guide accompanying the research team to each household. The average total time for each household survey was 60 minutes. Fishers were informed about the research project by village leaders or Beach Management Unit leaders. Average survey duration ranged from 90 to 120 minutes. All efforts were made to ensure the reliability of results by using the same survey items and survey team for every survey, which were conducted in Kiswahili.

4.2.4 Model building and variable selection

4.2.4.1 Operationalisation of objectives

Three response variables were assigned to the objective (Table 18).

Table 18. Aim, objectives and response variables. Response variable codes correspond to household survey items shown in Appendix A.

Aim: investigate impact of blasting reduction	
Objective	*Response variable*
3. assess impact of the reduction on fishing in general, fish availability and fishing derived income	- Impact of govt. campaign on fishing (5.08#) - Fish availability over 5 years (5.13#) - Change in fishing income over 5 years (4.11#)

The first means of determining the impact of the reduction was to assess respondents' perception of changes in fishing following the government campaign. Respondents were asked to state their level of agreement with the statement: "The government campaign against blasting has improved fishing in this area" with a 5-point Likert response scale ranging from 'strongly disagree' to 'strongly agree' (Figure 24). "Improved" was defined as increases in fish catches, and/or increases in income, and/or general improvement in fishing, for example an increased sense of security or well-being. The original levels were collapsed to three levels during analysis to improve model fit and simplify interpretation. The model predicting perception of changes in fishing therefore used a multinomial logistic regression with three possible outcomes: disagree, neutral and agree.

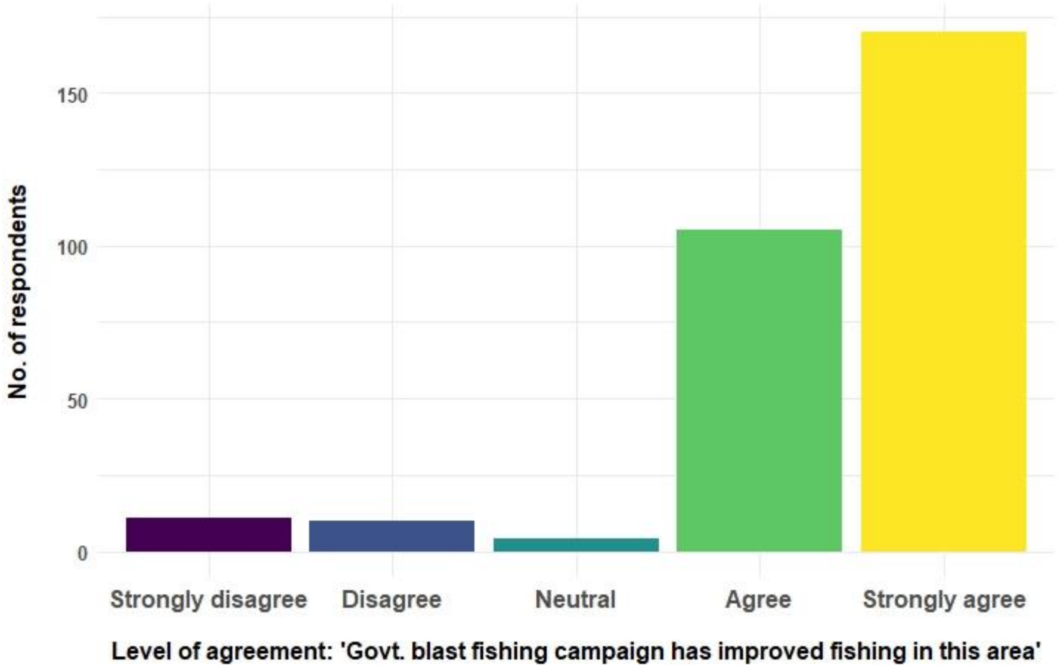

Figure 24. Level of agreement with the statement: "The government's campaign against blast fishing has improved fishing in this area" (n = 300) in 19 coastal villages in Tanzania in 2019.

Secondly, trends in fish availability between 2014 and 2019 were determined using a 5-point Likert response scale ranging from 'significantly decreasing' to 'significantly increasing' (Figure 25). The original levels were collapsed to three levels during analysis to improve model fit and simplify interpretation. The model predicting perceived changes in fish availability used a multinomial logistic regression with three possible outcomes: decreasing, stable and increasing. Additionally, Kruskal-Wallis tests with a Holm-Bonferroni correction were performed to determine whether there were significant differences between the three levels for target catch species, gears, fishing transport modes, fishing grounds and attitudes towards marine resource management (See Table 20, Table 21, Table 22, Table 23 and Table 24 for details on explanatory variables).

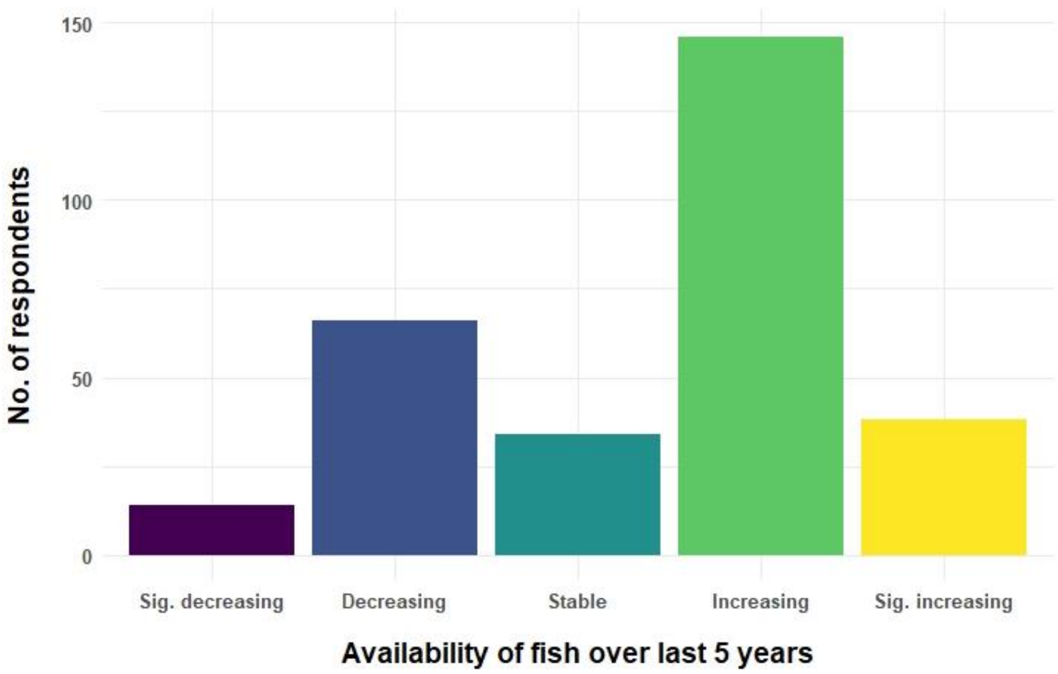

Figure 25. Reported availability of fish over the past 5 years (2014-2019) (n = 298) in 19 coastal villages in Tanzania in 2019.

Lastly, changes in household fishing income between 2014 and 2019 were assessed using a 5-point Likert response scale ranging from ‘significantly decreasing’ to ‘significantly increasing’ (Figure 26). Only households were included in this analysis, fisher focus groups were excluded due to discrepancies in data collection. As before, the original levels were collapsed to three levels in the final analysis and the model used a multinomial logistic regression with three levels in the response variable: decreasing, stable and increasing.

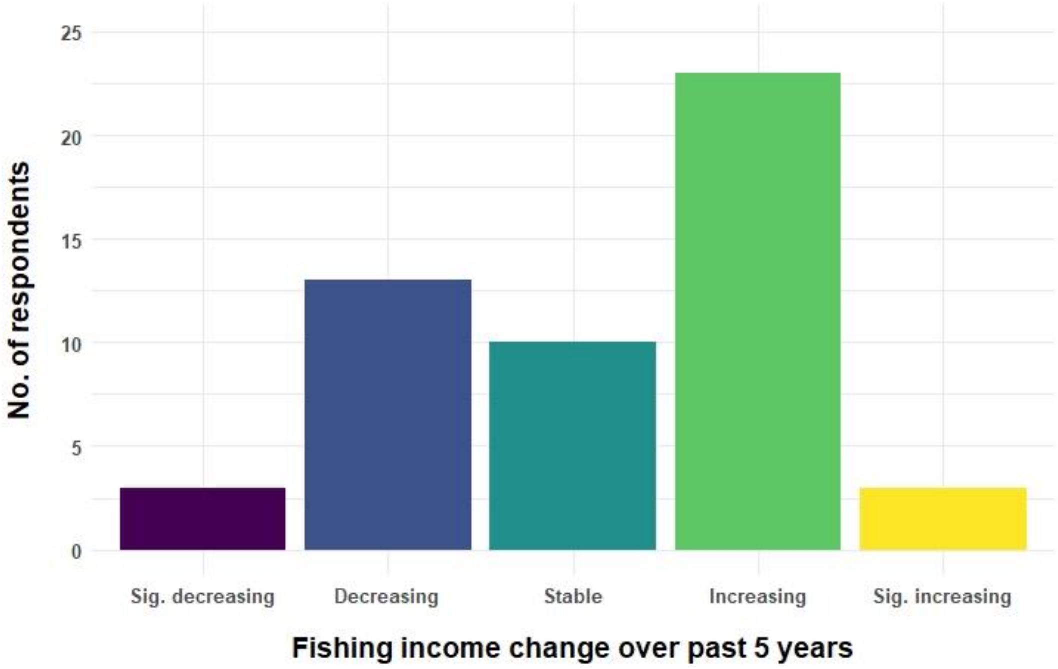

Figure 26. Changes in household fishing income over the past 5 years (2014-2019) (n = 52) in 18 coastal villages in Tanzania in 2019.

4.2.4.2 Explanatory variables

The selection of predictor variables was based on previous socio-economic and ecological surveys conducted in the region (Cinner et al., 2012, Tanzanian NBS, 2015), and were grouped according to Ostrom's (2009) framework for analysing social-ecological systems (Figure 27).

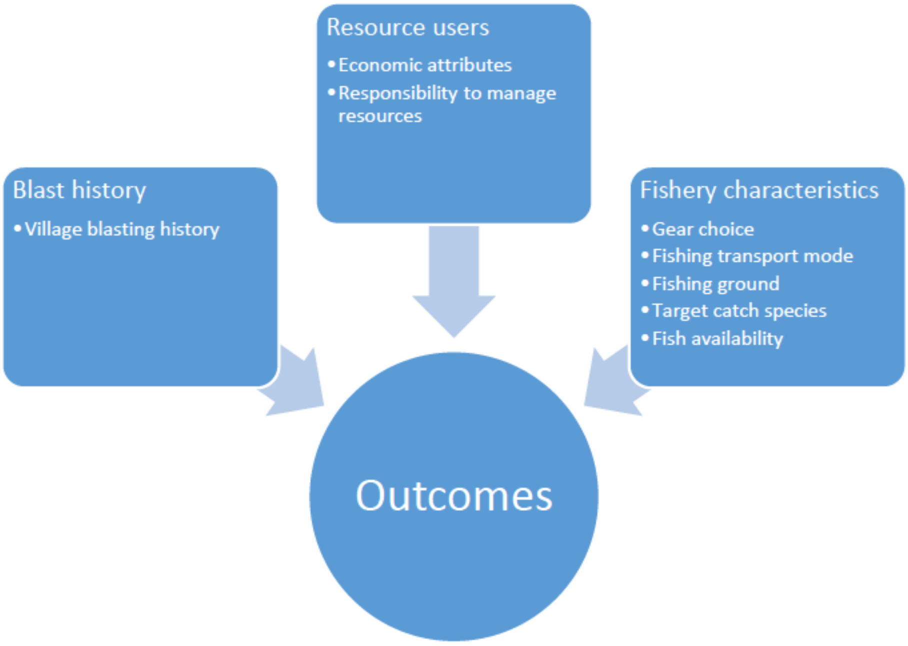

Figure 27. Response variables derived from Tanzanian NBS (2015) and Cinner (2012) and grouped according to Ostrom (2009).

As the primary focus was on the effect of blast fishing history on the impact of the blasting reduction, a model was created using the blasting history of each village as a predictor (Table 19). The blast fishing history of an area was determined through information obtained from local experts, as well as two surveys that recorded blasting incidences (Braulik et al., 2017, Tanzania Blast-Fishing Monitoring Network, 2018). Survey sites were coded as having a low or high blasting history; 66% of respondents came from villages with a high blasting history. However, it should be noted that the binary classification of blasting as low or high is problematic due to the complex nature of blasting. In the absence of empirical data on the village level, the classification system used is an approximation. The determination of a village's blasting history took into account blasting in the immediate vicinity, as well as blasting in nearby fishing grounds that were reportedly used by fishers from that village. This classification is therefore by necessity based on an amalgamation of local expert advice and anecdotal evidence from respondents and should be treated with caution.

Table 19. Blast history model explanatory variable. Variable codes correspond to operationalised variables shown in Appendix B, marked with *.

Explanatory variable	**Description**
Village blast history (1.00b*)	Dummy variable, low = 0 and high = 1

Secondly, in order to explore the possibility that alternative factors had influenced changes in fishing, a series of candidate models were created to represent resource user economic characteristics and fishery characteristics, including gear choice, target catch species and fish availability (only used as an explanatory variable for the campaign response model) (Table 20, Table 21 and Table 22). Fishing transport mode and fishing ground choice were not included as candidate models due to discrepancies in data collection which led to distorted model output, but were included in Kruskal-Wallis tests. After removing correlated variables, the economic model comprised housing standard and total fishing derived income (Table 20). Although not strictly an indicator of financial status, the use of housing standard through the assessment of household attributes to establish economic status in developing countries has precedence in recent large-scale Tanzanian studies, and is commonly used in developing countries where incomes are highly variable (The World Bank 2015).

For the analysis on household fishing derived income, respondents were also surveyed on income derived from all sources as well as household economic trends. Although these variables were not included in the economic model due being highly correlated with purely fishing derived income, they remain important as a point of comparison to household fishing income trends. The household survey sample included non-fishing and fishing households.

Table 20. Candidate model explanatory variables. Variable codes correspond to household survey items shown in Appendix A, marked with #, or with operationalised variables shown in Appendix B, marked with *.

Explanatory variable	**Description**	
MODEL: GEARS		
Variables (4.15a – 4.15j*)	Gear choices based on previous surveys conducted in Tanzania	Transformed into dummy variables

Explanatory variable	Description	
MODEL: TARGET CATCH SPECIES		
Variables (5.01a – 5.01q*)	Target species choices based on previous surveys conducted in Tanzania	Transformed into dummy variables
MODEL: RESOURCE USER ECONOMIC CHARACTERISTICS		
- Housing standard (3.13*)	Aggregated index incorporating variables 3.01-3.12#, higher score showed higher housing standard. Z-score standardised.	Numerical variable
- Total fishing income (4.1e*)	Average household fishing income over 7 days	Numerical variable
MODEL: FISH AVAILABILITY		
- Fish availability trends (5.13#)	Trends in fish availability over a 5-year period	5-point Likert scale

Finally, significant associations between gears, fishing transport modes and target catch species were established using χ^2 tests and Cramer's V tests; variables that were significantly strongly associated with one another were removed (Cramer's V $\geq$ 0.1). Thereafter, lasso regression was performed where relevant on each model to select the most important variables. The final variables used for gears (Table 21), target catch species (Table 22), fishing transport modes (Table 23) and fishing grounds (Table 24) were described following previous surveys in Tanzania, see respective tables for details.

Table 21. Final selection of gears used for candidate model and Kruskal-Wallis analysis following variable selection. Based on Tanzanian NBS (2015) and Wells et al. (2007).

Gear	**Description**	**Kiswahili**
Gill net	Mono-filament nets with 5-10 cm mesh size, deployed from boats on fringing and offshore reefs, and open sea	Nyavu
Shark net	Mono-filament net with 12-20 cm mesh size, deployed from boats on mainly offshore reefs and open sea	Jarife
Long line	Multiple hooks and line, deployed from boats	Longline / Kaputi
Hand line	Single hook and line, deployed from the shore and boats	Mshipi
Fish trap	Usually deployed from smaller boats on fringing reefs	Madema
Octopus stick	Hooked stick used by divers to extract octopus from reefs	Mdeke
Fins and mask	Used by divers to extract octopus, lobster and squid from reefs	Pelepele

Table 22. Final selection of common catch species used for candidate model and Kruskal-Wallis analysis following variable selection. Based on field observations and Hempson (2008), Jiddawi and Öhman (2002) and Moshy and Bryceson (2016).

Family		**Species**	**Common name**	**Kiswahili**
CARCHARHINIDAE	Requiem sharks	e.g. *Carcharhinus amblyrhynchos*	e.g. Grey reef	Papa
SCOMBRIDAE	Mackerels	e.g. *Scomberomorus plurilineatus*	e.g. Kanadi kingfish	Nguru
	Tuna	e.g. *Thunnus albacares*	e.g. Yellowfin tuna	Jodari
LUTJANIDAE	Snappers	e.g. *Lutjanus argentimaculatus*	e.g. Mangrove red snapper	Red snapper
CARANGIDAE	Trevallys	e.g. *Caranx tille*	e.g. Tille trevally	Kolekole
	Jacks			

Family		Species	Common name	Kiswahili
ENGRAULIDAE	Anchovies	e.g. *Stolephorus commersonnii*	e.g. Commerson's anchovy	Dagaa mcheli
DASYATIDAE	Rays	e.g. *Pastinachus sephen;*	e.g. Feathertail stringray;	Taa
		Taeniura lymma	Bluespotted stringray	Taa (Bocho)
SERRANIDAE	Groupers	*Cephalopholis argus*	Bluespotted grouper	Chewa
LETHRINIDAE	Emperors	e.g. *Lethrinus harak*	e.g. Thumbprint emperor	Changu
MULLIDAE	Goatfish	e.g. *Upeneus tragula*	e.g. Freckled goatfish	Mkundaji
SIGANIDAE	Rabbitfish	*e.g. Siganus canaliculatus*	e.g. Whitespotted spine foot	Tasi / Chafi
SCARIDAE	Parrotfish	*e.g. Calotomus carolinus; Calotomus spinidens*	e.g. Carolines parrotfish; Spinytooth parrotfish	Pono / Kangu
CAESIONIDAE	Fusiliers	*Caesio xanthonota*	Yellowfin fusilier	Kibua mbono
OCTOPODIDAE	Octopus	*Octopus cyanea*	Day octopus	Pweza
LOLIGINIDAE	Squid	e.g. *Loligo duvauceli*	e.g. Indian squid	Ngisi
PALINURIDAE	Spiny lobsters	*e.g. Panulirus ornatus*	e.g. Ornate spiny lobster	Kambakoche / kamba

Table 23. Final selection of fishing transport modes used for Kruskal-Wallis analysis following variable selection. Based on Tanzanian NBS (2015) and Wells et al. (2007).

