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Fish to fight: Does catching more fish increase conflicts in Indonesia?

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ABSTRACT

To what extent do marine-based economic activities influence the onset of violent conflict? Despite ongoing debate over several decades around the relationship between natural resources and violent conflict, little of the relevant research has addressed the marine environment. Based on satellite data in Indonesia, this paper exploited geographical variations in ocean productivity to provide new evidence on the relationship between fisheries and violent conflict. Using a search-by-radius approach, we compiled a sample of 757 cells to represent spatial interactions and spillovers between land-based conflicts and catch landings on the sea. We found that both industrial and non-industrial catches exhibit a statistically significant positive influence on the occurrence of conflict events. Additionally, increased illegal, unreported and unregulated (IUU) catches are more likely than legal catches to cause violent conflict. An increase in fish catches in Indonesian waters fuels conflict of every kind, among which protests and riots are most sensitive to fisheries while fighting and terrorism are least sensitive. Overall, these empirical findings support the hypothesis that increased competition for common-pool resources contributes to the onset of violent conflict.

1. Introduction

Failures of natural resource management are increasingly recognized as a major source of social instability and civil conflict. For example, weak state capacity to manage lucrative resource rents from diamonds has deepened ethnic fractionalization in Africa (Lujala, Gleditsch, & Gilmore, 2005). Similarly, windfalls from oil-field discovery have increased the risk of political violence and armed conflict in oil-producing countries (Lei & Michaels, 2014). In conflict-prone regions, the undesirable consequences of civil conflict extend beyond direct casualties and economic loss to broader issues such as poverty and changes in victims' social behaviours (Abadie & Gardeazabal, 2003; Blattman & Miguel, 2010; Voors et al., 2012). To formulate effective development and resource management policies, it is imperative to understand the causal link between natural resources and conflict. However, the nature of this relationship is not well understood, and whether natural resources are beneficial or harmful to social stability within a country or region remain unresolved in the literature (Bhattacharyya & Mamo, 2021; Cotet & Tsui, 2013; van der Ploeg, 2011).

The relevant literature has until now focused largely on conflicts related to high-value non-renewable resources, such as oil, diamonds and other mineral resources. Previous studies have suggested that natural resources contribute to the increased incidence of conflict in four distinct ways. First, the presence of valuable natural resources is likely to motivate resource wars by incentivizing fighting and the elimination of competitors (Caselli, Morelli, & Rohner, 2015; Collier, 2004; Koren, 2018; Schollaert, van, de, & gaer, 2009). Second, rich natural resources make armed conflict more feasible by providing the financial resources to develop insurgent capacity (Collier, Hoeffler, & Rohner, 2008; Dube & Naidu, 2015; Nunn & Qian, 2014). Third, scarcity of natural resources and resultant inequalities in resource allocation generate social tensions and provoke conflict among competing groups (Caselli & Coleman, 2013; Hodler, 2006). Finally, weak institutions, such low government accountability and high levels of corruption, creates a resource curse whereby the potential benefits of natural resource wealth translate into violent conflict (Le Billon, 2014; Ross, 2015). On the other hand, these issues may not arise when natural resources drive income shocks that sufficiently increase the opportunity cost of fighting (Miguel, Satyanath, & Sergenti, 2004). There is recent evidence of this effect in Colombia

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(Dube & Vargas, 2013) and in Africa (McGuirk & Burke, 2020), where an increase in the price of agricultural products has deterred violent conflict.

Building on the available evidence, this paper uses detailed information about the geographical location of conflict events and associated levels of violence in Indonesia to explore the mechanisms through which fisheries affect conflict. The global prevalence of such conflicts has been widely reported (Bulte, Folmer, & Heijman, 1995; Hendrix & Glaser, 2011; Parker & Vadheim, 2017; Spijkers et al., 2019). As a common-pool resource, stock depletion and increased competition are seen as major catalysts for fisheries-related conflict (Costello, 2012; Pomeroy et al., 2007; Smith & Wills, 2018).[1] The level of resource competition in fisheries is further escalated by illegal, unreported and unregulated (IUU) fishing, which not only threatens resource sustainability but poses a risk to maritime security (Agnew et al., 2009; Cabral, Mayorga, Clemence, Lynham, Koeshendrajana, Muawanah, Nugroho, Anna, & Mira, 2018). Recent empirical studies have shown that fishers are more likely to engage in sea piracy when their legal income opportunities are adversely affected by oceanographic conditions (Axbard, 2016; Flückiger & Ludwig, 2015). However, empirical understanding of the relationship between fisheries and land-based conflict remains limited. A gap in the existing literature pertains to the insufficient exploration of the spillover effects of fisheries. The impact of fisheries in one area may not only affect conflicts within the same region but can also spill over into neighbouring areas. One of the most important contributions of our paper is to use a "search-by-radius" approach to examine conflicts within a 100 nautical mile radius surrounding fisheries. This method effectively considers both local and adjacent conflicts influenced by fisheries, thereby offering an opportunity to assess the impact of distant offshore fisheries on land-based conflicts.

As the sixth largest exclusive economic zone (EEZ) in the world, Indonesia is a pertinent case for present purposes. Ocean-based activities are central to national and regional economic development (FAO, 2021), and the fisheries sector also plays a crucial role as an essential source of food and employment for vast coastal communities (Béné et al., 2016; George, Adelaja, & Weatherspoon, 2020). The current situation in Indonesia highlights the importance of understanding conflict patterns and their causal relation to fisheries. Since the end of the 1990s, Indonesia has experienced major conflicts involving violence, civilian causalities and the destruction of infrastructure at community and national levels (Barron, Kaiser, & Pradhan, 2009). The causes and consequences of these conflicts are complex and multifaceted (Brambilla & Jones, 2020), but anecdotal evidence suggests that many are fisheries-related (Aragon, 2001; Muawanah, Pomeroy, & Marlessy, 2012; Thorburn, 2001).

Assessing the impact of fisheries on conflict events is not a trivial task for at least two reasons. First, while fisheries are marine-based, most of the conflict events are recorded on land territory. As the two activities are by construction not observed at the same location, and thus their relationship needs to be considered at a geographical scale. However, it is inadvisable to use institutional boundaries such as country, district or village for this purpose, as conflict patterns are highly correlated with unobservable characteristics of institutional boundaries (de Ree & Nillesen, 2009; Martin-Shields & Stojetz, 2019) and so confound the fishery-conflict relationship. For example, while there are many cross-country panel studies of conflict and natural resources (Bazzi & Blattman, 2014; Cotet & Tsui, 2013), these nation-level analyses may aggregate too much information at the expense of regional nuances (Berman, Couttenier, Rohner, & Thoenig, 2017).[2]

Second, while our primary concern here is the impact of fisheries on conflict, the impact of conflict on fishing activities remains ambiguous. Previous literature suggests a feedback effect wherein conflict contributes to a decline in fisheries catches due to environmental destruction and a threat to the safety of fishing operators (Gleditsch, 1998; Schwartz, Deligiannis, & Homer-Dixon, 2018). On the other hand, conflict may drive an increase in fishing when populations displaced by conflict in inland areas migrate to coastal regions and rely on fishing for subsistence and livelihood. Additionally, when coastal infrastructure is destroyed by conflict, distant water fishing vessels may exploit the opportunity and engage in fishing activities (Belhabib, Dridi, Padilla, Ang, & Le Billon, 2018). These feedback effects may bias estimates of how fisheries impact conflict. This problem of endogeneity is a long-standing issue in the relevant literature (Miguel et al., 2004).

To address these issues, we performed a geographically disaggregated analysis based on grid cell data at 1×1 degree resolution, enabling us to assess how fisheries influence the number of conflicts within a given cell and in neighbouring areas. By analysing the spatial spillover effects of catch landings on land-based conflicts based on a search-by-radius approach, our study contributes to the understanding of the complex interactions between fisheries and terrestrial disputes. This focus allows us to identify potential areas of intervention and inform policymaking aimed at mitigating conflicts related to fisheries and their influence on land-based disputes. To identify the causal relationship, we adopted an instrumental-variables approach exploiting geographical variations in ocean productivity as an instrument. Ocean productivity is determined solely by exogenous environmental factors that include chlorophyll concentration and sea surface temperature (SST) (Henson et al., 2010; Nelson & Smith, 1991). As ocean productivity is known to be a key driver of fisheries productivity (Piroddi, Giovanni, & Villy, 2010; Stock, John, Rykaczewski, Asch, Cheung, Dunne, Friedland, Lam, Sarmiento, & Watson, 2017), the geographical variations in ocean productivity facilitate investigation of how exogenously determined fishery shocks affect conflict.

The rest of the paper is structured as follows. Section 2 provides an overview of Indonesian fisheries and the potential channels through which fisheries might affect conflict. Section 3 describes the data and the grid cell sample construction. Section 4 outlines the empirical strategy for assessing the causal effect of fisheries on conflict. Section 5 presents the main findings and assesses the robustness of those results. This section also explores possible mechanisms through which fisheries affect conflict. Section 6 discusses the findings and their implications for policy, followed by conclusions in Section 7.

2. Background

As the world's largest archipelagic state, Indonesia has one of the richest marine habitats and the second largest capture fishery production sector globally. The country's fisheries sector accounts for 21% of its agricultural economy, providing direct employment for six million people in 2012 (FAO, 2021). The importance of fish as an essential source of animal protein has driven a fourfold increase in per capita annual consumption of fish products over

[1] In relation to renewable resources, previous studies have investigated water-related conflict (Dimitrov, 2002; Gleick, 1993; Zeitoun, Mirumachi, Warner, Kirkegaard, & Cascão, 2020). As a fundamental resource for most human activities, competition and disputes over freshwater are recognized as a national security issue in water-scarce countries. In addition, conflict over forest resources has been studied (Bazzi et al., 2021; Hares, 2009; Sarsons, 2008).

[2] Berman et al. (2017) noted that country-level aggregation may result in noisy estimates and attenuation bias because of the unobserved heterogeneity within as well as across countries. The present study differs from previous studies by relying on geocoded information for the case country that includes geographical variations in oceanographic conditions to assess the relationship between fisheries and conflict.

the last four decades (FAO, 2021). Fishery activities in Indonesia fall into two broad categories: an industrial sector operated by commercially oriented entrepreneurs with large fishing boats, and a non-industrial sector involving subsistence and commercial fishers with motorized or non-motorized fishing boats (Halim et al., 2019). As compared to other major fishing countries, one distinguishing feature of Indonesia's fisheries sector is that marine capture is dominated by small-scale operators. According to FAO (2021), about 95% of total fish production comes from small-scale fisheries, and small unpowered or outboard-engine boats account for 67% of the country's fishing vessels.

As the competent national authority, Indonesia's Ministry of Marine Affairs and Fisheries (MMAF) is responsible for managing fishing licenses, monitoring fishing activities, preventing illegal fishing and conserving fisheries resources (Muawanah et al., 2012). The government's top-down management approach focuses mainly on the enforcement of fishing licensing and vessel registration for large-scale industrial producers (Halim et al., 2019), typically for vessels larger than 30 GT. In contrast, non-industrial fisheries are managed by provincial governments or local community-based resource management systems (Satria & Matsuda, 2004; Yamazaki, Resosudarmo, Girsang, & Hoshino, 2018b). However, despite current management efforts at national and local levels (Muawanah et al., 2018), Indonesia's fisheries sector is experiencing increasing pressure from overexploitation, and the prevalence of IUU fishing has further complicated the management of marine areas, posing additional risks to sustainability (Cabral et al., 2018).

Previous studies provide anecdotal evidence that three possible channels through which fisheries might affect conflict. The first of these relates to disputes that directly involve fishing operators (i.e., "fish wars"). These conflicts have long been the subject of theoretical studies (Levhari & Mirman, 1980) and have also been documented widely in Indonesia and elsewhere (Muawanah et al., 2012; Yamazaki, Resosudarmo, Girsang, & Hoshino, 2018a). The main causes of fish wars in Indonesian waters include vague claims related to sea territory and excessive resource competition. In Papua, for example, migration from highland to coastal regions aggravated competition between migrants and traditional resource user groups. This dispute later escalated into violent conflict, fuelled by opposing claims regarding territorial user rights (Koczberski & Curry, 2004).