Fishing transport	Description	Kiswahili
Fibreglass boat	Used with an engine, straight stern, 3 – 10 m long	Fibre / Boti
Dhow boat	Used with sail, wooden planked boat with pointed stern and prow, 3 – 6 m long	Dau
Dugout canoe	Used with sail, paddle or poles, 2 – 4.5 m long	Mtumbwi
Foot fisher	Use of fins, masks, octopus sticks and nets is common	Miguu

Table 24. Fishing grounds used for Kruskal-Wallis analysis. Based on field observations.

Fishing ground	Description
Open sea	Reachable only by boat that was not in the vicinity of reefs
Offshore reef	Reachable only by boat in the vicinity of coral reefs
Fringing reef	Coral reef reachable by boat or swimming in the vicinity of the shore
Shore	Area accessible from the shore or by swimming

4.2.5 Analysis

The data were analysed using R v4.0.2 (R Core Team, 2017) with the mlogit v1.1.0 (Croissant, 2020) and glmnet v4.0-2 (Friedman, Hastie, & Tibshirani, 2010) packages. Figures were produced using the ggplot2 (Wickham, 2009) and ggeffects (Lüdecke, 2018) packages. The full reproducible code is available in Appendix C.

4.3 ETHICS AND LIMITATIONS

Ethical concerns related to my study included risk for participants and obtaining informed consent. When taking part in the household or fisher group survey, the immediate risk for the participants was low. Information that could identify the participants, such as full names and GPS locations of houses was retained only by myself, and digitalised daily. All paper records of sensitive information were erased following each day's fieldwork, and no audio or video taping took place. Efforts were made to ensure that participants were informed before granting consent by having the village guide and translator provide oral and written information about the study and its impacts.

There are several limitations of my study. Firstly, in the research design process, two large datasets, one on socioeconomic conditions in Tanzania and one with empirical blast fishing data were assumed to be available and suitable for analysis. These datasets were not used in the analysis due to unsuitability and access issues, which required the analysis to take a substantially different path to the one planned. The survey methods and specific survey items had been designed to build upon these two longitudinal datasets, and because their unavailability only became apparent at the end of data collection, data collection could not be altered or adjusted to fit the revised research questions. This resulted in large parts of the collected data being unusable for the project. Retrospectively revising research questions and modelling approaches meant relying on collected data as response variables that were not originally intended for such purposes, leading to a limited array of analysis options.

Secondly, my sample was overwhelmingly dominated by male respondents: 1.65% of the fisher respondents were female, and 12.24% of household heads. This can be justified due to the reality that the majority of households are headed by men and that artisanal fishing in Tanzania is dominated by male fishers. Additionally, the majority of female fishers are shore fishers who target sessile invertebrates and anchovies and therefore do not use explosives. However, excluding them from data collection is problematic because women play an active and vital role in the Tanzanian fishery sector as whole through the collection of the species mentioned above, as well as processing, marketing and distributing fishery products (Kleiber, Harris, & Vincent, 2015; Moshy, Bryceson, & Mwaipopo, 2015). Within the limits of my time and budget, I attempted to address this issue by surveying all adults in each household, thereby allowing women to also contribute their perspectives. However, the lack of female respondents, particularly in the fisher focus groups, undoubtedly biased the results and this bias should be taken into account when interpreting the results.

Finally, the experimental design contains bias and is somewhat unbalanced due to the non-random site selection. Challenges to the validity of the results may arise due to the purposive selection of villages based on their blasting histories, as opposed to a truly random selection. However, prior information on village characteristics was gathered so as to ensure a sample that was as representative as possible. In addition, although all attempts were made to randomly select households, logistical constraints and outdated or inaccurate population records resulted in a sample that was not truly random and therefore biased. The results should therefore be treated with caution and interpreted with this limitation in mind.

4.4 RESULTS

4.4.1 Objective 1: Impact of blast fishing reduction

4.4.1.1 Impact of campaign against blasting on fishing

Blasting history did not significantly predict respondents' assessment of the government campaign, and neither did any other candidate model. The government campaign was reported to have improved fishing in the local area by 92% of respondents. In contrast to central and southern districts, there were no respondents in the northern districts Mkinga and Pangani who disagreed that the campaign had improved fishing. Lindi Rural had the highest percentage of respondents that disagreed the campaign had improved fishing (Figure 28). Barring isolated reports of blasting in 2019 in Mkinga and Tanga City, respondents reported that blasting had ceased entirely following the campaign. Respondents commented that fish catches and income have increased, and that a reduction in blasting has also meant an increased sense of security and ease while fishing as well as during everyday life. Conversely, two fisher groups and 11 householders reported incidences of violence against suspected blast fishers by naval personnel, and there were also criticisms of the naval raids on blast fishing hotspots, in particular the destruction of homes, boats and gear.

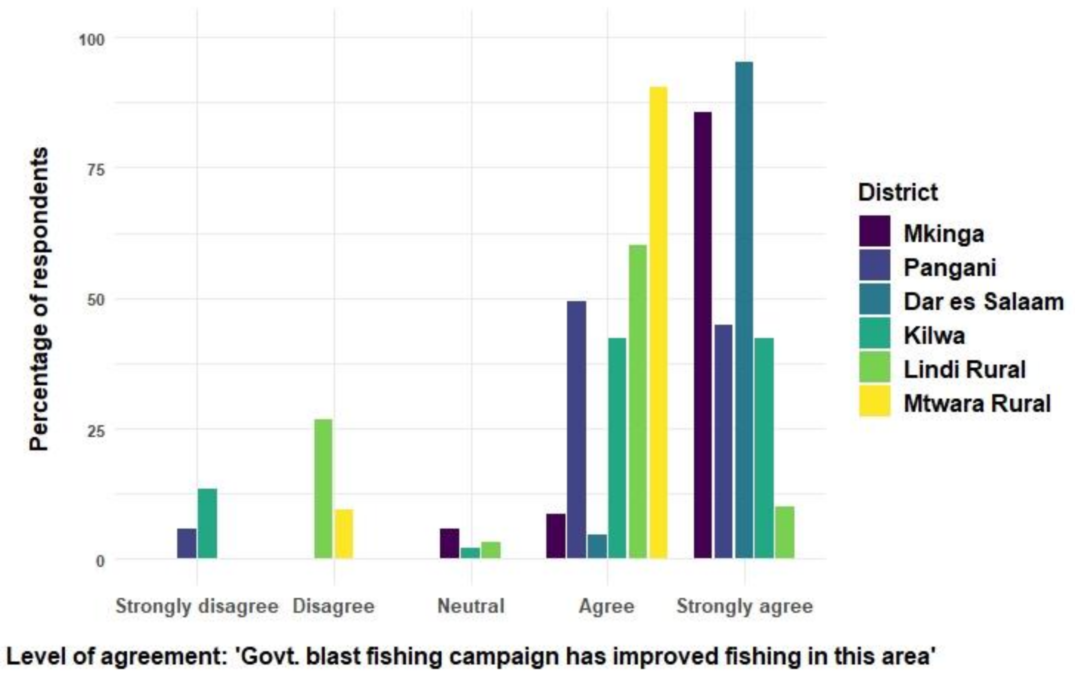

Figure 28. Level of agreement with the statement: "The government's campaign against blast fishing has improved fishing in this area" (n = 300) by district and percentage of respondents in 19 coastal villages in Tanzania in 2019.

4.4.1.2 Fish availability trends from 2014-2019

A high blasting history significantly increased the odds that respondents perceived fish availability as increasing rather than decreasing (P = 0.017), and as stable rather than decreasing (P = 0.01) (Table 25). Models using all levels of the response variable as the reference category confirmed the blasting history predicted all changes in fish availability. Models using gears and target catch species as predictor variables produced significant but unreliable results, and were therefore discarded. Other candidate models were not significant.

Table 25. Multinomial regression summary for fish availability trends predicted by blasting history. P-values with * indicate ≤ α 0.05.

	Fish availability 2014-2019 (ref = Decrease)			
Coefficient	*Odds Ratios*	*std. Error*	*Conf. Int (95%)*	*P-Value*
Blast history (high) : Stable	33.00	1.04	4.30 – 253.05	0.001*
Blast history (high) : Increase	1.92	0.27	1.13 – 3.28	0.017*
R^2 McFadden	0.054			

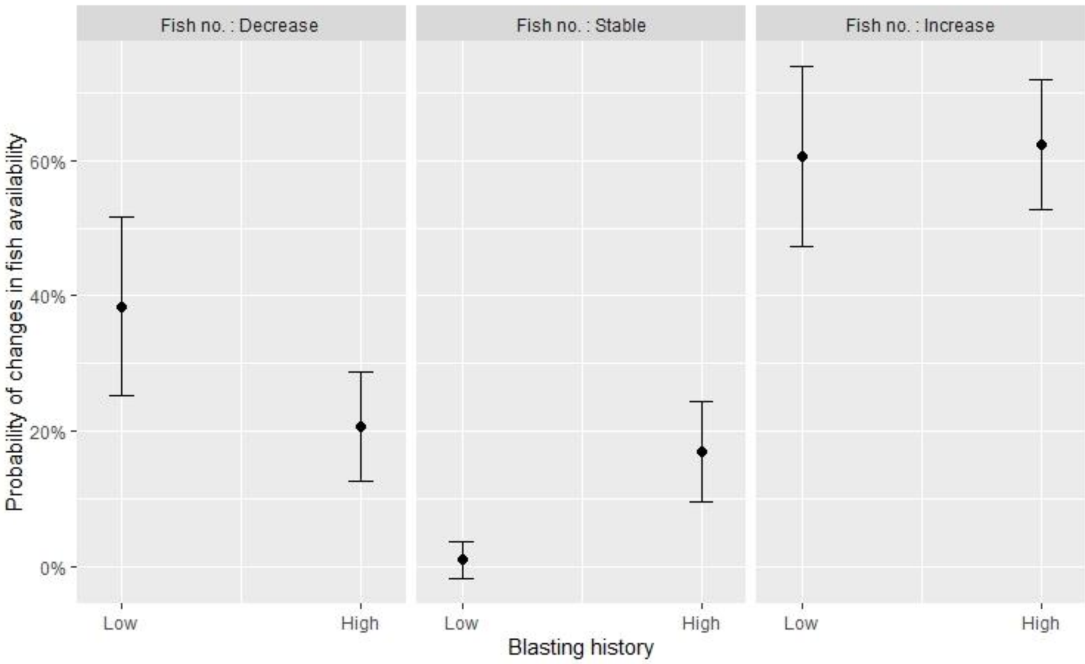

Figure 29. Probability of fish availability decreasing, increasing, or remaining stable plotted by blasting history with predicted model values. Error bars show 95% confidence intervals.

Fishing income significantly predicted fish availability. As fishing income increased, respondents were 3.6 times more likely to indicate that fish availability was increasing rather than decreasing (P < 0.001) (Table 26). No other candidate model predicted fish availability. Candidate models for both catch species and gear produced significant but unreliable results, and were therefore excluded from the final analysis.

Table 26. Multinomial regression summary for fish availability trends predicted by fishing income. P-values with * indicate ≤ α 0.05.

	Fish availability 2014-2019 (ref = Decrease)			
Coefficient	*Odds Ratios*	*std. Error*	*Conf. Int (95%)*	*P-Value*
log(Fishing income) : Stable	1.18	0.30	0.66 – 2.11	0.57
log(Fishing income) : Increase	3.59	0.23	2.29 – 5.62	<0.001*
R^2 McFadden	0.097			

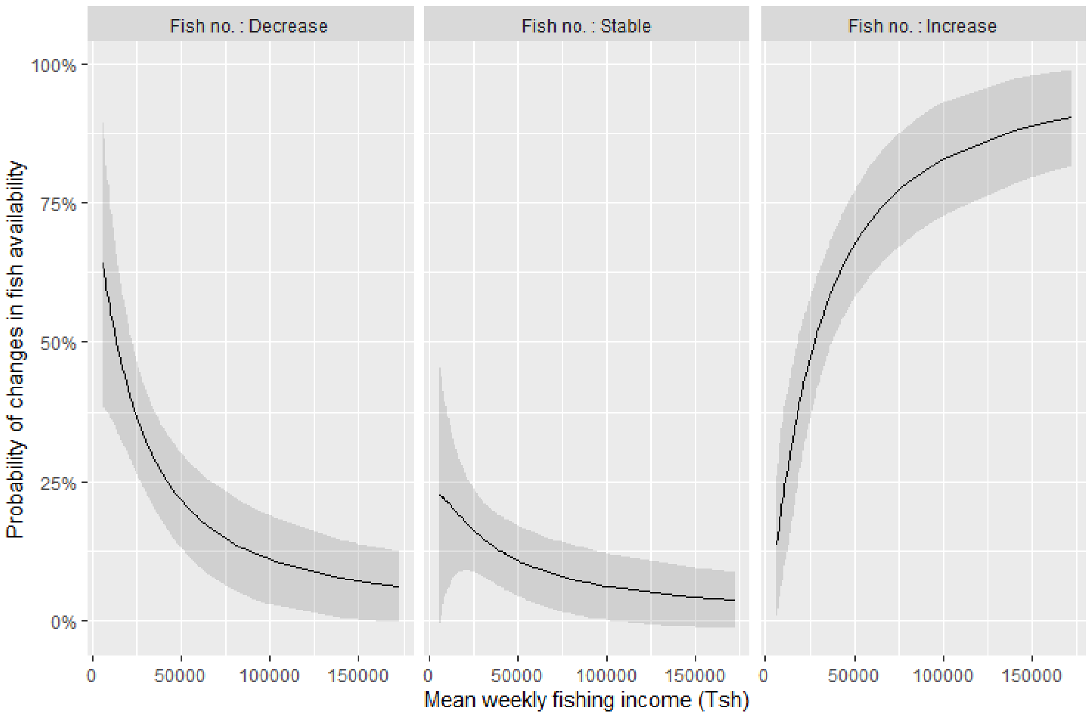

Figure 30. Probability of fish availability decreasing, increasing, or remaining stable plotted by mean weekly fishing income (Tsh) with predicted model values. Bands show 95% confidence intervals.

Kruskal-Wallis tests revealed significant differences between decreasing, stable and increasing fish availability for a number of gears, fishing transport modes and target catch species (Table 27). There were no significant differences found for fishing grounds. These tests were performed on the entire dataset; it was not possible to compare Kruskal-Wallis tests for low and high blasting history villages because no respondent from low blasting history villages perceived fish availability as stable.

Table 27. Kruskal-Wallis test results for fish availability with adjusted p-values using Holm-Bonferroni correction. Variables in *italics* and adjusted p-values with * indicate ≤ α 0.05.

Variable	**Kruskal-Wallis test statistic**	**P-value**	**Adj. p-value**
GEARS			
Gill net	9.75	<0.01	0.03*
Shark net	0.02	0.89	1
Long line	20.29	<0.01	<0.01*
Hand line	6.56	0.01	0.18
Fish trap	30.42	<0.01	<0.01*
Octopus stick	31.58	<0.01	<0.01*
Fins and mask	1.70	0.19	1
FISHING TRANSPORT MODE			
Foot fisher	13.57	<0.01	<0.01*
Dhow	34.21	<0.01	<0.01*
Dugout	2.88	0.09	1
Fibreglass boat	31.42	<0.01	<0.01*
FISHING GROUNDS			
Open sea fishing ground	0.79	0.38	1
Offshore reef fishing ground	0.09	0.77	1
Fringing reef fishing ground	5.94	0.01	0.24
Shore fishing ground	0.15	0.70	1
TARGET CATCH SPECIES			
Groupers	0.22	0.64	1
Snappers	23.46	<0.01	<0.01*
Sharks	45.77	<0.01	<0.01*
Lobsters	1.32	0.25	1
Emperors	17.06	<0.01	<0.01*

Variable	**Kruskal-Wallis test statistic**	**P-value**	**Adj. p-value**
Goatfish	4.59	0.03	0.48
Rabbitfish	0.51	0.48	1
Trevallys	4.53	0.03	0.48
Octopus	0.15	0.70	1
Squid	10.60	<0.01	0.02*
Mackerels	17.90	<0.01	<0.01*
Parrotfish	18.93	<0.01	<0.01*
Rays	27.47	<0.01	<0.01*
Anchovies	4.23	0.04	0.52
Tuna	99.46	<0.01	<0.01*
Fusiliers	1.49	0.22	1

The majority of respondents (62%) reported that fish availability had increased between 2014 and 2019 (Figure 31). Mkinga district had the highest percentage of respondents that reported significant decreases in fish availability (33.3%), as well as the highest percentage reporting significant increases (45.5%) (Figure 31). In Mkinga district, respondents reporting significant decreases used every gear except shark nets or long lines; respondents reporting significant increases used exclusively hand lines and gill nets. Target species also varied in this district: those reporting significant decreases exclusively targeted reef-based fish, whereas those reporting significant increases targeted squid, mackerels and anchovies. Only 2.4% of Dar es Salaam respondents reported stable or declining catches (Figure 31). 60% of respondents from Mtwara Rural district reported decreases, while 25% reported significant increases (Figure 31). According to some communities, increases have been seen not only in the number of fish but also in the size of the fish caught, as well as in the types of fish available, some of which were scarce or unavailable when blast fishing was prevalent.