The second channel from fisheries to conflicts is related to contentious development that adversely impacts the welfare of coastal communities. In a region where communities are highly dependent on fisheries for their food and livelihood, public protests and demonstrations against development authorities are commonplace. While these may begin peacefully, they can quickly escalate into violent confrontation with police and government actors (Haryadi & Wahyudin, 2018). Finally, the increasing pressure on fishing and the resulting resource depletion can have spillover effects in other sectors. In particular, an increasing number of studies across various disciplines have noted the link between fisheries and maritime crimes such as piracy, trafficking and smuggling (Axbard, 2016; Belhabib, Le Billon, & Wrathall, 2020; Halim et al., 2019; Mackay, Hardesty, & Wilcox, 2020).

3. Data

3.1. Conflict

The conflict data were sourced from the Armed Conflict Location and Event Data (ACLED) project (Raleigh, Linke, Hegre, & Karlsen, 2010) for two reasons. First, ACLED records geolocation data for each conflict event. National Violence Monitoring System (NVMS) and Village Potential Statistics (PODES) are the other two widely used conflict datasets that are also publicly available for Indonesia. However, the geographical location of conflict events is not recorded in these datasets. For the current research design that uses spatial interaction of conflict and catch landings, the ACLED dataset is the only source of the conflict variables. Our sample includes the 599 events recorded for Indonesia in 2015.[3] Of these, 90% (540 cases) relate to village or town level while 9% (53 cases) relate to regional level, with only 1% (6 cases) recorded at province level.

Second, ACLED provides detailed information about conflict participants and types (Table 1).[4] In 2015, Indonesia's most common conflicts were protests (63%) that did not typically involve severe violence. Along with civilian conflicts that included protests, riots and strategic developments, accounting for more than 80% of all such events, 33 armed conflicts (battles and explosions) were also recorded in 2015.[5]

3.2. Fisheries

Indonesian fisheries data were collected from Global Fisheries Landings v4.0 (Watson, 2017). The database was developed using multiple sources supplied by international and fisheries science agencies, including the Food and Agriculture Organization (FAO), the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR), the Northwest Atlantic Fisheries Organization (NAFO) and the International Council for the Exploration of the Sea (ICES). Spatial information from regional fisheries management organisations (RFMOs) and satellite-based vessel Automatic Identification System (AIS) was also used to improve the precision of data. The data include landings of industrial and non-industrial catch in tonnes for grid cell intervals of 0.5 degrees (latitude and longitude). The database usefully separates industrial and non-industrial fishing according to catch taxonomic composition (Pauly & Zeller, 2016), reported type of fishing gear and fishing location. For example, non-industrial fishing typically involves a relatively large number of small-scale fishing boats in inshore coastal areas while industrial fishing predominates in offshore wasters and uses large boats and technologically sophisticated gear (Muawanah et al., 2018).

To the best of our knowledge, Global Fisheries Landings v4.0 (Watson, 2017) is the only publicly available geocoded catch data, which has been widely used in previous studies (e.g., Miller et al., 2019, Boyce, Lotze, Tittensor, Carozza, & Worm, 2020). There are two other datasets that include geocoded fisheries information – the Global Fishing Watch (GFW) and Visible Infrared Imaging Radiometer Suite (VIIRS). However, these datasets are not employed in this study for two reasons. First, these datasets only provide information about the fishing effort (e.g., location of fishing vessels and the time spent for fishing) and no catch information

[3] The year 2015 was chosen because the first recorded conflict in ACLED is January 1, 2015; as our fisheries data (Global Fisheries Landings v4.0) only cover the years 1950–2015, our conflict and fisheries data intersect only for 2015, and our analysis was necessarily based on cross-sectional data.

[4] On December 2, 2015, for instance, fishers and local people mounted a theatrical demonstration in Muara Angke, North Jakarta, opposing the ongoing coastal reclamation project to create 17 manmade islands (Event-ID 402 from ACLED).

[5] In the ACLED dataset, only 1.5% of total conflict events in 2015 were documented as involving fisher groups directly. This limited representation could be attributed to various factors, such as the propensity of small-scale fishers to engage in various livelihoods and their absence from official fisher group registries. Therefore, identifying the links between fish catches and fisheries-related conflicts, and how they differ from other types of conflict is challenging using only ACLED data. To conduct a more in-depth analysis to address these research questions, we would suggest exploring an alternative source of data or approaches to identify fisheries-related conflicts. This includes text analysis in news articles or social media data, as suggested by Maerz & Puschmann, 2020).

Table 1
ACLED types and number of conflicts in Indonesia for 2015.

Type	Description	Number
Battles	A battle between two violent armed groups.	33
Remote violence	Events were engaging in conflict did not require the physical presence of the perpetrator. For example, bombings, IED attacks and missile attacks.	5
Protests	Protests are public demonstrations that participants do not engage in violence, though violence may be used against them. Often – though not always – protests are against a government institution.	380
Riots	Riots are violent form of public demonstrations. The participants engage in violent acts, including but not limited to rock throwing and property destruction.	99
Strategic development	Important activities of violent groups, but they are not violent in themselves. The inclusion of such events is limited, as its purpose is to capture pivotal events within campaigns of political violence.	17
Violence against civilians	Violence against civilians is violent groups commit violence against civilians who are not armed. Insurgents, governments, militias, external forces and rioters can all commit violence against civilians. Protesters are also civilians, and severe violence against protesters falls into this category.	65

Note: Total number of conflicts is 599.

is included. Second, since small-scale fishing vessels typically do not have AIS or Vessel Monitoring System (VMS), their fishing efforts have incomplete representation in these datasets. The installation of AIS and VMS is mandatory only for vessels with a gross tonnage above a certain threshold (Imo, 2015). Moreover, the relationship between fishing effort and ocean productivity is not as well established as the link between catches and ocean productivity. In the Indonesian context, therefore, relying solely on these fishing effort data for this study is problematic.