Breaking down the changes in fish availability by target species showed that every species apart from fusiliers and goatfish were more frequently reported as increasing rather than decreasing or significantly decreasing (Figure 32). The majority of respondents reported all pelagic species to be increasing rather than stable or decreasing; the picture was ambiguous for reef-based, semi-demersal and demersal species. Users of all gear types except octopus sticks reported increasing rather than decreasing fish availability (Figure 33). There was no discernible pattern to be seen in fish availability by fishing ground or fishing transport mode (Figure 34 and Figure 35). The detrimental effect of flooding, strong winds and storms on fish availability was identified as a dominant cause for decreasing fish availability, particularly by respondents in northern districts.

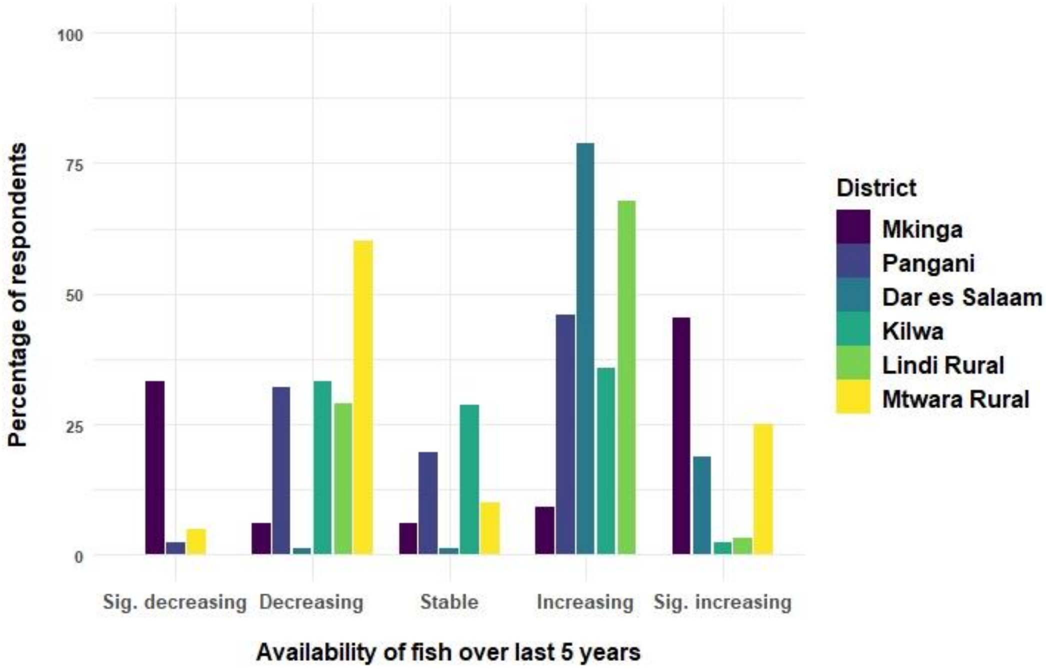

Figure 31. Reported availability of fish over the past 5 years (2014-2019) (n = 298) by district and percentage of respondents in 19 coastal villages in Tanzania in 2019.

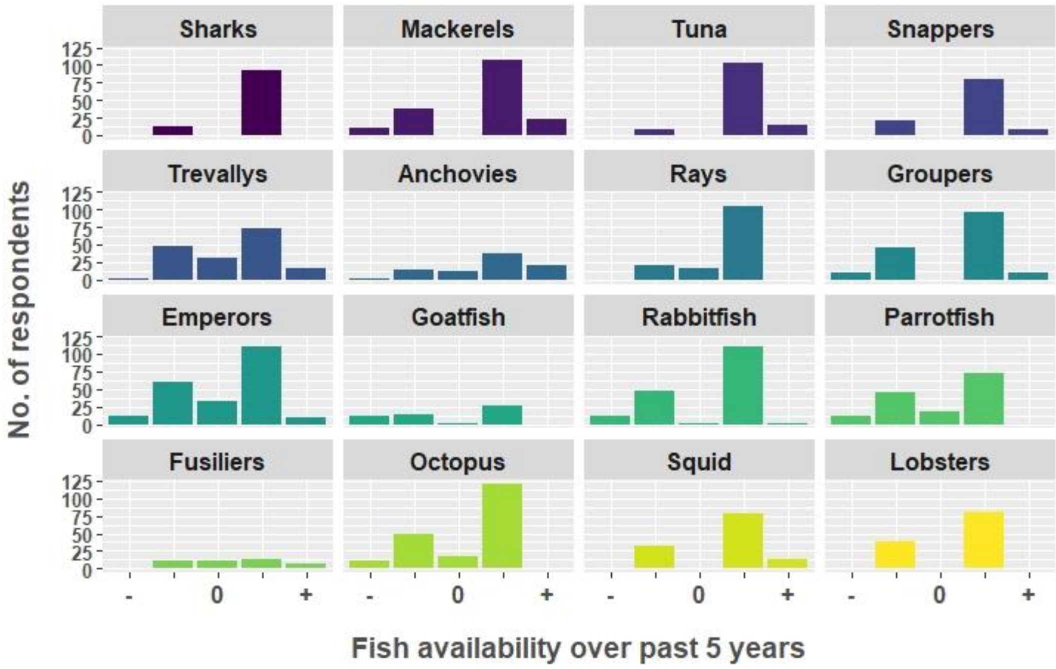

Figure 32. Frequently targeted species by number of respondents and fish availability (2014-2019) in 19 coastal villages in Tanzania in 2019.

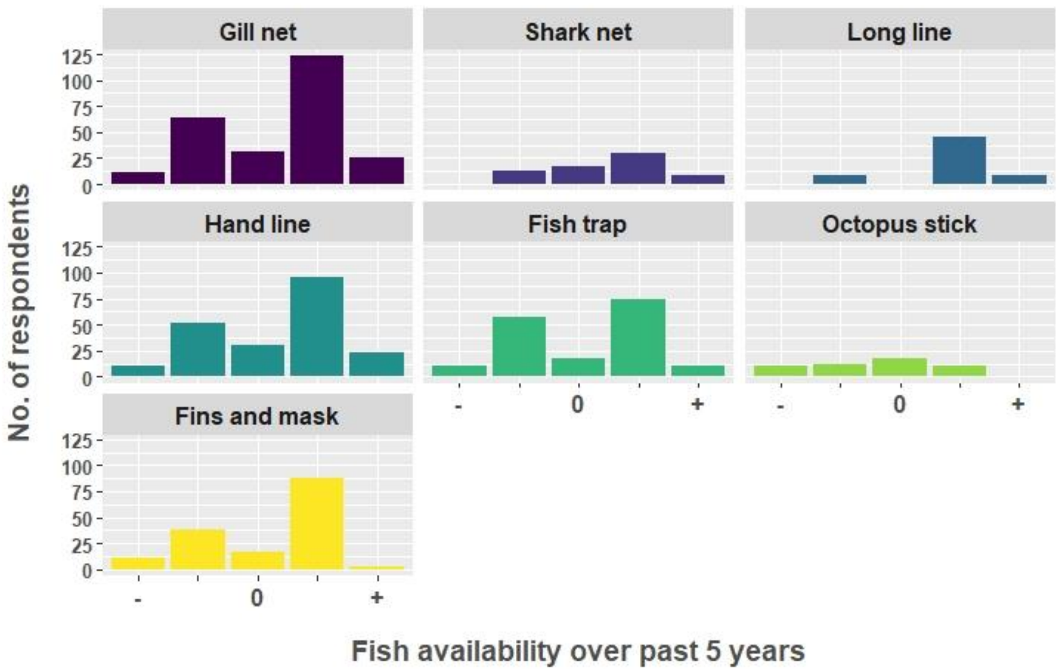

Figure 33. Frequently used gears by number of respondents and fish availability (2014-2019) in 19 coastal villages in Tanzania in 2019.

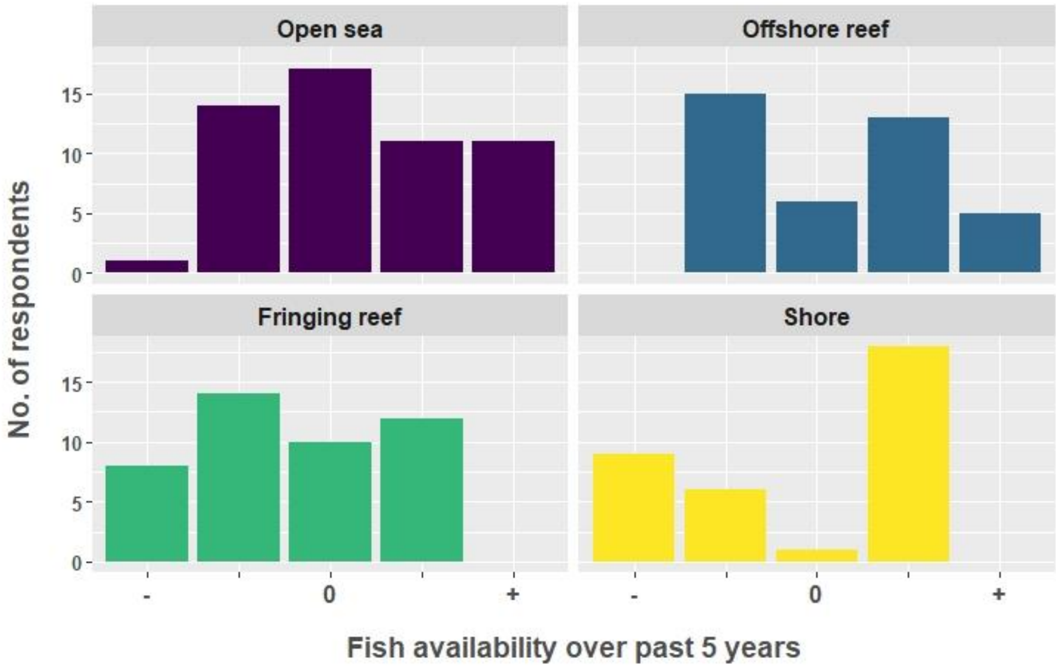

Figure 34. Fishing grounds by number of respondents and fish availability (2014-2019) in 19 coastal villages in Tanzania in 2019.

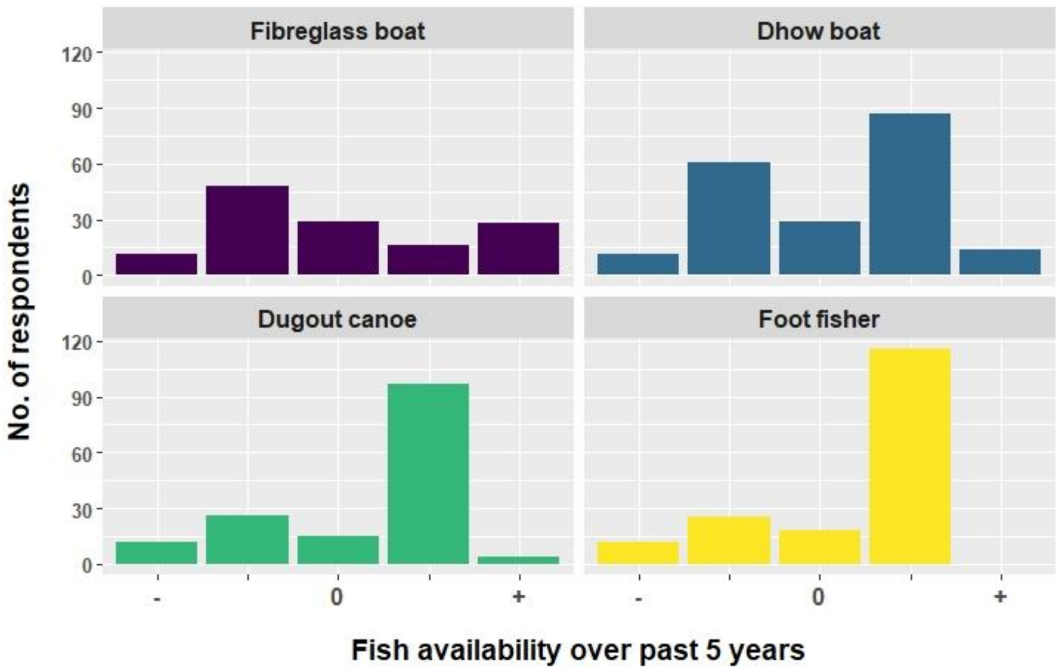

Figure 35. Fishing transport modes by number of respondents and fish availability (2014-2019) in 19 coastal villages in Tanzania in 2019.

Breaking down target catch species, gears, fishing grounds and fishing transport modes by blasting history showed higher increases in pelagic species from low blasting history villages than high blasting history villages (Figure 36). Conversely, higher increases in trevallys, anchovies, goatfish, parrotfish and squid were reported by high blasting history villages (Figure 36). Long lines were used exclusively by respondents from high blasting history villages, and the majority of shark net users also came from high blasting history villages (Figure 37). Fishing grounds and fishing transport modes displayed no discernible pattern (Figure 38 and Figure 39).

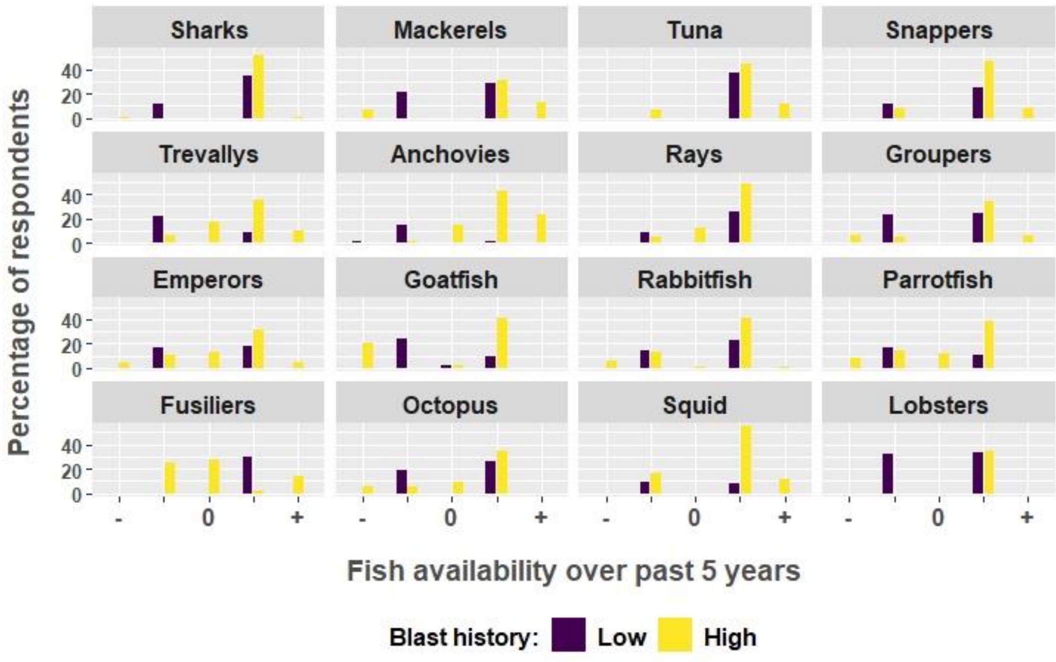

Figure 36. Frequently targeted species by percentage of respondents, village blasting history and fish availability (2014-2019) in 19 coastal villages in Tanzania in 2019.

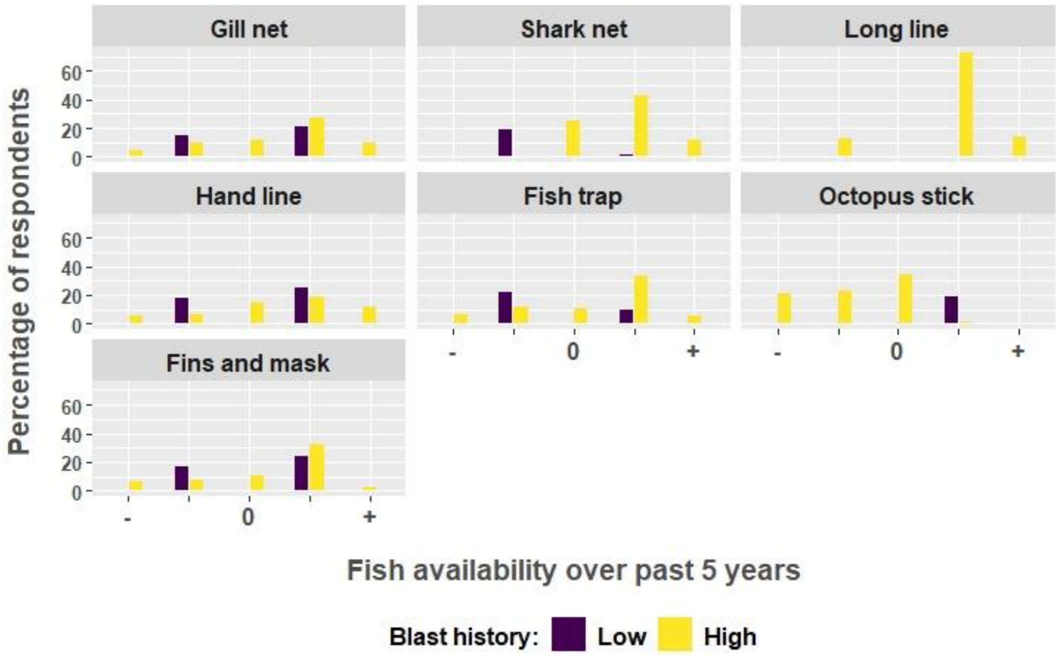

Figure 37. Frequently used gears by percentage of respondents, village blasting history and fish availability (2014-2019) in 19 coastal villages in Tanzania in 2019.

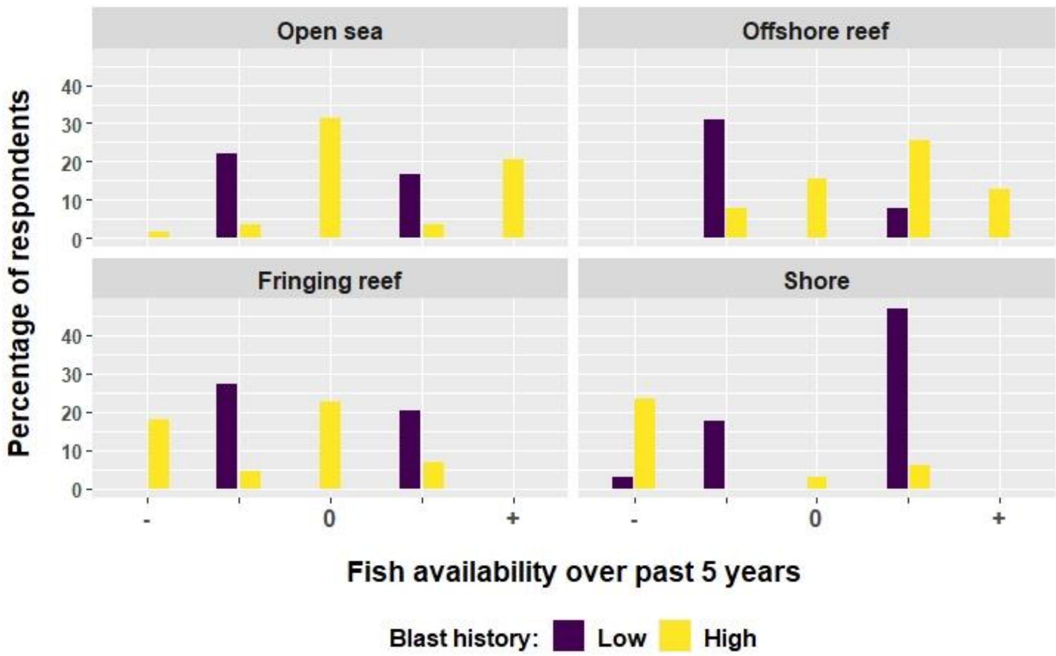

Figure 38. Fishing grounds by percentage of respondents, village blasting history and fish availability (2014-2019) in 19 coastal villages in Tanzania in 2019.

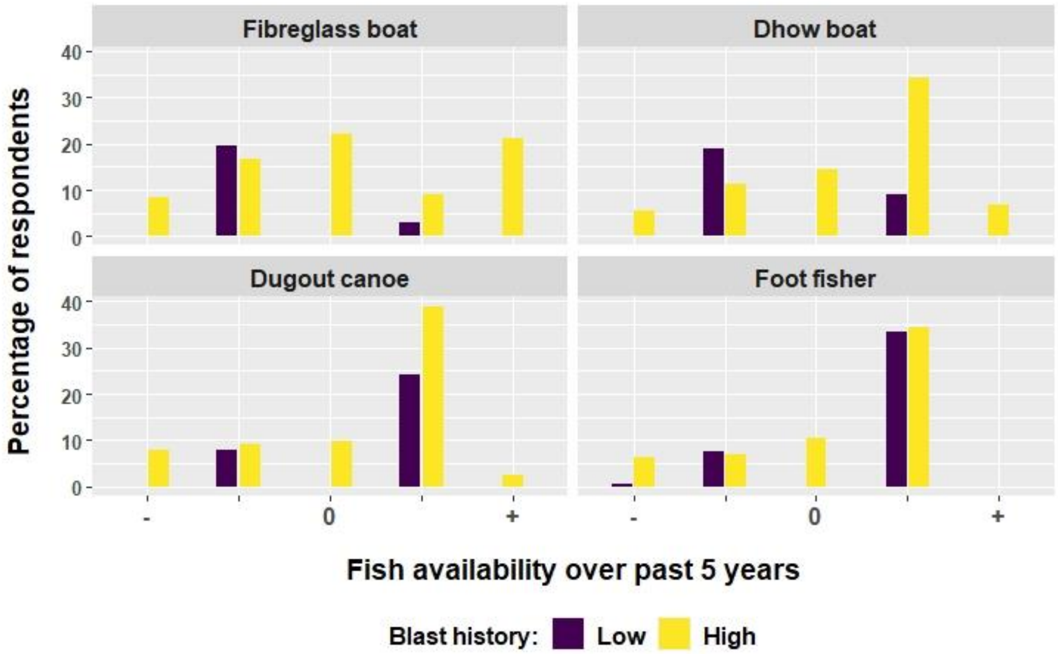

Figure 39. Fishing transport modes by percentage of respondents, village blasting history and fish availability (2014-2019) in 19 coastal villages in Tanzania in 2019.

4.4.1.3 Household fishing income trends from 2014-2019

Half of all households reported that their fishing derived income had increased between 2014 and 2019, 19% reported stable income and 31% reported decreasing income. In contrast to the district distribution for fish availability, only Dar es Salaam households reported significant decreases (Figure 40). Blasting history did not significantly predict household fishing income trends, and neither did any other candidate model reveal useful predictors of changes in household fishing derived income. Candidate models for both catch species and gear produced significant but unreliable results, and were therefore excluded from the final analysis. Half of all households indicated that their general economic situation was much worse or worse now than it was 12 months ago. 51% of the households earned their primary income from fishing and 47.98% of this subset indicated that their general economic situation was much worse or worse than 12 months ago. However, 50.77% of the same subset reported stable, increasing or sharply increasing income from fishing over the past five years. Additionally, household fish catches (separate from overall fish availability) have been increasing; 40.90% of households said that fish catches had increased since 2016. As when respondents were queried about fish availability trends, recent extreme weather events were commonly cited as the cause for decreased income, both from farming and fishing activities.

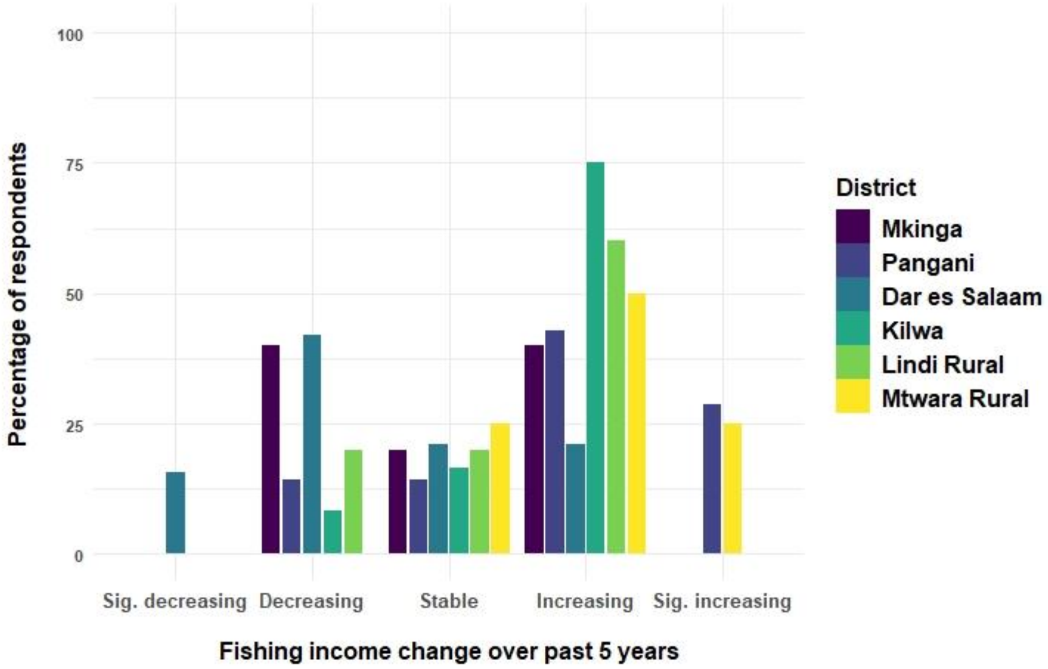

Figure 40. Changes in household fishing income over the past 5 years (2014-2019) (n = 52) by district and percentage of respondents in 18 coastal villages in Tanzania in 2019.

4.5 DISCUSSION

No model predicted the perception of the government's campaign against blast fishing. The failure of the blast history model to produce significant results may be due to inaccuracies in the classification of blasting history. Several local experts were consulted, and when using one classification system, the perception of the campaign was significantly predicted by blasting history: high blasting history villages were more likely to perceive the campaign positively than low blasting history villages. However, the final and most accurate protocol used for the analysis revealed that no factors significantly predicted respondents' perceptions. This could also be due to sampling bias: out of the seven districts, only three included control sites with a low blasting history. It was also surprising that fish availability trends did not predict the response to the campaign, as both variables displayed similar distributions. The literature suggests that when communities perceive direct benefits from enforcement measures, such as the increased fish catches cited by respondents in this study, they are more likely to support enforcement and adhere to rules (e.g. Gorris, 2016). However, we were unable to find evidence to support this link. This may be due to the considerable among-district variation, in which more respondents from southern districts Lindi and Mtwara reported both critical views of the campaign and decreased fish catches than those from northern districts. This variation emphasises the importance of considering fisheries governance on small spatial scales, and allowing for variability and complexity within a nation-wide enforcement campaign (Dietz, Ostrom, & Stern, 2003).

Although modelling was unsuccessful, the very positive assessment of the government campaign supports previous studies, in which it was argued that while blasting may provide individual financial benefits in the short-term, blasting generates short- and long-term negative effects for individuals and communities (Cesar et al., 1997, Pet-Soede et al., 1999). The uneven distribution of benefits from blast fishing, even in the short-term, is particularly relevant for this study as anecdotal evidence in Tanzania suggests that while blasting was widespread, it was not practised by the majority of fishers, rather by small numbers of locals financed by middlemen and well-connected officials (Slade and Kalangahe, 2015). The near universal nature of the reports of blasting cessation suggest that the campaign was not only positively viewed, but successful in its goal. The response to the campaign was not unanimously positive:

allegations of violence against suspected blast fishers and the destruction of homes and gears in blasting hotspots mirror those levelled following the 1997 campaign Operation Pono, albeit to a far lesser extent (Rubens, 2016; Rubens 2019). Moreover, positive reviews of the campaign and the reports that blasting has virtually disappeared should be treated with caution. Fear of reprisals and previous negative experiences with navy-led anti-blasting campaigns may have prevented respondents from openly expressing criticism or judgement on the campaign, and led them to hide blasting incidences in the vicinity. However, even allowing for these caveats, the impression gained during data collection is that the campaign achieved its goal largely without the negative outcomes of Operation Pono, in which allegations of human rights abuses were made (Rubens, 2016).

Respondents from high blasting history villages were significantly more likely than those from low blasting villages to perceive fish availability as increasing rather than stable or decreasing; this could suggest that following the reduction in blasting, communities in previous blast fishing hotspots have observed recovery in fish stocks. The literature concurs that extensive repeated blasts reduce habitat complexity (e.g. Fox et al., 2003) and that loss of rugosity can negatively affect species richness and abundance (Tyler, Manica, Jiddawi, & Speight, 2011), and biomass (Ainsworth et al., 2008). Blasting directly destroys reefs and associated species, particularly smaller fish with thin-walled swimbladders (Calud et al. 1989), and indirectly affects apex predators through the reduction of food sources and breeding grounds, such as pelagic species commonly fished in Tanzania like tuna and sharks (Tudela, 2004). There is also consensus that recovery following blasting is temporally variable, ranging from rapid to no observable regrowth, and depends on factors such as current strength and the level of destruction (e.g. Alcala, 2000; Fox & Caldwell, 2006; Riegl & Luke, 1999).

However, what has received substantially less attention in the literature is the specific assessment recovery of fish stocks following blasting cessation. There is evidence that fish biomass can quickly increase on blasted and neighbouring healthy reefs once blasting ceases, particularly herbivore biomass (Raymundo et al., 2007, Verheij, Makoloweka, & Kalombo, 2004). Moreover, the removal of disturbances in general and an increase in protection should encourage fish species repopulation, albeit at substantially different rates (e.g. Russ & Alcala, 2004). Therefore our finding, although perception-based, supports the limited data available in the literature showing that a relatively rapid recovery of fish stocks following blasting cessation is possible. This provides further support that blasting cessation has, in a relatively short time frame, benefited both coastal fishers and coral reef ecosystems. Incorporating catch data with the perception-based data to triangulate this finding would be useful, although unfortunately reliable catch data is currently unavailable in Tanzania. The implementation of the new electronic E-CAS catch data collection platform will hopefully improve the situation and open up new possibilities for future analysis and research. Finally, it should be noted that although there were significantly greater odds of these respondents perceiving fish availability as stable rather than decreasing, this odds ratio should not be applied numerically due to the overly large confidence interval. The confidence interval reveals a limitation of the dataset and could be addressed with further data collection.

Mean weekly fishing income also proved useful in predicting fish availability trends. My model showed that as fishing income increased, respondents were more likely to perceive fish availability as increasing rather than decreasing, displaying a significant link between catch volume and value. Some respondents cited changes in market demand and taxation as having negatively affected fishing income, irrespective of catch volume, and so it is encouraging to see that perceived fish availability is strongly and positively linked with increased fishing income. Also encouraging is that the majority of respondents reported increases at all: previous studies in Tanzania have almost universally received reports of declining catches (e.g. Katikiro, 2014; Silas et al., 2020).

The significant differences seen using Kruskal-Wallis tests between perceived decreasing, stable and increasing fish availability for some species support the model findings. The majority of respondents reported all pelagic species as increasing, and Kruskal-Wallis tests for these pelagic species including sharks, snappers, mackerels and tuna confirmed significant differences between the three levels of the response variable. This confirms the reports from respondents in Kigamboni and Kinondoni districts of dramatic increases in tuna catches. The picture was more ambiguous for reef-based, semi-demersal and demersal species. Although the data are perception based, they may suggest that mobile pelagic species were able to avoid areas of high disturbance when blasting was frequent, and therefore more quickly repopulate coastal fishing grounds once disturbance ceased. Reef-dependent and demersal species on the other hand may need more time to recover, as their primary ecosystems rebuild. If this were to be true, however, it would contradict previous findings in which herbivores repopulated faster than larger predatory species following the removal of disturbances (McClanahan 2000, Russ & Alcala, 2004). These speculations aside, the tests revealed no discernible pattern among reef-based, demersal, semi-demersal and pelagic species, and neither could an obvious pattern be identified for associated gears and fishing transport modes. This may be due to the constraints of the test used: all levels of response variable must be different from one another to return a significant result, and thus significant differences between decreasing and increasing catches for example may not have been revealed. This area remains nonetheless a promising area for future research.

There were some discrepancies observed between fish availability by target catch species and gears. For example, although the majority of respondents reported increasing octopus catches, respondents using octopus sticks reported stable or declining catches rather than increasing catches. Moreover, not all respondents who reported targeting octopus also indicated a use of sticks, and vice versa. This may be a simple omission because respondents believed it to be obvious and therefore not worth mentioning, or because they were indeed using other gears. Additionally, householders were generally less accurate in how they reported target catch species and gear use than fisher groups. Some fisher groups were very critical of the campaign and the destruction of homes and gears as mentioned previously, and therefore perhaps also had a negative bias on perceived fish availability which may have skewed the data.

Household fishing income trends were not significantly predicted by blast fishing history or any other candidate model, which may be due to the small sample size. Although the models themselves were not significant predictors of changes in household fishing income, comparing the results with total household income and household economic trends raises a number of questions. Although the majority of households indicated that they had experienced a worsening economic situation over the past 12 months, including those households with a fisher as primary earner, the majority also indicated that fishing derived income had increased. This suggests that in general, coastal village households are experiencing greater economic precarity in comparison to one year ago, independent of whether they depend on fishing as a primary income source, and that there are factors influencing general household income trends apart from fish catches and fishing income. This apparent discrepancy could be explained by the welfare function of small-scale fishing in developing countries, in which households increase fishing activities in response to decreased income from other sources (Béné, Hersoug, & Allison, 2010). Unprecedented weather conditions including floods, strong winds and drought also emerged as a prominent theme from the surveys. Given that a large proportion of households rely on farming as a primary or secondary source of food and income, these weather events could explain the discrepancy between reported trends in fish availability, fishing income, and fish catches. However, further analysis is needed to fully understand these factors, as well as identify the drivers of the considerable variability observed among villages.

Interesting discrepancies were observed between and within districts for all three indicators. Although all Mkinga district respondents reported positive impressions of the campaign, they had the highest percentage by far of any district reporting significant decreases in fish availability, as well as the highest percentage reporting significant increases. There were also differences observed between reports of fish availability and fishing derived household income, despite fishing income significantly predicting fish availability. This may be due to the fact that fish availability analysis was performed on the entire dataset, while household fishing derived income excluded fisher group respondents. However, the differences for example seen in Mtwara Rural district, in which approximately two thirds reported decreasing fish availability but no household reported decreasing or significantly decreasing fishing derived income, suggest that there are important distinctions to be made between households deriving some or part of their income from fishing and those respondents selected by village and BMU leaders for fisher group interviews. The considerable among-district variation observed for all three indicators of the reduction of blast fishing also suggests that negative impacts of blasting and positive effects of the reduction were not distributed evenly. This is not surprising given the considerable variation among districts for a wide range of demographic and socioeconomic factors, including population density, income levels, education levels, urbanisation (Kilama, 2016, Tanzanian NBS, 2015), as well as among the adjacent coastal ecosystems (Griffiths, 2005).

The picture that emerges from the analysis above is one of positive outcomes as coastal communities and ecosystems navigate the new terrain following the campaign. We have established a link between blasting history and fish availability, and explored the community perceptions of the anti-blasting government campaign as well as household income trends following blasting reduction. What is striking is the preliminary evidence that even within one to two years following the dramatic reduction in blasting, communities are reporting increased fish availability and incomes. This gives hope that artisanal fisheries can recover, even with heavily blasted reefs such as in Tanzania. In conclusion, my analysis showed that the reduction of blasting in Tanzania has had a perceived positive impact on fishing in general, fish availability and fishing derived income by coastal fishing communities. The collection of longitudinal income data would further understanding of the interactions between blasting history and fishing income. Longitudinal data on ecological markers including fish diversity and abundance across villages with low and high blasting would further allow the impact of the reduction to be measured and modelled. Finally, my study did not consider geographical and market factors such as possible climate change impacts and fisher access to infrastructure and markets. These factors may well be highly influential, and should be considered for future research.