From the database, we retrieved catch data on industrial and non-industrial fishing within 200 nautical miles (nmi) of Indonesia. The database also contains separate information about estimated IUU fishing catches, based on a combination of surveillance, trade and stock assessment data. In terms of geographical coverage, we included all data recorded within 200 nmi of shore,[6] as some offshore fishing by Indonesian vessels occurs (legally or illegally) outside the EEZ, exacerbating overfishing and resource degradation (Arias & Pressey, 2016).[7]

3.3. Ocean productivity

To identify the causal relationship between fisheries and conflict in Indonesia, spatial variation in the chlorophyll-based ocean productivity (OP) index, which is known to determine geographical differences in catch, was used as an instrumental variable (C. A. Stock et al., 2017). The ocean productivity data was retrieved from the Oregon State University website (http://sites.science.oregonstate.edu/ocean.productivity/index.php), which provides a global grid of 1050×2160 cells with a spatial resolution of 0.167 degrees in latitude and longitude. The ocean productivity index is based on the Vertically Generalized Production Model (VGPM), which estimates net primary production from chlorophyll using a temperature-dependent description of chlorophyll-specific photosynthetic efficiency (Behrenfeld & Falkowski, 1997b; Behrenfeld & Falkowski, 1997a). This is calculated as:

$$OP_{c,m} = chl_{c,m} \times SST_{c,m} \times daylight_{c,m} \times v_{c,m} \quad (1)$$

where $chl_{c,m}$ is chlorophyll concentration; $SST_{c,m}$ is sea surface temperature; $daylight_{c,m}$ is hours of daylight (i.e., potential duration of photosynthesis); and $v_{c,m}$ is the volume function in cell c and month m. The volume function represents primary production from the surface to a depth of 1% of surface light (euphotic depth); this was included to account for the effects of light on water column production at different depths. We used the monthly data for ocean productivity ($OP_{c,m}$), to calculate the mean ocean productivity for 2015 in each c, where $OP_c = 1/12 \times \sum_m OP_{c,m}$.

3.4. Sample construction

The unit of observation is a 1×1 degree cell within 200 nmi of the Indonesian shore. The choice of this cell size also means that provinces are the level above the cell. For present purposes, a larger cell size is therefore not advisable because we control unobserved regional heterogeneity in economic, social, and climatic conditions using province fixed effects (see Section 4).[8] Data with the same spatial resolution have been commonly used in previous studies examining the relationship between conflict and potential causes (Harari & Ferrara, 2018; Hunziker & Cederman, 2022), whereas other studies, including Axbard (2016) and Berman et al. (2017), have used a broader (2×2 degree) or finer (0.5×0.5 degree) spatial scale.

Cells that included other countries' land territory (i.e., Malaysia, Singapore, Philippines) and those that did not contain any sea area were dropped from the sample, which meant that 757 cells were included in the analysis (see Appendix, Fig. A1). The catch variable was constructed by matching catch data to ocean productivity data for each 1×1 degree cell in terms of the spatial resolution. Rather than matching conflict data with other sea-based data (i.e., fisheries and ocean productivity) within each cell, we constructed the conflict variable by using a "search-by-radius" approach to count the number of conflict events or fatalities around each cell (Fig. 1). This is because the fisheries and conflict data were recorded on sea and land, respectively. As no conflict observations were recorded in about 52% of the cells in our sample that contained no land area, the use of the search-by-radius approach to link land- and sea-based data enabled us to determine whether increasing fishing intensity in a given sea area altered conflict patterns in adjacent land areas. For the baseline case, we used a search radius of 100 nmi from cell edges to construct the conflict variable. We also performed a sensitivity analysis to assess how the baseline results would respond to different search ranges (0, 50, 150 and 200 nmi) as well as the possible spatial correlation between cells.[9]

3.5. Sample characteristics

Table 2 shows summary statistics for the variables used in the analysis (conflicts, fisheries and ocean productivity), and Fig. 2

[6] This 200 nmi distance corresponds to EEZs that extend 200 nmi from the coastal baseline of a country. EEZs grant the coastal state sovereign rights to explore, exploit and manage the natural resources within the zone, including fisheries and other natural resources.

[7] For example, the Strait of Malacca is less than 200 nautical miles wide, and we therefore included all observations in the Strait.

[8] A smaller cell size may allow us to control regional heterogeneity at a lower geographical level (e.g., districts). However, this poses a risk of spillovers between cells; e.g., fishers catch fish in areas far from home.

[9] The use of the search-by-radius approach may result in a situation where one fisheries observation affects multiple conflicts. In practice, this can happen when catches from a cell are landed at different locations or by different community groups. We recognized this and assessed the sensitivity of the baseline results using a 0 nmi search radius. Since each conflict is linked to a unique fisheries observation, in this case, the risk of counting the same conflict twice is eliminated. Despite this adjustment, the results do not change qualitatively (Section 5.2).