4.6 REFERENCES

Agrawal, A. (2001). Common property institutions and sustainable governance of resources. *World development, 29*(10), 1649-1672. doi:10.1016/S0305-750X(01)00063-8

Ainsworth, C. H., Varkey, D. A., & Pitcher, T. J. (2008). Ecosystem simulations supporting ecosystem-based fisheries management in the Coral Triangle, Indonesia. *Ecological Modelling, 214*(2-4), 361-374. doi:10.1016/j.ecolmodel.2008.02.039

Alcala, A. C. (2000). Blast fishing in the Philippines, with notes on two destructive fishing activities. *Silliman Journal, 41*(2), 27-47.

Béné, C., Hersoug, B., & Allison, E. H. (2010). Not by rent alone: analysing the pro-poor functions of small-scale fisheries in developing countries. Development Policy Review, 28(3), 325-358. doi:10.1111/j.1467-7679.2010.00486.x

Béné, C., Chijere, A. D., Allison, E. H., Snyder, K., & Crissman, C. (2012). *Design and implementation of fishery modules in integrated household surveys in developing countries. Living Standards Measurement Study – Integrated Surveys on Agriculture*. Penang, Malaysia: The WorldFish Center. 83 pp.

Braulik, G., Wittich, A., Macaulay, J., Kasuga, M., Gordon, J., Davenport, T. R. B., & Gillespie, D. (2017). Acoustic monitoring to document the spatial distribution and hotspots of blast fishing in Tanzania. *Marine Pollution Bulletin, 125*(1-2), 360-366. doi:10.1016/j.marpolbul.2017.09.036

Burke, L., Reytar, K., Spalding, M., & Perry, A. (2011). *Reefs at Risk Revisited*. Washington, DC: World Resources Institute. 130 pp.

Calud, A., Rodriguez, G., Aruelo, R., Aguilar, G., Cinco, E., Armada, N., & Silvestre, G. (1989). Preliminary Results of a Study of the Municipal Fisheries in Lingayen Gulf. In G. Silvestre, E. Miclat, & T. E. Chua (Eds.), *Towards Sustainable Development of the Coastal Resources of Lingayen Gulf, Philippines* (Vol. 17, pp. 43-62).

Cesar, H., Lundin, C. G., Bettencourt, S., & Dixon, J. (1997). Indonesian coral reefs - an economic analysis of a precious but threatened resource. *Ambio, 26*(6), 345-350.

Cinner, J. E., McClanahan, T. R., MacNeil, M. A., Graham, N. A., Daw, T. M., Mukminin, A., . . . Jiddawi, N. (2012). Comanagement of coral reef social-ecological systems. *Proceedings of the National Academy of Sciences, 109*(14), 5219-5222. doi:10.1073/pnas.1121215109

Croissant, Y. (2020). mlogit: Multinomial Logit Models (Version version 1.1-0): R package. Retrieved from https://CRAN.R-project.org/package=mlogit

de la Cruz, D. W., Villanueva, R. D., & Baria, M. V. B. (2014). Community-based, low-tech method of restoring a lost thicket of Acropora corals. *ICES Journal of Marine Science / Journal du Conseil, 71*(7), 1866-1875.

Dietz, T., Ostrom, E., & Stern, P. C. (2003). The struggle to govern the commons. *science, 302*(5652), 1907-1912.

Fox, H. E., & Caldwell, R. L. (2006). Recovery from blast fishing on coral reefs: a tale of two scales. *Ecological Applications, 16*(5), 1631-1635.

Fox, H. E., Mous, P. J., Pet, J. S., Muljadi, A. H., & Caldwell, R. L. (2005). Experimental Assessment of Coral Reef Rehabilitation Following Blast Fishing. *Conservation Biology, 19*(1), 98-107. doi:10.1111/j.1523-1739.2005.00261.x

Fox, H. E., Pet, J. S., Dahuri, R., & Caldwell, R. L. (2003). Recovery in rubble fields: long-term impacts of blast fishing. *Marine Pollution Bulletin, 46*(8), 1024-1031. doi:10.1016/s0025-326x(03)00246-7

Friedman, J., Hastie, T., & Tibshirani, R. (2010). Regularization Paths for Generalized Linear Models via Coordinate Descent. *Journal of Statistical Software, 33*(1), 1-22.

Gorris, P. (2016). Deconstructing the Reality of Community-Based Management of Marine Resources in a Small Island Context in Indonesia. *Frontiers in Marine Science, 3*(120), 1-15. doi:10.3389/fmars.2016.00120

Griffiths, C. L. (2005). Coastal marine biodiversity in East Africa. *Indian Journal of Marine Sciences, 34*(1), 35-41.

Grosh, M., & Glewwe, P. (2000). *Designing Household Survey Questionnaires for Developing Countries. Lessons from 15 Years of the Living Standards Measurement Study*. Washington DC, USA: The World Bank. 365 pp.

Hempson, T. N. (2008). *Impacts of Dynamite Fishing on Coral Reef Communities in the Tanga Region, Tanzania.* (MSc). University of Cape Town, Cape Town.

Jiddawi, N. S., & Öhman, M. C. (2002). Marine fisheries in Tanzania. *Ambio, 31*(7), 518-527.

Kamat, V. (2014). "The Ocean is our Farm": Marine Conservation, Food Insecurity, and Social Suffering in Southeastern Tanzania. *Human Organization, 73*(3), 289-298.

Katikiro, R. E. (2014). Perceptions on the shifting baseline among coastal fishers of Tanga, Northeast Tanzania. *Ocean & Coastal Management, 91*, 23-31. doi:10.1016/j.ocecoaman.2014.01.009

Kilama, B. (2016). Where are the poor: Region and District Poverty Estimates for Tanzania, 2012. Dar es Salaam: REPOA. June 30.

Kleiber, D., Harris, L. M., & Vincent, A. C. (2015). Gender and small-scale fisheries: a case for counting women and beyond. Fish and Fisheries, 16(4), 547-562. doi:10.1111/faf.12075

Kumar, K. (2006). *Conducting Mini Surveys in Developing Countries (PN-ADG-566).* USAID Bureau for Policy and Program Coordination. https://dec.usaid.gov/dec/content/Detail.aspx?vID=47&ctID=ODVhZjk4NWQtM2YyMi00YjRmLTkxNjktZTcxMjM2NDBmY2Uy&rID=MTMzNTk2. 40 pp.

Lüdecke, D. (2018). ggeffects: Tidy Data Frames of Marginal Effects from Regression Models. Journal of Open Source Software, 3(26), 772-777. doi:10.21105/joss.00772

Mahongo, S. (2017). Capturing and documenting lessons and experiences of EU-WWF Fisheries Co-Management Programme Final Report. Dar es Salaam, Tanzania: WWF Tanzania. 25 pp. doi:10.13140/RG.2.2.26964.55685

McClanahan, T. R., Bergman, K., Huitric, M., McField, M., Elfwing, T., Nyström, M., & Nordemar, I. (2000). Response of fishes to algae reduction on Glovers Reef, Belize. *Marine Ecology Progress Series, 206*, 273-282.

McManus, J. W., Reyes Jr, R. B., & Nanola Jr, C. L. (1997). Effects of Some Destructive Fishing Methods on Coral Cover and Potential Rates of Recovery. *Environmental Management, 21*(1), 69-78. doi:10.1007/s002679900006

Moshy, V. H., Bryceson, I., & Mwaipopo, R. (2015). Social-ecological Changes, Livelihoods and Resilience Among Fishing Communities in Mafia Island Marine Park, Tanzania. Forum for Development Studies, 42(3), 529-553. doi:10.1080/08039410.2015.1065906

Moshy, V. H., & Bryceson, I. (2016). Seeing Through Fishers' Lenses: Exploring Marine Ecological Changes Within Mafia Island Marine Park, Tanzania. *SAGE Open, 6*(2). doi:10.1177/2158244016641716

Ostrom, E. (2009). A General Framework for Analyzing Sustainability of Social-Ecological Systems. *science, 325*(5939), 419-422.

Pet-Soede, C., Cesar, H. S. J., & Pet, J. S. (1999). An economic analysis of blast fishing on Indonesian coral reefs. *Environmental Conservation, 26*(2), 83-93. doi:10.1017/s0376892999000132

Pollnac, R., Christie, P., Cinner, J. E., Dalton, T., Daw, T. M., Forrester, G. E., . . . McClanahan, T. R. (2010). Marine reserves as linked social–ecological systems. *Proceedings of the National Academy of Sciences, 107*(43), 18262. doi:10.1073/pnas.0908266107

R Core Team. (2017). R: A language and environment for statistical computing. Vienna, Austria.

Raymundo, L. J., Maypa, A. P., Gomez, E. D., & Cadiz, P. (2007). Can dynamite-blasted reefs recover? A novel, low-tech approach to stimulating natural recovery in fish and coral populations. *Mar Pollut Bull, 54*(7), 1009-1019. doi:10.1016/j.marpolbul.2007.02.006

Riegl, B., & Luke, K. E. (1999). Ecological Parameters of Dynamited Reefs in the Northern Red Sea and their Relevance to Reef Rehabilitation. *Marine Pollution Bulletin, 37*(8), 488-498. doi:10.1016/S0025-326X(99)00104-6

Rogers, A., Blanchard, J. L., & Mumby, P. J. (2018). Fisheries productivity under progressive coral reef degradation. *Journal of Applied Ecology, 55*(3), 1041-1049. doi:10.1111/1365-2664.13051

Rubens, J. (2016). *Review of the status of blast fishing in Tanzanian marine waters: with recommendations for priority interventions*. Dar es Salaam, Tanzania: Hotel Association of Tanzania (HAT) & BEST Dialogue. 61 pp.

Rubens, J. (2019). *Combating blast-fishing in Tanzanian marine waters: Progress, achievements & lessons 2016-2018*. Dar es Salaam, Tanzania: Hotel Association of Tanzania (HAT) & BEST Dialogue. 38 pp.

Russ, G. R., & Alcala, A. C. (2004). Marine reserves: long-term protection is required for full recovery of predatory fish populations. Oecologia, 138(4), 622-627. doi:10.1007/s00442-003-1456-4

Silas, M. O., Mgeleka, S. S., Polte, P., Sköld, M., Lindborg, R., de la Torre-Castro, M., & Gullström, M. (2020). Adaptive capacity and coping strategies of small-scale coastal fisheries to declining fish catches: Insights from Tanzanian communities. *Environmental Science & Policy, 108*, 67-76. doi:10.1016/j.envsci.2020.03.012

Silva, P. (2006). *Exploring the linkages between poverty, marine protected area management, and the use of destructive fishing gear in Tanzania*. The World Bank. http://econ.worldbank.org. 43 pp.

Slade, L. M., & Kalangahe, B. (2015). Dynamite fishing in Tanzania. *Marine Pollution Bulletin, 101*(2), 491-496. doi:10.1016/j.marpolbul.2015.08.025

Stamatopoulos, C. (2002). *Sample-based fishery surveys. A technical handbook*. (9251046999). Rome, Italy: FAO. 144 pp.

Tanzania Blast-Fishing Monitoring Network. (2018). *Blast records*. Retrieved from: www.tz-blast-monitoring.net/

Tanzanian National Bureau of Statistics (NBS). (2015). *National Panel Survey (NPS) - Wave 4, 2014 - 2015*. Retrieved from: www.nbs.go.tz

Tudela, S. (2004). *Ecosystem effects of fishing in the Mediterranean: an analysis of the major threats of fishing gear and practices to biodiversity and marine*

habitats. General Fisheries Commision for the Mediterranean. Rome: FAO. 58 pp.
Tyler, E. H. M., Manica, A., Jiddawi, N., & Speight, M. R. (2011). A role for partially protected areas on coral reefs: maintaining fish diversity? *Aquatic Conservation: Marine and Freshwater Ecosystems, 21*(3), 231-238. doi:10.1002/aqc.1182
Verheij, E., Makoloweka, S., & Kalombo, H. (2004). Collaborative coastal management improves coral reefs and fisheries in Tanga, Tanzania. *Ocean & Coastal Management, 47*(7-8), 309-320. doi:10.1016/j.ocecoaman.2004.07.002
The World Bank. *Tanzania - Measuring Living Standards within Cities, Dar es Salaam 2014-2015 (TZA_2014_DAR-LSMS_v01_M)*. Retrieved from: https://microdata.worldbank.org/index.php/catalog/3399
Wells, S., Makoloweka, S., & Samoilys, M. (2007). *Putting Adaptive Management into Practice: Collaborative Coastal Management in Tanga, Northern Tanzania*. Nairobi, Kenya: IUCN & Irish Aid. 197 pp.
Wickham, H. (2009). *ggplot2: Elegant Graphics for Data Analysis.* New York: Springer-Verlag.

Chapter 5: Conclusion

My study undertook to explore blast fishing as a global phenomenon as well as to determine blast fishing drivers and impacts of the blasting reduction in Tanzania. In Chapter 2, I assessed the literature on the global status of blast fishing, elucidating broad causes, implications and solutions. In Chapter 3, I analysed causal factors underlying involvement in blast fishing and the reduction of the activity in Tanzania using primary data gathered from households and fishers. In Chapter 4, I investigated how Tanzania's coastal fishing communities and their fish stocks have been affected by the reduction of blast fishing, again drawing upon my primary data.

Using a comprehensive search across academic databases and grey literature, my literature review of blasting across the globe pointed to a lack of effective enforcement and governance structures as important blast fishing drivers. In contrast to the literature in which poverty is cited as the predominant blasting driver, my analysis suggests that while socioeconomic factors may contribute to blasting, they are not its primary cause. A combination of targeted deterrence measures and the implementation of co-managed coastal fisheries in which local communities and governments collectively manage marine resources emerged as the most effective solution.

These conclusions were supported by primary data collected in Tanzania. Collected using structured household and fisher surveys, these quantitative data do not support poverty as a primary driver of blasting. To the contrary, higher fishing incomes significantly predicted the profitability of blasting being selected as a primary cause of blasting. There was strong evidence to show that the primary cause of the blasting reduction were the enforcement measures undertaken by the Tanzanian government. As with the primary causes of blasting, fishing income significantly predicted the primary reasons for the reduction. Respondents with higher fishing derived incomes were more likely to select the government campaign as driving blasting reduction over community-based education programs, suggesting that higher income earners were less likely to be deterred by the "soft" enforcement of community groups. Respondents cited increased fish catches, increased diversity of fish species and increased feelings of peace and security as benefits seen after the reduction of blasting. High blasting histories predicted higher perceived fish availability, and increases in fishing income were significantly associated with increased reported fish catches over the past five years. In contrast to previous studies, the majority of respondents indicated that fish availability is increasing, which was replicated across the majority of individual target catch species and for fishers using a range of fishing gears.

My thesis made an important and significant contribution to the existing knowledge concerning blast fishing in Tanzania and across the globe in several ways. My literature review updated and expanded the body of knowledge on blasting as a global phenomenon and found evidence to challenge the existing theory pointing to poverty as the primary blasting driver. Moving from the global to the Tanzanian context revealed a gap in the literature regarding the drivers and impacts of the historically unprecedented reduction in blasting observed between 2016 and 2018. There is a large body of work in Tanzania and elsewhere assessing both the impact of blasting on reefs and associated fish species, and the recovery of coral reef ecosystems following blasting cessation. The literature concurs that blasting has a singularly destructive impact on coral reefs and associated species, and that recovery is highly variable. Blasting causality is also widely discussed in the literature, and remains under debate. These assertions had not, however, been critically examined in the light of the recent anti-blasting government campaign. My study sought therefore to address to address this gap. My analysis revealed significant links between blasting drivers and socioeconomic factors, as well as among blasting, fish availability and fishing-derived income. The association between blasting drivers and socioeconomic factors echoed my conclusion from studying the literature, providing no support for the theory that blasting is caused by poverty, and strengthening the argument for effective enforcement measures against blasting. My finding provides tentative support for the literature arguing that relatively rapid recovery of certain fish stocks is possible following the removal of blasting disturbance, and paints a generally positive picture of the impact of the government campaign.

The findings of this study have several limitations. Firstly, the absence of empirical data on blasting meant relying on a binary classification system for survey sites and respondents. This system, while derived from expert opinion, cannot by design encompass the complexities of blasting activities, in which fishers frequently travelled to fishing grounds not adjacent to their villages. The relationships found between blasting and other variables should therefore be interpreted with this in mind. Secondly, due to the non-random selection of survey sites, sampling bias undoubtedly influenced the analysis, despite all attempts to select representative survey sites. Finally, due to the cultural framework of Tanzanian coastal fishing households and the limited time and budget of this study, it was not possible to fully explore the influence of gender and women's views are clearly underrepresented in these data. There were also possible issues with model fit for the reasons for blasting reduction, and so output from this model should be treated with especial caution.

In conclusion, my findings point to a complex relationship between economic drivers and blasting causation, as well as a positive impact of blasting reduction on both fishing derived income and fish stocks. These data provide support for importance of enforcement in controlling blasting, and paint an encouraging picture of the resilience of coastal fisheries to extended disturbances such as seen in Tanzania. My analysis indicates that the recovery of fish stocks following blasting reduction is possible. There remains much that is not well understood about recovery of fish populations following blasting reduction, however, and further ecological research would support a deeper understanding of the recovery rates of herbivores and carnivores associated with coral reef ecosystems. A deeper exploration of the feelings of responsibility towards marine resource management is recommended, given the initial findings on the significant differences observed between low and high blasting history villages. There are very likely other factors influencing the decisions to blast or cease blasting, including market, geographical, climactic and political forces. Studies incorporating secondary data on these forces would illuminate further the complex interwoven drivers of blasting. The inclusion of longitudinal income data would also considerably enhance the scope of any further studies, and should be considered for future research. Finally, a substantial quantity of qualitative data was generated during data collection in addition to the quantitative data analysed here. It was beyond the scope of this thesis to fully explore the themes raised therein, but the inclusion of such data would undoubtedly improve the understanding of this topic through the triangulation of the quantitative data.

Appendices

Appendix A

Household and fisher surveys

Melissa Hampton-Smith
School of Environmental and Rural Science
University of New England
Armidale, NSW 2351, Australia

Phone (TZ) +255 758 578 755
Email mhampto2@myune.edu.au

Dept. Phone (AUS) +61 2 6773 2323
Dept. Email (AUS) ers-sabl@une.edu.au

Reduction of Blast Fishing in Tanzania: An Analysis of Deterrence Measures and Outcomes

UNE Human Research Ethics Committee Approval No.: HE19-003 Valid to: 05 May 2020

HOUSEHOLD AND INDIVIDUAL QUESTIONNAIRE

Name of interviewer: ……………………………………………………………………………

Date: ………../………../………………
DD MM YYYY

Region: ……………………………………………………………………………

Village: ……………………………………………………………………………

Household ID: ………………………

Name of data entry person: ……………………………………………………………………………

Date entered: ………../………../………………
DD MM YYYY

Module 1: Household roster

	1.1. UID Enter HH ID + HH roster position	1.2. What is (NAME)'s relationship to the head of the household? HEAD...1 SPOUSE....................................2 SON/DAUGHTER........................3 STEP SON/DAUGHTER.............4 SISTER/BROTHER........................5 GRANDCHILD.............................6 FATHER/MOTHER.....................7 OTHER RELATIVE......................8 LIVE-IN SERVANT.......................9 OTHER NON-RELATIVES...........10	1.3. In what month and year was (NAME) born? Write 99/99 if this is unknown. MM/YY	1.4. Sex M.......1 F.........2
1				
2				
3				
4				
5				
6				
7				
8				
9				

	1.5. How old is (NAME)? YEARS	1.6. What is (NAME)'s marital status? MONOGAMOUS MARRIED...1 POLYGAMOUS MARRIED.......2 LIVING TOGETHER.................3 SEPARATED.............................4 DIVORCED...............................5 NEVER MARRIED.....................6 WIDOWED..............................7	1.7. For how many years has (NAME) lived in this community? Enter 99 if lived here from birth, => 1.11. YEARS	1.8. Where did (NAME) move from? ANOTHER VILLAGE IN THIS DISTRICT ....1 ANOTHER COASTAL DISTRICT ....2 ANOTHER DISTRICT...................3 ANOTHER COUNTRY.................4	1.9. Why did (NAME) move here? WORK RELATED.......................................1 SCHOOL / STUDIES...............................2 MARRIAGE...3 OTHER FAMILY REASONS.........................4 BETTER SERVICES / HOUSING................5 LAND / PLOT..6 OTHER, SPECIFY......................................7
1					
2					
3					
4					
5					
6					
7					
8					
9					

	1.10. Which religion is (NAME) a part of? CHRISTIAN……………………………….1 MUSLIM…………………………………..2 OTHER……………………………………..3 NON-BELIEVER…………………………4	1.11. What tribe does (NAME) come from?	1.12. What is the highest education level completed by (NAME)? NO EDUCATION……………….1 PRIMARY…………………………..2 SECONDARY……………………..3 APPRENTICESHIP………………4 UNIVERSITY & EQUIV………..5	~~1.13. What potential income generating skills does (NAME) have?~~ ~~List all skills that could generate an income if the job possibilities existed.~~ ~~HANDICRAFTS…………………….1~~ ~~AGRICULTURE…………………….2~~ ~~FISHING…………………………….3~~ ~~TRADE E.G. CARPENTER……….4~~ ~~OTHER, SPECIFY………………….5~~
1				
2				
3				
4				
5				
6				
7				
8				
9				

Module 2: Finances

	2.1 Is (NAME) over 18 years of age? YES......1 NO.......2 If NO, => end.	2.2 In what type of work did [NAME] spend most of [NAME]'s time in the last 12 months: PAID EMPLOYEE..............................1 SELF EMPLOYED (NON-AGRIC)........2 FISHING...3 UNPAID FAMILY HELPER.................4 OWN FARM OR SHAMBA................5 UNPAID APPRENTICESHIP..............6 OTHER, SPECIFY..............................7 If answer = 3, complete Module 5	2.3 What has (NAME) done for work over the past 5 years? PAID EMPLOYEE..............................1 SELF EMPLOYED (NON-AGRIC)........2 FISHING...3 UNPAID FAMILY HELPER................4 OWN FARM OR SHAMBA................5 UNPAID APPRENTICESHIP................6 OTHER, SPECIFY................................7	2.4 What type of fishing does this household engage in? NOT INVOLVED.....1 FISHER..................2 CONSUMER...........3 SELLER....................4 PROCESSOR..........5	2.5 Why did (NAME) stop doing this work?	2.6 Does [NAME] receive payment in cash or in other forms from the employer for this work? YES......1 NO.......2 If NO, => 2.13.
1						
2						
3						
4						
5						
6						
7						
8						
9						

	2.7 How much was [NAME]'s last payment? IF RESPONDENT HAS NOT YET BEEN PAID, ASK: What payment does [NAME] expect? TSH	2.8 What period of time did this payment cover? HOUR...1 DAY...2 WEEK..3 FORTNIGHT..................................4 MONTH.......................................5 QUARTER.....................................6 HALF YEAR...................................7 YEAR..8	2.9 What was (NAME)'s total income over the past 7 days? TSH	2.10 Was this normal? YES......1 NO.......2 If YES, => 2.13.	2.11 Why was this income not normal?	2.12 What is a normal income over 7 days? TSH
1						
2						
3						
4						
5						
6						
7						
8						
9						

	2.13 Does this household receive any income not mentioned previously? YES, SPECIFY.........1 NO..........................2	Specify	2.14 Does this household have access to credit? YES......1 NO.......2 If NO, => 2.16.	2.15 How would (NAME) describe the ease of access to credit? VERY DIFFICULT.....................1 DIFFICULT...............................2 NEITHER DIFFICULT NOR EASY.......................................3 EASY.......................................4 VERY EASY..............................5	~~2.16 Is (NAME) currently in debt (more than 1 week's salary)?~~ ~~YES......1~~ ~~NO.......2~~	2.17 How has the economic status of this household changed over the past 12 months? MUCH WORSE..........................1 WORSE.....................................2 STABLE.....................................3 BETTER....................................4 MUCH BETTER..........................5
1						
2						
3						
4						
5						
6						
7						
8						
9						

3.1. What is the status of the main residence? OWNED.........................1 RENTED.........................2 FREE.............................3	3.2. The walls of the main dwelling are predominantly made of what materials? POLES, BRANCHES, GRASS..............................1 MUD AND STONES...........2 MUD BRICKS.....................3 CONCRETE, CEMENT, STONES............................4 OTHER, SPECIFY................5	3.3. The roof of the main dwelling is predominantly made of what materials? GRASS, LEAVES, BAMBOO...........................1 MUD AND GRASS...............2 CONCRETE, CEMENT.........3 METAL SHEETS..................4 TILES.................................5 OTHER, SPECIFY................6	3.4. The floor of the main dwelling is predominantly made of what materials? EARTH........................1 CONCRETE, CEMENT, TILES, TIMBER..............2 OTHER, SPECIFY...........3	3.5. What is the main toilet facility usually used in this household? NO TOILET........................1 OPEN PIT WITHOUT SLAB..................................2 PIT LATRINE WITH SLAB..................................3 POUR FLUSH.....................4 FLUSH TOILET....................5 OTHER, SPECIFY................6	3.6. Major fuel used for cooking? FIREWOOD...................1 PARAFFIN......................2 ELECTRICITY..................3 GAS ....4 CHARCOAL.....................5 DUNG.............................6 OTHER, SPECIFY.............7
3.7. Major fuel used for lighting? ELECTRICITY.....................1 SOLAR............................2 GAS................................3 LAMP OIL ....4 CANDLE ....5 FIREWOOD.....................6 PRIVATE GENERATOR.....7 OTHER, SPECIFY.............8	3.8. What is HH main source of electricity? TANESCO.........................1 COMMUNITY GENERATOR.....................2 SOLAR PANELS...........................3 OWN GENERATOR...........4 CAR/MOTORBIKE BATTERY.........................5 OTHER, SPECIFY.............6	3.9. What is the household's main source of drinking water in the rainy season? PIPED WATER INSIDE DWELLING.........................1 STANDPIPE/TAP................2 WATER VENDOR...............3 WELL WITH PUMP............4 RIVER, SPRING, POND, RAINWATER.......................5 OTHER, SPECIFY................6	3.10. How long does it take to get water from drinking water source to this dwelling in the rainy season? GO AND RETURN TRIP, INCLUDE WAITING TIME MINS	3.11. What is the household's main source of drinking water in the dry season? PIPED WATER INSIDE DWELLING.........................1 STANDPIPE/TAP................2 WATER VENDOR...............3 WELL WITH PUMP............4 RIVER, SPRING, POND, RAINWATER.......................5 OTHER, SPECIFY................6	3.12. How long does it take to get water from drinking water source to this dwelling in the dry season? GO AND RETURN TRIP, INCLUDE WAITING TIME MINS

Module 4: Household fishing effort

	4.1 Please list the members of your household who were involved in fishing during the last 12 months. This includes fish processing or trading, full or part time. Enter in order from HH roster.	~~4.2 About how many weeks was [NAME] a fisher during the last 12 months?~~ During those weeks, about how many days per week did [NAME] fish? ~~During those days, about how many hours per day did [NAME] fish?~~ WEEKS	DAYS	HOURS	4.3 For how long has (NAME) been fishing? YRS	4.4 Is fishing (NAME)'s primary income? YES……1 NO…….2 If YES, => 4.7.	4.5 Was fishing (NAME)'s primary income in the past? YES……1 NO…….2	4.6 When was fishing (NAME)'s primary income? YEAR	4.7 What was (NAME)'s income from fishing in the past 7 days? TSH
1									
2									
3									
4									
5									
6									
7									
8									
9									

	4.8. Was this normal? YES……1 NO…….2 If YES, => 4.11	4.9 Why was this income not normal?	4.10 What is (NAME)'s typical income from fishing over 7 days? TSH	4.11. Over the past 5 years, has the household income from fishing changed? INCREASING A LOT…………1 INCREASING……………………2 HASN'T CHANGED……………3 DECREASING……………………4 DECREASING A LOT………..5	4.12. Does (NAME) have other sources of income? YES……1 NO…….2 If NO, => 4.14.	4.13. What is (NAME)'s secondary income source?	4.14. Was (NAME)'s fish catches prior to 2015 higher, lower or the same as now? HIGHER…………………………..1 LOWER…………………………….2 THE SAME……………………….3
1							
2							
3							
4							
5							
6							
7							
8							
9							

	4.15. Did any household member during the last 12 months use any [FISHING GEAR]? Mark with an X	4.16. How many [FISHING GEAR] are owned by the household? NO.	~~4.17. Which are the household's preferred fishing gear?~~ ~~Mark with an X~~	4.18. If you or any household member had to buy a [FISHING GEAR], how much would you have paid during the last 12 months? TSH	~~4.19. How many units of [FISHING GEAR] did the household buy during the last 12 months?~~ ~~NO.~~	~~4.20. What were the total costs of fuel, oil and maintenance per week for [FISHING GEAR] operated during the last 12 months?~~ ~~TSH~~	~~4.21. How much did the household pay to rent [GEAR] in the last 12 months?~~ ~~TSH~~	~~4.22. Did the household have any other costs over the past 12 months?~~ ~~E.g. licenses, taxes, thread for sewing nets, buoys.~~ ~~TSH~~
Mosquito net (Usipa)								
Beach seine (Kambuzi)								
Net (Nyavu)								
Trawl nets (Jarife)								
Longline								
Handline (Mshipi)								
Fish traps (Madema)								
Stick (Mdeke)								
Fins, incl mask (Pelepele)								
Foot fisher (Miguu)								
Sail (Mashua)								
Twin-hull boat (Ngalawa)								
Dhow								
Dugout (Mtumbwi)								
Motorboat (Mashine/Fibre)								
Other, specify								

Module 5: Fisheries

	5.1. Please list up to five main species of fish that you or any member of your household have landed as a fisher during the last 12 months. Mark with an X	~~5.2. What is the household's preferred fish to catch?~~ ~~Mark with an X~~	5.3. Does this household sell or trade any of the catch? YES......1 NO.......2 If NO, => 5.5.	~~5.4. What is the household's preferred fish to sell or trade?~~ ~~Mark with an X~~	5.5. Please list up to five main species of fish that you or any member of your household eat regularly. Mark with an X	5.6. How often does the household eat these fish? ONCE PER DAY............1 ONCE PER WEEK.........2 ONCE PER MONTH.....3
Grouper (Chewe)						
Snapper (Kelea/Maginge)						
Shark (Papa)						
Lobster (Kambakoche)						
Emperor fish (Changu)						
Goatfish (Mkundaji)						
Rabbit fish (Tasi)						
Trevally (Kolekole)						
Octopus (Pweza)						
Squid (Ngisi)						
Mackerel/Kingfish (Nguru)						
Parrotfish (Pono)						
Ray (Taa)						
Sardine (Dagaa)						
Tuna (Jodari)						
Other, specify						

5.7. How much do you agree with this statement: "I could easily stop fishing and make my living elsewhere" STRONGLY DISAGREE...........1 DISAGREE............................2 NEUTRAL.............................3 AGREE.................................4 STRONGLY AGREE................5	5.8 How much do you agree with this statement: "The government's campaign against blast fishing has improved fishing in this area" STRONGLY DISAGREE...........1 DISAGREE............................2 NEUTRAL.............................3 AGREE.................................4 STRONGLY AGREE................5	5.9 How much do you agree with this statement: "MPAs rules in this area are fair" STRONGLY DISAGREE...........1 DISAGREE............................2 NEUTRAL.............................3 AGREE.................................4 STRONGLY AGREE................5	5.10. How much do you agree with this statement: "Most fishers follow the MPAs rules in this area" STRONGLY DISAGREE...........1 DISAGREE............................2 NEUTRAL.............................3 AGREE.................................4 STRONGLY AGREE................5 If answer is 4 or 5 => 5.13
5.11 Who breaks the rules? PEOPLE FROM THIS AREA...........................1 PEOPLE FROM OTHER AREAS.....................2 OTHER...3	5.12 What kind of rules do people break? FISH IN FORBIDDEN AREAS.........................1 USE FORBIDDEN FISHING GEARS...............2 CATCH FORBIDDEN FISH..............................3 OTHER...4	5.13 Over the past 5 years has the number of fish in the sea changed? INCREASING A LOT....................1 INCREASING...............................2 HASN'T CHANGED...............3 DECREASING.........................4 DECREASING A LOT.............5	5.14 If you got 50% less catch for a whole year, would you: KEEP FISHING THE SAME........................1 CHANGE FISHING GROUNDS..................2 CHANGE FISHING GEAR..........................3 FISH MORE OFTEN..................................4 FISH LESS OFTEN AND WORK ELSEWHERE....................................5 STOP FISHING..6

5.15 On a scale of 1 to 4, where 1 means the most responsible and 4 the least, please indicate below who has the most reponsibility for managing fishing and marine resources?		5.16 On a scale of 1 to 4, where 1 means the most responsible and 4 the least, please indicate below who has the most responsibility for preventing blast fishing?		5.17 On a scale of 1 to 4, where 1 means the most important reason and 4 the least, please indicate below what the reasons are for blast fishing?		5.18 On a scale of 1 to 4, where 1 means the most important reason and 4 the least, please indicate below why blast fishing decreased?	
The government		The government		It's easier		The government	
The village		The village		You can earn more money		Community groups	
Fishers only		Fishers only		Traditional methods don't work		No more fish	
NGOs		NGOs		There is no punishment for blasting		Other ways make more money	

Melissa Hampton-Smith
School of Environmental and Rural Science
University of New England
Armidale, NSW 2351, Australia

Phone (TZ) +255 758 578 755
Email mhampto2@myune.edu.au

Dept. Phone (AUS) +61 2 6773 2323
Dept. Email (AUS) ers-sabl@une.edu.au

Reduction of Blast Fishing in Tanzania: An Analysis of Deterrence Measures and Outcomes

UNE Human Research Ethics Committee Approval No.: HE19-003 Valid to: 05 May 2020

UPEMBUZI KATIKA KAYA

Jina la anaehojiwa: ....

Tarehe: ..../............./......................
DD MM YYYY

Mkoa: ....

Kijiji: ....

Kitambulisho cha Kaya: ....

Jina la mdadisi: ....