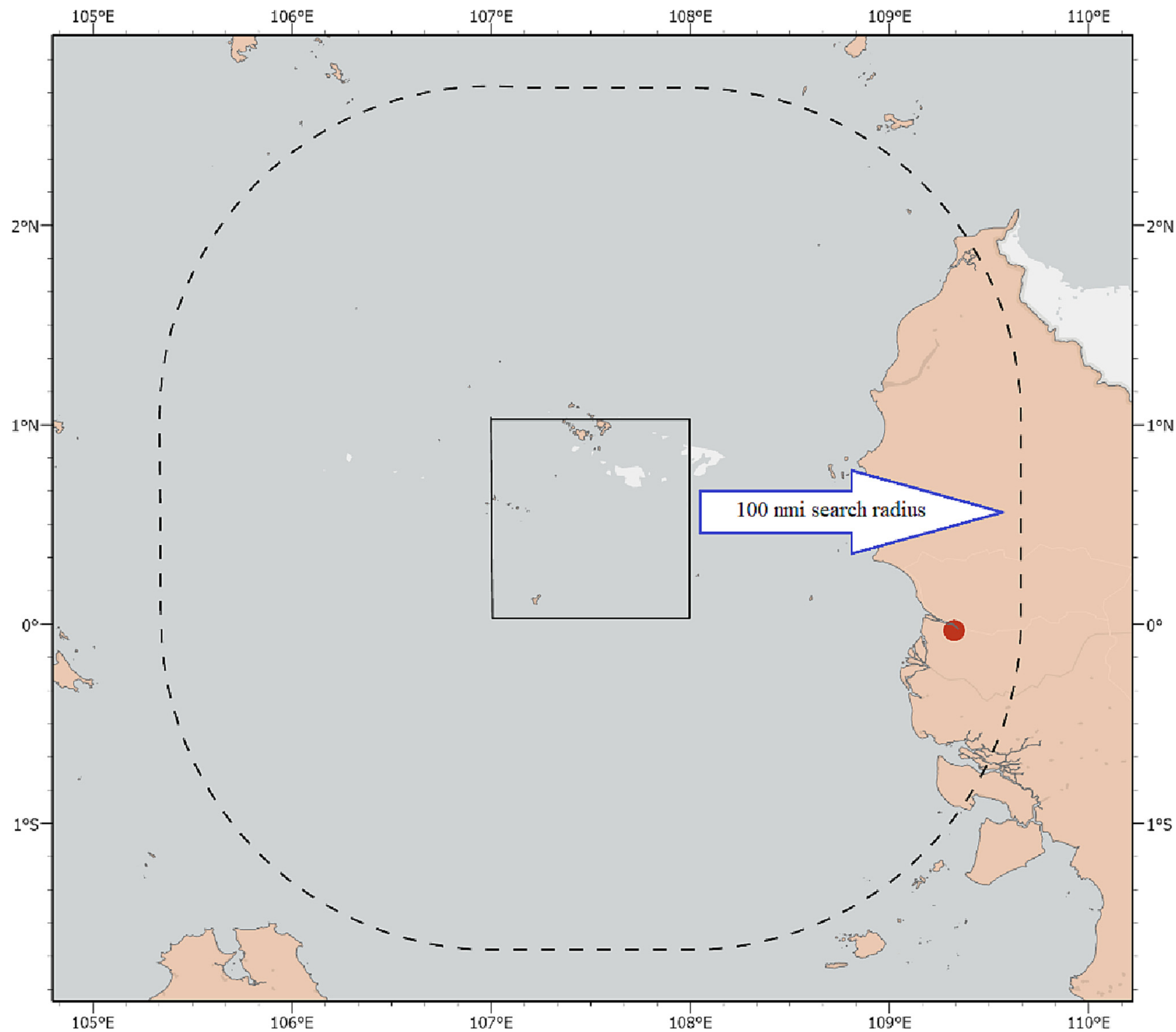

Fig. 1. An example of the search-by-radius approach to link fisheries data (solid black cell) with conflict data (red coloured dot). The dotted line shows the boundary within a search radius of 100 nmi. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

shows the geographical distribution of the 599 conflict events and total fisheries catch. The distribution of conflicts is highly skewed; for example, while the mean number of conflicts in each cell is less than 1 (0.724), the maximum number of conflicts within a cell (around the national capital Jakarta) is 133, accounting for about 22% of all conflicts in 2015.[10] Although the probability of observing a conflict in a given cell is relatively low (9%), there were 12 conflicts on average within 100 nmi of each cell. By construction, the mean number of conflicts generally increases with search radius, as some conflicts are matched to multiple cells.

The geographical distribution of fisheries catches is also highly skewed towards western regions, where fisheries have developed faster than in other areas. The overexploitation of marine resources is of particular concern in these regions (FAO, 2021; Heazle & Butcher, 2007). There is a moderate positive correlation between conflicts and fisheries catches (see Appendix, Table C1), and Fig. 2 shows that adjacent areas of high fishing intensity are also likely to experience some conflict events. For example, the area of highest fishing intensity is the Strait of Malacca, which coincides with the highest concentration of conflicts in Sumatra Island's western coastal provinces (Aceh, North Sumatra, Riau, Jambi and South Sumatra).

4. Empirical strategy

To evaluate the impact of fisheries on conflict, we employed the following structural equation:

$$conflict_{c,p} = \beta catch_c + \gamma_p + \varepsilon_{c,p} \quad (2)$$

The dependent variable $conflict_{c,p}$ refers to the number of conflicts or fatalities in cell c and province p. Our primary interest is the coefficient of $catch_c$, which denotes the quantity of fish caught in cell c. The equation also includes province fixed effects γ_p to

[10] A simple log-transformation of the conflict and catch variable is not advisable to reduce the skewness because of zero values in many observations. Alternatively, we transformed the conflict and catch variable by taking $\ln(conflict_{c,p} + \varepsilon)$ and $\ln(catch_c + \varepsilon)$, where ε is 0.001. We estimated our models (Section 4) with the transformed variables and found no changes in the conclusions.

Table 2
Summary statistics.

	Obs.	Mean	S.D.	Min	Max
(a) Conflict variable with different search ranges ($conflict_{c,p}$)					
Number of conflicts (0 nmi)	757	0.703	5.537	0	133
Number of conflicts (50 nmi)	757	4.548	15.911	0	167
Number of conflicts (100 nmi)	757	11.337	26.269	0	195
Number of conflicts (150 nmi)	757	21.338	37.742	0	214
Number of conflicts (200 nmi)	757	34.894	50.229	0	264
Fatalities (100 nmi)	757	1.823	4.046	0	32
(b) Fisheries variable ($catch_c$)					
Total catch (000 tonnes)	757	9.402	11.341	0.0003	95.188
Industrial catch (000 tonnes)	757	3.566	4.001	0.0003	30.564
Non-industrial catch (000 tonnes)	757	5.836	8.169	0	67.585
IUU catch (000 tonnes)	757	3.999	5.663	0.00002	61.298
Industrial IUU catch (000 tonnes)	757	2.155	3.933	0.00002	44.369
Non-industrial IUU catch (000 tonnes)	757	1.844	2.558	0	23.208
(c) Instrumental variable (OP_c)					
Ocean productivity index	742	575.025	474.746	161.996	3216.1

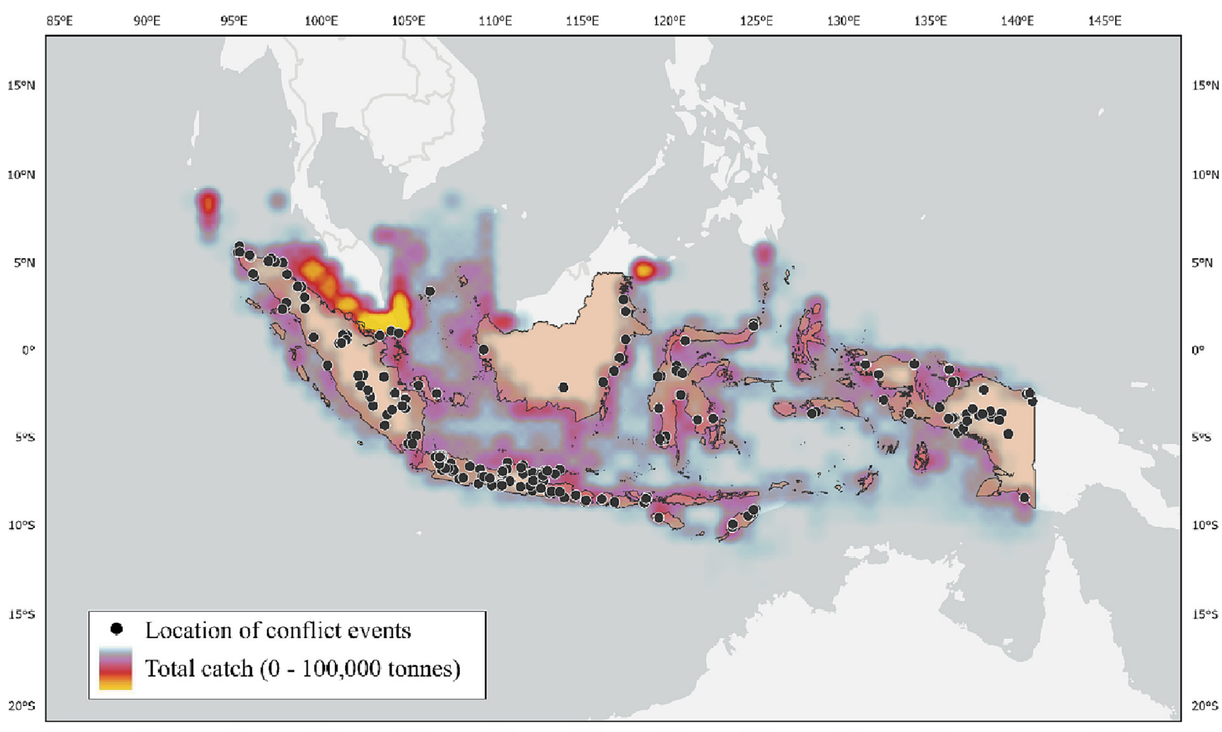

Fig. 2. Geographical distribution of total catch and conflict events at a 1 × 1 degree cell in Indonesia for 2015. The geographical distributions of industrial and non-industrial catches are presented in Appendix B.

control for factors potentially associated with regional differences in conflict patterns, including economic, social, and climatic conditions.[11]

4.1. Regional heterogeneity

The omission of province fixed effects may bias the estimated effect of fisheries on conflict in either a positive or negative direction. However, the overall consequence of omitting province fixed effects is ambiguous because the direction of the bias that arises from these factors depends on the way in which they are associated with conflict and fisheries catches. We have identified four potential factors that may be particularly overlooked due to the omission of province fixed effects. First, fish catches are expected to be high in regions with a large population of fishers. At the same time, the number of conflicts is expected to increase with the increasing density of human settlements (Acemoglu, Fergusson, & Johnson, 2020). In such a case, the omission of regional differences in population may lead to an upward bias in the estimated effect of fisheries on conflict.[12]

Second, the failure to control for regional differences in climatic conditions may bias the estimates downward. Previous research suggests that severe climatic conditions in terms of temperature, rainfall, and drought intensity increase the risk of violent conflict (Burke, Hsiang, & Miguel, 2015; Maystadt & Ecker, 2014), whereas

[11] Provinces are the level above the cells in our sample, meaning that we are exploiting variation within provinces in the empirical strategy.

[12] It is also possible that the population size is positively correlated with ocean productivity. For example, people may be more likely to migrate to places with historically good fishing conditions, and this may also result in higher fish catches and a greater likelihood of conflict onset. Province fixed effects are thus included in the first-stage regression to block this back-door path.

severe climatic conditions such as increasing rainfall during the monsoon season and strong ocean winds are known to negatively impact on fisheries productivity (Allison et al., 2009; Lam et al., 2020).

Third, differences in economic conditions across provinces, including income and employment opportunities and the level of resource dependency, influence the relationship between fisheries and conflict. For example, regions that heavily depend on a single natural resource are more susceptible to circumstances in which a small number of groups or individuals seek control over the resource, compared to regions with a more diversified economy and a broader range of resources. The resulting power imbalance and exploitation can create social unrest that ultimately leads to conflicts (Deligiannis, 2012). Previous studies also suggest that areas with better economic conditions are more likely to invest in establishment of equitable and sustainable fisheries (Bennett, 2019; Cisneros-Montemayor et al., 2021). Therefore, the failure to control for regional differences in economic conditions can lead to an underestimation of the impact of fish catches on conflict.

Finally, previous literature suggests social and political instability as a key driver of conflicts. Indonesia's diverse population can lead to tensions between ethnic and religious groups, intensified by political actors using identity politics, resulting in communal violence and conflicts (Aspinall, 2011). This means that socio-political factors such as ethnic heterogeneity, religious differences, and political uncertainty exacerbate tensions across different regions, contributing to social unrest and separatist movements (Ostwald, Tajima, & Samphantharak, 2016). Social actors at individual and institutional levels have also been suggested as a key player in regional fisheries development (Satria & Matsuda, 2004; Stacey et al., 2021). In such a case, the failure to control for regional differences in socio-political factors may bias the estimates upward.

4.2. Endogeneity

Moreover, OLS estimation of equation (2) is likely to suffer from endogeneity arising from reverse causality. More particularly, fisheries in a given cell may be adversely affected in at least two ways by conflict in adjacent areas. First, conflicts in coastal areas may hinder fishing activities by posing a threat to the safety of fishing operators, preventing the use of harbour or sea areas and limiting access to input or output markets (Hendrix & Glaser, 2011; Pomeroy et al., 2007). Second, the fishermen themselves might seek to affect catch landings by participating in protests or riots. The parameter β in (2) is likely to be underestimated neglecting the significant negative feedback effect of fisheries on conflict.