Tarehe ya udadisi: ..../............./......................
DD MM YYYY

Sehemu 1. Taarifa za Mwanakaya

	1.1. UID Orodha ya Wanakaya	1.2. Ni nini uhusiano wa [JINA] na Mkuu wa Kaya? MKUU WA KAYA...............................1 MKE/MUME.....................................2 MTOTO WA MKUU / WA KAYA........3 MTOTO WA KUFIKIA..........................4 DADA / KAKA....................................5 MJUKUU WA MKUU WA KAYA........6 MZAZI WA MKUU WA KAYA.............7 NDUGU / JAMA WENGINE (TAJA).....8 MTUMISHI WA NYUMBANI.............9 WATU WENGINE (TAJA).................10	1.3. Je, ni mwaka na mwezi gani [JINA] alizaliwa? KAMA HAJUI MWEZI ANDIKA '99/99'	1.4. Jinsia ya anaehojiwa ME.......1 KE.........2
1				
2				
3				
4				
5				
6				
7				
8				
9				

	1.5. [JINA] ana umri gani? MIAKA	1.6. Hali ya ndoa ya [JINA]: NDOA YA MKE MMOJA……………….1 NDOA ZA MKE ZAIDI YA MMOJA…2 WANAISHI PAMOJA KINYUMBA…………………………………3 WAMETENGANA……………………….4 TALAKA………………………………….….5 HAJAOA/HAJAOLEWA………………..6 MJANE………………………………………7	1.7. Kwa miaka mingapi [JINA] ameishi kwenye jamii hii? ANDIKA '99' KAMA AMEISHI TOKA KUZALIWA => qu 1.10. MIAKA	1.8. Je, [JINA] alihamia hapa kutoka wilaya gani? KIJIJI KINGINE KATIKA HII WILAYA…………………………………1 WILAYA NYINGINE YA PWANI …………………………………………..2 WILAYA NYINGINE………………..3 NCHI NYINGINE…………………….4	1.9. Je, ni nini sababu za [JINA] kuhamia hapa? KIKAZI…………………………………………………1 MASOMO………………………………………………2 NDOA……………………………………………….…3 SABABU NYINGINE ZA KIFAMILIA……………4 MAKAZI/HUDUMA NZURI……………………..5 ARDHI………………………………………………….6 NYINGINE(TAJA)…………………………………7
1					
2					
3					
4					
5					
6					
7					
8					
9					

	1.10. Dini ya Mshiriki MKRISTO……………………………….1 MUISLAM……………………………..2 NYINGINE……………………………3 ASIYEAMINI…………………………4	1.11. Unatoka kabila gani?	1.12. Je, [JINA] amefikia kiwango gani cha juu cha elimu? SIJASOMA……………………….1 MSINGI…………………………….2 SEKONDARI…………………….3 KUJIFUNZA……………………..4 CHUO KIKUU…………………..5	~~1.13. Ni ujuzi upi muhimu wa kuingiza kipato ambao (JINA) unao?~~ ~~Orodhesha ujuzi wowote ambao unaweza kukuingizia kipato endapo kuna uwezekano wa kufanya kazi hiyo.~~ ~~KAZI ZA MIKONO…………………………………1~~ ~~KILIMO……………………………………………2~~ ~~UVUVI……………………………………………3~~ ~~BIASHARA, MFANO UFUNDI SEREMALA……4~~ ~~MENGINEYO, ONESHA…………………………5~~
1				
2				
3				
4				
5				
6				
7				
8				
9				

Sehemu 2: Fedha

	2.1. JE, [JINA] ANA MIAKA 18 AU ZAIDI? NDIYO…………1 HAPANA……..2 Ikiwa HAPANA, => mwisho	**2.2. Je, ni katika shughuli gani ya kiuchumi ambapo umetumia muda wako mwingi katika kipindi cha miezi 12 iliyopita:** MFANYAKAZI ALIYELIPWA…………………1 KAZI BINAFSI ZA KUJIAJIRI…………………2 UVUVI………………………………………………3 KUSAIDIA FAMILIA BILA MALIPO………..4 ANAMILIKI SHAMBA LAKE MWENYEWE…………………………………5 KUJIFUNZA KWA KUJITOLEA……………6 NYINGINE TAJA…………………………………7 If answer = 3, complete module 5	**2.3. Ni kwa namna gani (JINA) umefanya kazi kwa miaka 5 iliyopita?** MFANYAKAZI ALIYELIPWA……………1 KAZI BINAFSI ZA KUJIAJIRI……………2 UVUVI…………………………………………3 KUSAIDIA FAMILIA BILA MALIPO….4 ANAMILIKI SHAMBA LAKE MWENYEWE……………………………5 KUJIFUNZA KWA KUJITOLEA………..6 NYINGINE TAJA……………………………7	**2.4. Ni kwa njia gani unajihusisha na shughuli za uvuvi?** SIJIHUSISHI/SISHIRIKI…..1 WAVUVI……………………2 WATUMIAJI………………..3 WACHUUZI…………………4 WAKAANGAJI……………..5 Jibu zaidi ya moja inawezekana	**2.5. Kwa nini (JINA) aliacha kufanya kazi hii?**	**2.6. Je, [JINA] anapokea ujira, mshahara au malipo mengine ya pesa taslimu au vitu kutoka kwa mwajiri wake anakofanya kazi?** NDIYO……………………1 HAPANA………………..2 Ikawa HAPANA, => 2.13.
1						
2						
3						
4						
5						
6						
7						
8						
9						

	2.7. Mara ya mwisho [JINA] alilipwa kiasi gani cha fedha? IWAPO MHOJIWA HAJAWAHI KULIPWA, MUULIZE: Anategemea kulipwa kiasi gani?	2.8. Malipo hayo yanahusisha kipindi gani? SAA................................1 SIKU...............................2 WIKI...............................3 WIKI 2.............................4 MWEZI...........................5 ROBO MWAKA..............6 NUSU MWAKA.............7 MWAKA MZIMA............8	2.9. Kipato chote cha (JINA) kilikuwaje katika kipindi cha siku 7 zilizopita? TSH	2.10. Je, kipato hicho kilikuwa halisi? NDIYO......1 HAPANA.......2 Ikiwa NDIYO, => 2.13.	2.11. Ni kwa nini kipato hiki hakikuwa halisi?	2.12. Kipato halisi ni kipi ndani ya siku 7? TSH
1						
2						
3						
4						
5						
6						
7						
8						
9						

	2.13. Je, kaya hii inapata kipato chochote nje ya kile kilichotajwa hapo awali kwenye swali la 2.3? NDIYO…………………1 HAPANA……………..2	Taja PESA, KIPINDI CHA MUDA	2.14. Je, unapata nafasi ya kupata mkopo? NDIYO……………….1 HAPANA……………2 Ikawa HAPANA, =>2.16.	2.15. Ni kwa namna ipi (JINA) unaweza kuelezea urahisi wa upatikanaji wa mkopo? NGUMU MNO……………….1 NGUMU………………………..2 SIYO NGUMU WALA SIYO RAHISI……………………………3 RAHISI……………………………4 RAHISI SANA…………………5	~~2.16. Je, kwa sasa (JINA) una mkopo (zaidi ya wiki 1 ya mshahara)?~~ ~~NDIYO……………….1~~ ~~HAPANA……………2~~	2.17. Ni kwa namna gani hali ya kiuchumi imebadilika katika kaya hii kwa kipindi cha miezi 12 iliyopita? MBAYA ZAIDI…………………………1 MBAYA……………………………………2 KUTOSHELEZA…………………………3 NZURI……………………………………4 NZURI ZAIDI…………………………5
1						
2						
3						
4						
5						
6						
7						
8						
9						

Sehemu 3: Kiwango cha maisha

3.1. Je, nani anayemiliki makazi ambamo kaya hii inaishi? MWENYEWE............1 AMEPANGA.............2 BURE.......................3	**3.2. Je, ni vifaa gani vilivyotumika kujengea kuta za nyumba kuu?** FITO, MATAWI NYASI.................................1 MATOPE NA MAWE..............................2 TOFALI ZA KUCHOMA ZA UDONGO...........................3 TOFALI ZA SARUJI............4 NYINGINE TAJA................5	**3.3. Ni vifaa gani vilivyotumika kuezekea nyumba kuu?** MAJANI, MATAWI, MIANZI..............................1 MATOPE NA NYASI............2 TOFALI ZA SARUJI.............3 PAA LA BATI.......................4 VIGAE................................5 NYINGINE , TAJA................6	**3.4. Ni vifaa gani vilivyotumika kusakafia nyumba kuu?** UDONGO.........................1 SIMENTI, ZEGE, VIGAE, MBAO...............................2 AINA NYINGINE, TAJA................................3	**3.5. Je, ni nini aina kuu ya choo kinachotumiwa na kaya hii kwa kawaida?** HAKUNA CHOO................1 CHOO CHA WAZI KISICHO NA MFUNIKO...................2 CHOO CHA SHIMO CHENYE MFUNIKO..........................3 CHOO CHA KUVUTA.........4 CHOO CHA KUMWAGIA MAJI................................5 NYINGINE, TAJA................6	**3.6 Je, ni nini nishati kuu ya kupikia?** KUNI.................................1 MAFUTA YA TAA...............2 UMEME...........................3 GESI...................................4 MKAA................................5 MABAKI YA WANYAMA.....6 NYINGINE, TAJA................7
3.7. Je, ni nini aina kuu ya nishati kwa ajili ya kuangazia? UMEME......................1 SOLA...........................2 GESI............................3 MAFUTA YA TAA ....4 MSHUMAA...................5 KUNI............................6 JENERETA BINAFSI........7 NYINGINE, (TAJA).........8	**3.8. Ni nini chanzo kikuu cha umeme wa kaya yako?** TANESCO..........................1 JENERATA YA JUMUIYA.....2 UMEME WA JUA................3 JENERATA BINAFSI............4 BETRI YA GARI/PIKI PIKI.....5 NYINGINE, TAJA................6	**3.9. Je, nini chanzo kikuu cha maji ya kunywa katika msimu wa masika?** MAJI YA BOMBA NDANI....1 PUMPU YA KUSIMAMA.....2 MUUZA MAJI....................3 KISIMA CHENYE PUMPU....4 MTO, CHEMCHEMI, BWAWA, MAJI YA MVUA...5 NYINGINE , TAJA................6	**3.10. Je, inachukua muda gani kwenda na kurudi, kuchota maji ya kunywa ya nyumbani katika msimu wa masika?** **KWENDA NA KURUDI PAMOJA NA KUSUBIRI** DAKIKA	**3.11. Je, nini chanzo J kikuu cha maji ya kunywa katika msimu wa kiangazi?** MAJI YA BOMBA NDANI....1 PUMPU YA KUSIMAMA.....2 MUUZA MAJI....................3 KISIMA CHENYE PUMPU....4 MTO, CHEMCHEMI, BWAWA, MAJI YA MVUA...5 NYINGINE , TAJA................6	**3.12. Je, inachukua muda gani kwenda a kurudi, kuchota maji katika msimu wa kiangazi?** **KWENDA NA KURUDI PAMOJA NA KUSUBIRI** DAKIKA

Sehemu 4: Shughuli za uvuvi kwenye kaya

	4.1. Tafadhali orodhesha wanakaya wote walioshiriki katika uvuvi katika kipindi cha miezi 12 iliyopita. Hii inajumuisha wote waliovua samaki, walioandaa samaki au kufanya biashara ya samaki, muda wote au kwa muda tu. Nakili majina kwa usahihi.	4.2. ~~Ni wiki ngapi kwa jumla [JINA] alikuwa mvuvi wa muda wote katika kipindi cha miezi 12 iliyopita?~~ Wakati wa wiki hizo, kadiria ni siku ngapi kwa wiki [JINA] alivua? ~~Katika siku hizo, kadiria [JINA] alitumia masaa mangapi kwa siku kuvua?~~			4.3. Kwa muda gani (JINA) umekuwa ukivua samaki?	4.4. Je, uvuvi ndiyo kazi ya msingi ya (JINA) ya kuingiza kipato? NDIYO………………..1 HAPANA……………2 Ikawa NDIYO, => 4.7.	4.5. Je, uvuvi ndiyo ilikuwa kazi ya msingi ya (JINA) ya kuingiza mapato hapo zamani? NDIYO………………..1 HAPANA……………2	4.6. Ni lini uvuvi ilikuwa kazi ya msingi ya (JINA) ya kuingiza kipato?	4.7. Ni kiasi gani cha mapato ya (JINA) yalitokana na uvuvi katika kipindi cha siku 7 zilizopita?
		WIKI	SIKU	MASAA	MWAKA			MWAKA	TSH
1									
2									
3									
4									
5									
6									
7									
8									
9									

	4.8. Je, kipato hicho kilikuwa halisi? NDIYO……….1 HAPANA…….2 Ikiwa NDIYO, => 4.11	4.9. Ni kwa nini kipato hiki hakikuwa halisi?	4.10. Kipato cha (JINA) halisi kutokana na uvuvi ni kiasi gani kwa kipindi cha siku 7? TSH	4.11. Kipindi cha miaka mitano iliyopita kipato cha kaya yako kutoka kwenye shughuli za uvuvi kimebadilika? KILIONGEZEKA SANA…………1 KILIONGEZEKA……………………2 HAKIJABADILIKA…………………3 KIMEPUNGUA……………………4 KIMEPUNGUA SANA………….5	4.12. Je, (JINA) ana chanzo kingine cha mapato? NDIYO……….1 HAPANA…….2 Ikawa HAPANA, => 4.14.	4.13. Ni njia gani nyingine mbadala ya (JINA) ya kupata kipato?	4.14. Je, unasaji wa samaki wa (JINA) ulikuwa juu, chini au uko vilevile kama sasa kabla ya 2016? JUU……………………………….1 CHINI…………………………..2 KIKO VILEVILE KAMA LEO……………………………..3
1							
2							
3							
4							
5							
6							
7							
8							
9							

	4.15. Kuna mwanakaya yeyote aliyejihusisha na shughuli za uvuvi katika kipindi cha miezi 12 iliyopita kwa kutumia [ZANA YA UVUVI]? Alama na X	4.16. Ni [ZANA ZA UVUVI] ngapi zinamilikiwa na kaya yako? Nambari	~~4.17. Ni mbinu zipi za uvuvi haramu kaya hii inapendelea kuzitumia katika uvuvi? Alama na X~~	4.18. Kama wewe au mwanakaya yeyote aliyejihusisha na uvuvi angenunua [ZANA ZA UVUVI], angelipa kiasi gani cha fedha katika kipindi cha miezi 12 iliyopita? TSH	~~4.19. Ni [ZANA ZA UVUVI] ngapi zilinunuliwa na wewe au mwanakaya yeyote katika kipindi cha miezi 12 iliyopita?~~	~~4.20. Nini ilikuwa jumla ya gharama kwa ajili ya mafuta, mafuta ya kulainishia mitambo na gharama za matengenezo kwa wiki kwa ajili ya [ZANA YA UVUVI] iliyotumika katika kipindi cha miezi 12 iliyopita? TSH~~	~~4.21. Ni kiasi gani cha fedha kaya yako ililipa kukodi [ZANA ZA UVUVI/ MOTA] kwa matumizi katika kipindi miezi 12 iliyopita? ANDIKA '0' KAMA HAKUNA KILICHOKODISHWA TSH~~	~~4.22. Je, kaya ilikuwa na gharama zingine katika kipindi cha miezi 12? TSH~~
Mosquito net (Usipa)								
Beach seine (Kambuzi)								
Net (Nyavu)								
Trawl nets (Jarife)								
Longline								
Handline (Mshipi)								
Fish traps (Madema)								
Stick (Mdeke)								
Fins, incl mask (Pelepele)								
Foot fisher (Miguu)								
Sail (Mashua)								
Twin-hull boat (Ngalawa)								
Dhow								
Dugout (Mtumbwi)								
Motorboat (Mashine/Fibre)								
Other, specify								

Module 5: Uvuvi

	5.1. Tafadhali orodhesha mpaka aina tano ya samaki ambao wewe au mwanakaya yeyote alivua katika kipindi cha miezi 12 iliyopita? Alama na X	~~5.2. Kaya inapendelea kutega samaki wa aina gani?~~ ~~Alama na X~~	5.3. Je, kaya huuza samaki wowote inaowavua? NDIYO...........1 HAPANA.........2 Ikiwa HAPANA, => 5.5	~~5.4. Je, kaya inapendelea kuuza samaki wa aina gani?~~ ~~Alama na X~~	5.5. Tafadhali taja aina tano kuu za samaki ambazo wewe au mwanachama yeyote wa kaya yako hula mara kwa mara Alama na X	5.6. Mara ngapi familia hula samaki hizi? MARA MOJA KWA SIKU....1 MARA MOJA KWA WIKI..................................2 MARA MOJA KWA MWEZI.............................3
Grouper (Chewe)						
Snapper (Kelea/Maginge)						
Shark (Papa)						
Lobster (Kambakoche)						
Emperor fish (Changu)						
Goatfish (Mkundaji)						
Rabbit fish (Tasi)						
Trevally (Kolekole)						
Octopus (Pweza)						
Squid (Ngisi)						
Mackerel/Kingfish (Nguru)						
Parrotfish (Pono)						
Ray (Taa)						
Sardine (Dagaa)						
Tuna (Jodari)						
Other, specify						

5.7. Ni kwa kiasi gani unakubaliana na usemi huu: “Ni rahisi kuacha shughuli za uvuvi na kwenda kuanzisha maisha yangu mahali pengine” NAKATAA KABISA...1 NAKATAA..2 SINA LOLOTE LA KUCHAGUA ....3 NAKUBALI...................................... ....4 NAKUBALI KABISA.....................................5	5.8. Ni kwa kiasi gani unakubaliana na usemi huu: “Kampeni ya serikali dhidi ya uvuvi wa mlipuko wa baruti imeboresha uvuvi katika eneo hili” NAKATAA KABISA...1 NAKATAA..2 SINA LOLOTE LA KUCHAGUA ....3 NAKUBALI...4 NAKUBALI KABISA.....................................5	5.9. Ni kwa kiasi gani unakubaliana na usemi huu: “Sheria zinazosimamia hifadhi ya bahari ni nzuri” NAKATAA KABISA...1 NAKATAA..2 SINA LOLOTE LA KUCHAGUA....................3 NAKUBALI...4 NAKUBALI KABISA.....................................5	5.10. Ni kwa kiasi gani unakubaliana na usemi huu: “Wavuvi wengi wanafuata sharia za uhifadhi wa bahari” NAKATAA KABISA...1 NAKATAA..2 SINA LOLOTE LA KUCHAGUA....................3 NAKUBALI...4 NAKUBALI KABISA.....................................5 Ikawa 4 or 5 => 5.13
5.11 Ni kina nani wanaovunja sheria? WATU KUTOKA ENEO HILI.........................1 WATU KUTOKA MAENEO MENGINE........2 NYINGINE TAJA...3	5.12 Ni aina gani ya sharia ambazo watu huvunja? KUVUA SAMAKI MAENEO YALIYOKATAZWA.....................................1 KUTUMIA VIFAA VYA UVUVI VILIVYOPIGWA MARUFUKU..................2 KUKAMATA SAMAKI WALIOPIGWA MARUFUKU...3 NYINGINE TAJA.....................................4	5.13 Zaidi ya miaka mitano iliyopita idadi ya samaki katika bahari imebadidika? IMEONGEZEKA SANA....................1 IMEONGEZEKA...............................2 HAIJABADILIKA...............................3 IMEPUNGUA.................................4 IMEPUNGUA SANA........................5	5.14 Kama unavua asilimia hamsini ambayo ni nusu ya idadi ya samaki kwa mwaka ambao umezoea kuvua kwa mwaka UTAENDELEA NA UVUVI ENEO HILOHILO..1 UTABADILI ENEO LA UVUVI........................2 UTABADILISHA VIFAAA VYA UVUVI...........3 UTAVUA KIDOGO HALAFU UFANYE KAZI NYINGINE ....4 UVUVI MARA NYINGI ZAIDI........................5 UTAACHA KUVUA.......................................6