To address the endogeneity problem, we exploited the exogenous variation of the chlorophyll-based ocean productivity index OP_c for two-stage least squares (2SLS). For present purposes, this variable is the ideal instrument that satisfies the two assumptions necessary to identify the causal impact of fisheries on conflict. First, the chlorophyll-based ocean productivity index does not directly affect land-based conflicts but only through fisheries activities since the concentration of chlorophyll in the sea or SST does not directly influence household behaviours or economic activities of other sectors. Second, the chlorophyll-based ocean productivity index captures regional differences in marine fisheries catches. In the biology literature, this index is widely used to estimate the abundance, growth and production patterns of fisheries resources (Hendiarti & Suwarso, 2005; Nurdin, Mustapha, Lihan, & Zainuddin, 2017; Semedi & Dewanti Dimyati, 2010). The first-stage regression also confirmed that, as the literature suggests, ocean productivity has a positive impact on all catch variables at the 1% significance level (Table 3). The Kleibergen-Paap Lagrange Multiplier test rejected the null hypothesis of under-identification (Kleibergen & Paap, 2006), and Stock and Yogo's F-statistics for the excluded instrument of ocean productivity also suggest that ocean productivity is a relevant instrument for the fisheries variable (Stock & Yogo, 2002).

Table 3
First-stage regressions.

Dependent variable	(1) Industrial catch	(2) Non-industrial catch	(3) Total catch
Ocean productivity	0.0012***	0.0052***	0.0064***
	(0.0004)	(0.0010)	(0.0012)
Observations	742	742	742
Province fixed effects	Yes	Yes	Yes
Kleibergen-Paap LM statistic for under-identification (*p*-value)	14.46 (0.000)	41.79 (0.000)	38.36 (0.000)
F statistics of excluded instruments (*p*-value)	11.68 (0.001)	37.92 (0.000)	32.42 (0.000)

Notes: The regressions are estimated by OLS with province fixed effects. The dependent variable is reported in the column head. The Conley-HAC standard errors (Conley & Molinari 2007) are reported in parentheses. We report Kleibergen-Paap Lagrange Multiplier (LM) statistics and F-statistics of excluded instruments to test for under-identification and weak instrument, respectively. The null hypotheses of these diagnostics tests are that the IV models are under-identified and that ocean productivity is a weak instrument. Significance at the 10%, 5% and 1% levels are indicated by *, ** and ***.

Despite the first-stage regression, the violation of exclusion restriction through omitted variables could still be a concern. For example, other climatic conditions may have a direct relationship with ocean productivity and conflict (Bazzi & Clemens, 2013; Sarsons, 2015). To address this concern, we estimated the correlation coefficient between conflict and ocean productivity with a subsample of observations that have low fisheries catches (i.e., the bottom 10 percentile). Theoretically, if the exclusion restriction is fulfilled, we should observe no correlation between conflict and ocean productivity in this subsample because ocean productivity only affects the conflict through fisheries. Consistent with this prediction, the correlation coefficient in the subsample of low catch areas is near zero (0.003) and statistically insignificant at any conventional significance level. In comparison, the correlation coefficient between conflict and ocean productivity with the full sample is 0.233 (see Table C1 in Appendix), which is statistically significant and larger in size. These results suggest that fisheries are the major channel through which ocean productivity affects conflict.

5. Results

5.1. Baseline results

Table 4 shows the OLS and 2SLS estimation results with and without province fixed effects. Industrial catch, non-industrial catch and their combined total respectively serve as the fisheries variable. Across all model specifications, there is consistent evidence of a statistically significant positive impact of fisheries on conflict within a range of 100 nmi. As expected (see Section 4), the magnitude of impact estimated by 2SLS is consistently higher than OLS estimates. The omission of province fixed effects also results in an underestimation of the impact, suggesting the presence of unobserved regional heterogeneity in conflict patterns. On that basis, we used the fixed effects 2SLS outcome to interpret the results.[13]

[13] As the dependent variable, $conflict_{c,p}$, represents a count of conflicts, we also estimated the baseline model using a Poisson IV with a control function estimator. This estimator addresses endogeneity issues present in standard Poisson regression. The control function approach is conducted in a single procedure, incorporating two stages of regression simultaneously, mitigating biases in the variance–covariance estimator from the second stage (Newey, 1984; Wooldridge, 2010). The results from this analysis are presented in Table E in the Appendix, suggesting that our baseline findings in Table 4 remain robust when employing a count data estimator.

Table 4
Effects of industrial and non-industrial fisheries on the number of conflicts and fatalities within 100 nautical miles.

	OLS			Pooled 2SLS			Fixed effects 2SLS			
Dependent variable	(1) Conflict	(2) Conflict	(3) Conflict	(4) Conflict	(5) Conflict	(6) Conflict	(7) Conflict	(8) Conflict	(9) Conflict	(10) Fatality
Industrial catch	1.962*** (0.384)			3.273*** (0.616)			7.945*** (2.991)			
Non-industrial catch		1.163*** (0.238)			1.777*** (0.340)			1.851*** (0.449)		
Total catch			0.800*** (0.158)			1.152*** (0.217)			1.501*** (0.377)	0.223** (0.100)
Observations	757	757	757	742	742	742	742	742	742	742
Province fixed effects	No	No	No	No	No	No	Yes	Yes	Yes	Yes
Instrumented	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Notes: The regressions are estimated by OLS and 2SLS. The dependent variable is reported in the column head. The catch variable is instrumented with the chlorophyll-based ocean productivity index (Table 3). The search radius is set at 100 nmi. The Conley-HAC standard errors (Conley & Molinari 2007) are reported in parentheses. Significance at 10%, 5% and 1% levels are indicated by *, **and ***.

The fixed effects 2SLS model indicates that an increase of one thousand tonnes in overall annual catch increases the number of conflicts within an area of 100 nmi around the cell by 1.501 cases. Comparing the impacts of industrial and non-industrial fishing, the number of conflicts associated with an increase in industrial catch is greater than for a non-industrial catch by roughly a factor of four (i.e., 7.945 cases for an additional thousand tonnes versus 1.851 cases for an additional thousand tonnes of non-industrial catch).[14] The analysis also confirms the positive impact of fisheries on both the number of conflicts and the number of fatalities; an additional thousand tonnes of annual catch increase the number of conflict-related deaths within 100 nmi of the cell by an average of 0.223.

5.2. Conflicts in alternative search radius

To assess the sensitivity of the fixed effects 2SLS results in Table 4 for a 100 nmi search radius, we ran regressions with search radiuses of 0, 50, 150 and 200 nmi. Estimated coefficients of the catch variable (β) with 95% confidence intervals (Fig. 3) show that the positive impact of fisheries on conflict remains the same regardless of the search radius value. For example, the estimated coefficient from the regression with a search radius of 0 nmi is positive and statistically significant, suggesting that an increase in fish catches in a cell leads to an increase in the number of conflicts within the same cell. The estimated coefficient and confidence interval generally increase with search radius, especially from 0 to 100 nmi. This increase in the estimated coefficient is expected because each cell is linked to a greater number of conflicts as the search radius increases. For example, for a search radius of 0 nmi, offshore cells are not linked to any conflict event, and the estimate considers only the relationship between conflicts and nearshore fishing.