5.15 Kwa kiwango cha 1 hadi 4 ambapo 1 inamaanisha anaewajibika zaidi na 4 anaewajibika kidogo .Tafadhali onyesha hapa chini ambaye ana jukumu zaidi la kusimamia rasilimali za uvuvi na bahari?		5.16 Kwa kiwango cha 1 hadi 4 ambapo 1 inamaanisha anaewajibika zaidi na 4 anaewajibika kidogo .Tafadhali onyesha hapa chini ambaye ana jukumu zaidi la kuzuia uvuvi haramu wa baruti?		5.17 Kwa kiwango cha 1 hadi 4 ambapo 1 inamaanisha anaewajibika zaidi na 4 anaewajibika kidogo .Tafadhali onyesha hapa chini sababu zinazosababisha uvuvi wa mlipuko wa baruti?		5.18 Kwa kiwango cha 1 hadi 4 ambapo 1 inamaanisha anaewajibika zaidi na 4 anaewajibika kidogo .Tafadhali onyesha hapa chini kwa nini uvuvi haramu umepungua?	
Serikali		Serikali		Ni rahisi		Serikali	
Kijiji		Kijiji		Unaweza kupata pesa zaidi		Vikundi vya jamii	
Wavuvi tu		Wavuvi tu		Mbinu za jadi hazifanyi kazi		Hakuna samaki zaidi	
Mashirika yasiyo ya serikali		Mashirika yasiyo ya serikali		Hakuna adhabu inayotolewa kutokana na uvuvi wa baruti		Kutafuta njia nyingine za kujipatia kipato zaidi	

Melissa Hampton-Smith
School of Environmental and Rural Science
University of New England
Armidale, NSW 2351, Australia

Phone (TZ) +255 758 578 755
Email mhampto2@myune.edu.au

Dept. Phone (AUS) +61 2 6773 2323
Dept. Email (AUS) ers-sabl@une.edu.au

Reduction of Blast Fishing in Tanzania:
An Analysis of Deterrence Measures and Outcomes

UNE Human Research Ethics Committee Approval No.: HE19-003 Valid to: 05 May 2020

CATCH SURVEY

Name of interviewer: ……………………………………………………………………

Date: ……………/…………/…………………
DD MM YYYY

Region: ……………………………………………………………………

Village: ……………………………………………………………………

Name of data entry person: ……………………………………………………………………

Date entered: ……………/…………/…………………
DD MM YYYY

Module 1: Crew Roster

	1.1. Ages of everyone on board. Start with the captain. YEARS	**1.2. Villages of everyone on board.** DISTRICT, VILLAGE	**1.3. Sex** M…….1 F………2	**1.4. In what month and years was (NAME) born?** Write 99/99 if this is unknown. MM/YY	**1.5. What is your average weekly income in the high and low season?** HIGH SEASON, LOW SEASON	**1.6. Where do you fish?** DEEP OPEN SEA……………………..1 OFF-SHORE REEF…………………..2 FRINGING REEF……………………3 SHORE…………………………………4 OTHER…………………………………5
1						
2						
3						
4						
5						
6						
7						
8						
9						

Module 2: Catch

	2.1. Which fish did you catch on this expedition? Mark with an X	**2.2. How is this fish measured?** KG/BUNDLE/BUCKET	**2.3. What is the approximate weight/amount of the catch?**	**2.4. What is the approximate value of the catch?** TSH	~~**2.5. What is the crew's preferred fish to catch?**~~ ~~Mark with an X~~	**2.6. Does this crew sell or trade any of the catch?** YES......1 NO.......2	~~**2.7. What is the crew's preferred fish to sell or trade?**~~ ~~Mark with an X~~
Grouper (Chewe)							
Snapper (Kelea/Maginge)							
Shark (Papa)							
Lobster (Kambakoche)							
Emperor fish (Changu)							
Goatfish (Mkundaji)							
Rabbit fish (Tasi)							
Trevally (Kolekole)							
Octopus (Pweza)							
Squid (Ngisi)							
Mackerel/Kingfish (Nguru)							
Parrotfish (Pono)							
Ray (Taa)							
Sardine (Dagaa)							
Tuna (Jodari)							
Other, specify							

Module 3: Expenses and profit

	3.1. Did this expedition use any [FISHING GEAR]? Mark with an X	~~**3.2. Which are this crew's preferred fishing gear?**~~ ~~Mark with an X~~	**3.3. If you had to purchase a [FISHING GEAR], how much would you have paid during the last 12 months?** TSH	**3.4. How many units of [FISHING GEAR] did you or any member of your crew purchase during the last 12 months?** NO.	**3.5. What were the running costs for (FISHING GEAR) per week over the past 12 months?** TSH	**3.6. How much did the crew pay to rent [GEAR] for use in the last 12 months?** TSH	~~**3.7. Did the crew have any other costs over the past 12 months?**~~ ~~E.g. licenses, taxes, thread for sewing nets, buoys.~~ ~~TSH~~	**3.8 How many people work in 1 boat / in 1 team?**
Mosquito net (Usipa)								
Beach seine (Kambuzi)								
Net (Nyavu)								
Trawl nets (Jarife)								
Longline								
Handline (Mshipi)								
Fish traps (Madema)								
Stick (Mdeke)								
Fins, incl mask (Pelepele)								
Foot fisher (Miguu)								
Sail (Mashua)								
Twin-hull boat (Ngalawa)								
Dhow								
Dugout (Mtumbwi)								
Motorboat (Mashine/Fibre)								
Other, specify								

Module 4: Marine resource management

4.1 How much do you agree with this statement: **"I could easily stop fishing and make my living elsewhere"** STRONGLY DISAGREE..........1 DISAGREE...........................2 NEUTRAL............................3 AGREE................................4 STRONGLY AGREE...............5	**4.2 How much do you agree with this statement:** **"The government's campaign against blast fishing has improved fishing in this area"** STRONGLY DISAGREE..........1 DISAGREE...........................2 NEUTRAL............................3 AGREE................................4 STRONGLY AGREE...............5	**4.3 How much do you agree with this statement:** **"MPAs rules in this area are fair"** STRONGLY DISAGREE..........1 DISAGREE...........................2 NEUTRAL............................3 AGREE................................4 STRONGLY AGREE...............5	**4.4 How much do you agree with this statement:** **"Most fishers follow the MPAs rules in this area"** STRONGLY DISAGREE..........1 DISAGREE...........................2 NEUTRAL............................3 AGREE................................4 STRONGLY AGREE...............5 If answer is 4 or 5 => 5.13
4.5 Who breaks the rules? PEOPLE FROM THIS AREA..........................1 PEOPLE FROM OTHER AREAS.....................2 OTHER...3	**4.6 What kind of rules do people break?** FISH IN FORBIDDEN AREAS.........................1 USE FORBIDDEN FISHING GEARS...............2 CATCH FORBIDDEN FISH..............................3 OTHER...4	**4.7 Over the past 5 years has the number of fish in the sea changed?** INCREASING A LOT...................1 INCREASING...............................2 HASN'T CHANGED...............3 DECREASING........................4 DECREASING A LOT.............5	**4.8 If you got 50% less catch for a whole year, would you:** KEEP FISHING THE SAME.................1 CHANGE FISHING GROUNDS..........2 CHANGE FISHING GEAR..................3 FISH MORE OFTEN...........................4 FISH LESS OFTEN AND WORK ELSEWHERE.....................................5 STOP FISHING.................................6

4.9 On a scale of 1 to 4, where 1 means the most responsible and 4 the least, please indicate below who has the most reponsibility for managing fishing and marine resources?		4.10 On a scale of 1 to 4, where 1 means the most responsible and 4 the least, please indicate below who has the most responsibility for preventing blast fishing?		4.11 On a scale of 1 to 4, where 1 means the most important reason and 4 the least, please indicate below what the reasons are for blast fishing?		4.12 On a scale of 1 to 4, where 1 means the most important reason and 4 the least, please indicate below why blast fishing decreased?	
The government		The government		It's easier		The government	
The village		The village		You can earn more money		Community groups	
Fishers only		Fishers only		Traditional methods don't work		No more fish	
NGOs		NGOs		There is no punishment for blasting		Other ways make more money	

University of New England

Melissa Hampton-Smith
School of Environmental and Rural Science
University of New England
Armidale, NSW 2351, Australia

Phone (TZ) +255 758 578 755
Email mhampto2@myune.edu.au

Dept. Phone (AUS) +61 2 6773 2323
Dept. Email (AUS) ers-sabl@une.edu.au

Reduction of Blast Fishing in Tanzania: An Analysis of Deterrence Measures and Outcomes

UNE Human Research Ethics Committee Approval No.: HE19-003 Valid to: 05 May 2020

UPEMBUZI WA UTEGAJI SAMAKI

Name of interviewer: ………………………………………………………………………

Date: …………/…………/…………………
DD MM YYYY

Region: ………………………………………………………………………

Village: ………………………………………………………………………

Name of data entry person: ………………………………………………………………………

Date entered: …………/…………/…………………
DD MM YYYY

Sehemu 1: MWONGOZA WAVUVI BAHARINI

	1.1. Miaka ya kila mmoja kwenye chombo Anza na Nahodha. MIAKA	**1.2. Vijiji kwa kila mmoja aliyeko kwenye chombo.** VILLAGE	**1.3. Jinsi** M.......1 F.........2	**1.4. Je, ni mwaka na mwezi gani [JINA] alizaliwa?** KAMA HAJUI MWEZI ANDIKA '99/99'	**1.5. Wastani wa kipato chako kwa wiki wakati wa msimu wa samaki wengi na wa samaki wachache?** HIGH SEASON, LOW SEASON	**1.6. Samaki wenu mnvua wapi?** BAHARI KUBWA...1 MWAMBA UNAOPATIKANA BAHARINI........2 MWAMBA UNAOPATIKANA PWANI.............3 PWANI..4 TAJA..5
1						
2						
3						
4						
5						
6						
7						
8						
9						

Sehemu 2: UVUAJI SAMAKI

	2.1. Ni samaki yupi umevua katika safari hii ya uvuvi? Alama na X	**2.2. Unapimaje samaki unaovua?** KG / FUNGU / SADO / 10 L NDOO / 20 L NDOO	**2.3. Makadirio ya wastani wa uzito wa samaki waliovuliwa ni ngapi?**	**2.4. Makadirio ya thamani ya samaki waliovuliwa ni kiasi gani?** TSH	~~**2.5. Ni samaki yupi anapendelewa kuvuliwa na wavuvi wa chombo hiki?**~~ ~~Alama na X~~	**2.6. Je, wavuvi wa chombo hiki wanauza samaki waliowavua?** NDIYO..........1 HAPANA.......2	~~**2.7. Wavuvi wa chombo hiki wanapendelea kuuza samaki wa aina gani?**~~ ~~Alama na X~~
Grouper (Chewe)							
Snapper (Kelea/Maginge)							
Shark (Papa)							
Lobster (Kambakoche)							
Emperor fish (Changu)							
Goatfish (Mkundaji)							
Rabbit fish (Tasi)							
Trevally (Kolekole)							
Octopus (Pweza)							
Squid (Ngisi)							
Mackerel/Kingfish (Nguru)							
Parrotfish (Pono)							
Ray (Taa)							
Sardine (Dagaa)							
Tuna (Jodari)							
Other, specify							

Sehemu 3: GHARAMA NA FAIDA

	3.1. Je, wavuvi katika safari hii ya uvuvi walitumia [MBINU] yoyote ya kutega samaki? Alama na X	~~**3.2. Ni mbinu zipi hupendelewa kutumiwa na wavuvi wa chombo hiki?**~~ ~~Alama na X~~	**3.3. Kama ungenunua [MBINU], ingekugharimu kiasi gani cha pesa katika kipindi cha miezi 12 iliyopita?** TSH	**3.4. Ni [ZANA ZA UVUVI] ngapi ilinunuliwa na wewe au mwanakaya yeyote katika kipindi cha miezi 12 iliyopita?** Nambari	**3.5. Gharama za uendeshaji wa zana za uvuvi kwa wiki (kwa miezi 12 ilitopita)?** TSH	**3.6. Ni kiasi gani cha fedha kaya yako ililipa kukodi [ZANA ZA UVUVI/ MOTA] kwa matumizi katika kipindi miezi 12 iliyopita?** TSH	~~**3.7. Je, kaya ilikuwa na gharama zingine katika kipindi cha miezi 12?**~~ ~~Kama vile leseni, kodi, nyuzi za kushonea mitego, maboya TSH~~	**3.8. Watu wangapi huwa kwenye mtumbwi/Kundi moja wakati wa uvuaji wa samaki?**
Mosquito net (Usipa)								
Beach seine (Kambuzi)								
Net (Nyavu)								
Trawl nets (Jarife)								
Longline								
Handline (Mshipi)								
Fish traps (Madema)								
Stick (Mdeke)								
Fins, incl mask (Pelepele)								
Foot fisher (Miguu)								
Sail (Mashua)								
Twin-hull boat (Ngalawa)								
Dhow								
Dugout (Mtumbwi)								
Motorboat (Mashine/Fibre)								
Other, specify								

Sehemu 4: USIMAMIZI WA RASLIMALI ZA MAJINI

4.1 Ni kwa kiasi gani unakubaliana na usemi huu: "Ni rahisi kuacha shughuli za uvuvi na kwenda kuanzisha maisha yangu mahali pengine" NAKATAA KABISA..1 NAKATAA..2 SINA LOLOTE LA KUCHAGUA ....3 NAKUBALI....................................... ....4 NAKUBALI KABISA.......................................5	4.2 Ni kwa kiasi gani unakubaliana na usemi huu: "Kampeni ya serikali dhidi ya uvuvi wa mlipuko wa baruti imeboresha uvuvi katika eneo hili" NAKATAA KABISA..1 NAKATAA..2 SINA LOLOTE LA KUCHAGUA ....3 NAKUBALI..4 NAKUBALI KABISA......................................5	4.3 Ni kwa kiasi gani unakubaliana na usemi huu: "Sheria zinazosimamia hifadhi ya bahari ni nzuri" NAKATAA KABISA..1 NAKATAA..2 SINA LOLOTE LA KUCHAGUA.....................3 NAKUBALI..4 NAKUBALI KABISA......................................5	4.4 Ni kwa kiasi gani unakubaliana na usemi huu: "Wavuvi wengi wanafuata sharia za uhifadhi wa bahari" NAKATAA KABISA..1 NAKATAA..2 SINA LOLOTE LA KUCHAGUA.....................3 NAKUBALI..4 NAKUBALI KABISA......................................5
4.5 Ni kina nani wanaovunja sheria? WATU KUTOKA ENEO HILI.........................1 WATU KUTOKA MAENEO MENGINE........2 NYINGINE TAJA...3	4.6 Ni aina gani ya sharia ambazo watu huvunja? KUVUA SAMAKI MAENEO YALIYOKATAZWA.....................................1 KUTUMIA VIFAA VYA UVUVI VILIVYOPIGWA MARUFUKU..................2 KUKAMATA SAMAKI WALIOPIGWA MARUFUKU..3 NYINGINE TAJA.....................................4	4.7 Zaidi ya miaka mitano iliyopita idadi ya samaki katika bahari imebadidika? IMEONGEZEKA SANA....................1 IMEONGEZEKA...............................2 HAIJABADILIKA...............................3 IMEPUNGUA.................................4 IMEPUNGUA SANA.......................5	4.8 Kama unavua asilimia hamsini ambayo ni nusu ya idadi ya samaki kwa mwaka ambao umezoea kuvua kwa mwaka UTAENDELEA NA UVUVI ENEO HILOHILO..1 UTABADILI ENEO LA UVUVI........................2 UTABADILISHA VIFAAA VYA UVUVI...........3 UTAVUA KIDOGO HALAFU UFANYE KAZI NYINGINE ....4 UVUVI MARA NYINGI ZAIDI........................5 UTAACHA KUVUA..6

4.9 Kwa kiwango cha 1 hadi 4 ambapo 1 inamaanisha anaewajibika zaidi na 4 anaewajibika kidogo .Tafadhali onyesha hapa chini ambaye ana jukumu zaidi la kusimamia rasilimali za uvuvi na bahari?		4.10 Kwa kiwango cha 1 hadi 4 ambapo 1 inamaanisha anaewajibika zaidi na 4 anaewajibika kidogo .Tafadhali onyesha hapa chini ambaye ana jukumu zaidi la kuzuia uvuvi haramu wa baruti?		4.11 Kwa kiwango cha 1 hadi 4 ambapo 1 inamaanisha anaewajibika zaidi na 4 anaewajibika kidogo .Tafadhali onyesha hapa chini sababu zinazosababisha uvuvi wa mlipuko wa baruti?		4.12 Kwa kiwango cha 1 hadi 4 ambapo 1 inamaanisha anaewajibika zaidi na 4 anaewajibika kidogo .Tafadhali onyesha hapa chini kwa nini uvuvi haramu umepungua?	
Serikali		Serikali		Ni rahisi		serikali	
Kijiji		Kijiji		Unaweza kupata pesa zaidi		Vikundi vya jamii	
Wavuvi tu		Wavuvi tu		Mbinu za jadi hazifanyi kazi		Hakuna samaki zaidi	
Mashirika yasiyo ya serikali		Mashirika yasiyo ya serikali		Hakuna adhabu inayotolewa kutokana na uvuvi wa baruti		Kutafuta njia nyingine za kujipatia kipato zaidi	

Appendix B

Operationalised variables

Operationalised variable	Code	Original survey items	Description
Village blast fishing history	1.00b	n/a	Villages coded as having low or high blasting history
Village	1.01c	n/a	Survey sites
Total average household income over 7 days	2.13d	2.7 – 2.13	Total normal household income and other income not previously mentioned, standardised over 7-day period
Housing standard	3.13	3.01 – 3.12	Housing standard index, aggregate of original survey items and transformed to standardised z-score
Total average fishing income over 7 days	4.1e	4.07, 4.1	Total fishing income per household, standardised over a 7-day period
Gear choice	4.15a – 4.15q	4.15	17 gear choices based on previous surveys conducted in Tanzania
Fishing ground	4.23a – 4.23d	4.23	4 fishing grounds
Target catch species	5.01a – 5.01q	5.01	17 target species choices based on previous surveys conducted in Tanzania

Appendix C

R code, data files and literature search files

Reproducible code, primary data files and literature search files may be found and accessed on Research UNE https://rune.une.edu.au/