These results indicate the presence of spatial spillovers resulting from the relationship between fisheries catch and conflicts. More specifically, as the search radius expands, the analysis incorporates surrounding geographical areas where fishing activities might potentially affect conflicts. The increase in the estimated coefficient, particularly from 0 to 100 nmi, implies that the impact of fisheries on conflicts is not merely restricted within the local area where fishing occurs but also extends to surrounding regions. However, when the search radius exceeds 100 nmi, the spillover effect of fisheries cannot be confirmed, as the estimated coefficient remains relatively constant at around 1.5 while the standard error (and hence the confidence interval) increases moderately.

5.3. Spatial correlation

A concern with the data is spatial correlation between cells that might be present because of the way in which the grid cell sample was constructed based on the search-by-radius approach. More specifically, the search-by-radius approach results in a situation where a conflict is linked to multiple fisheries observations. To ensure that our baseline results are not the artifact of spatial correlation,[15] we estimated the spatial autoregressive (SAR) 2SLS model (Drukker, Prucha, & Raciborski, 2013; Kelejian & Prucha, 2010), in which the structural equation in (2) is replaced by the following equation:

$$conflict_{c,p} = \beta catch_c + \gamma_p + \lambda W conflict_{c,p} + u_{c,p} \quad (3)$$

$$u_{c,p} = \rho W u_{c,p} + \varepsilon_{c,p} \quad (4)$$

where W is a 742×742 spectral-normalized spatial weight matrix based on the haversine distance for the longitude and latitude of sample cells.[16] The spatial autoregressive parameters λ and ρ measure the extent of spatial interactions in the dependent variable $conflict_{c,p}$ and error term $u_{c,p}$, respectively. The SAR-2SLS model shows that the positive impact of fisheries on conflict remains robust after accounting for spatial autocorrelation (Table 5). The magnitude of impact estimated by SAR-2SLS is smaller than the baseline estimates.

5.4. Asynchronicity

Another potential concern with the baseline estimate is the lack of time variation in the data due to the unavailability of conflict and fisheries database that can be used to construct a panel dataset (see Sections 3.1-3.2). Although the cross-sectional data used in the study allow us to estimate the contemporaneous relationship

[14] The exclusion restriction of the instrumental variable requires the condition Γ=0 to be satisfied in the equation $conflict_{c,p} = \beta catch_c + \Gamma OP_c + \gamma_p + \varepsilon_{c,p}$. To further assess the sensitivity of our results to this assumption, we applied a plausible exogeneity test (Conley et al., 2012) that allows Γ to take a non-zero value. The test reports a confidence interval of β while relaxing the exclusion restriction. The 95% confidence interval of β is estimated at [1.83, 19.75] for the industrial catch; [0.58, 3.50] for the non-industrial catch; and [0.48, 2.92] for the overall catch. These results suggest that our baseline results in Table 4 are robust to possible violation of the exclusion restriction assumption.

[15] It is important to note that despite using a search radius of 0 nmi, which links each conflict to a specific observation of fish catches, we still found a positive impact of fisheries on conflict (see Section 5.2).

[16] Each element in the spatial weight matrix W is expressed as $w_{i,j} = d_{i,j}^{-1}$, where $d_{i,j}$ is the haversine distance (in miles) from the centroid of cell i to the centroid of cell j. Each element of the spatial weight matrix was spectral normalized by dividing it by the moduli of the largest eigenvalues of the matrix W. The measured distance for the centroids of the two closest cells lie within approximately 68 miles of each other, and the two most distant cells are 3,783 miles apart.

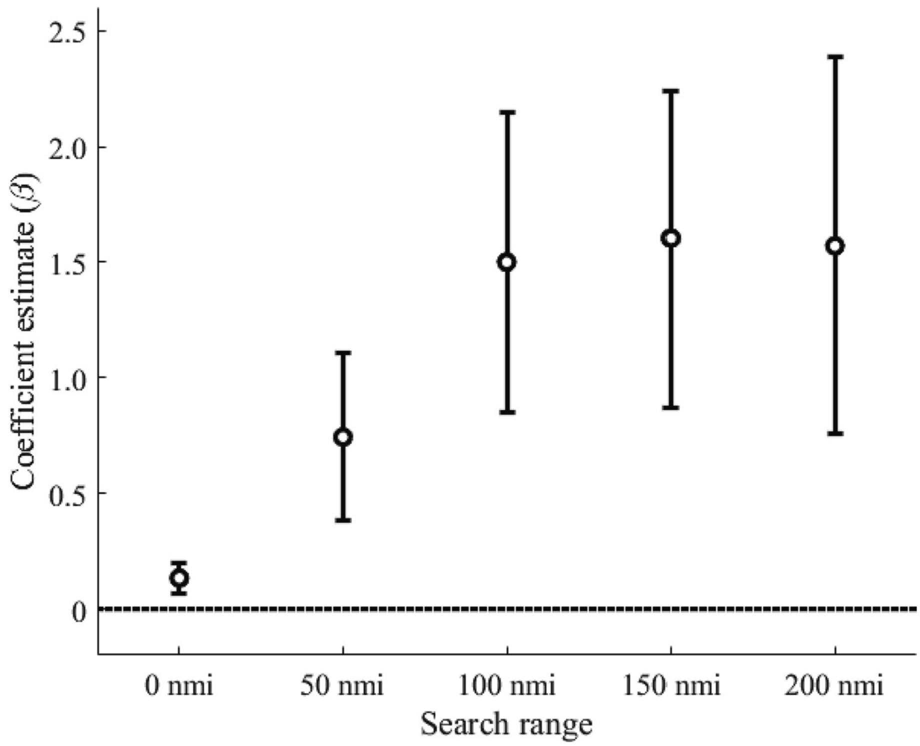

Fig. 3. Estimates of the coefficient β in equation (2) with 95% confidence intervals with different search radiuses. The regressions are estimated by 2SLS with province fixed effects where the dependent variable is the number of conflicts. The explanatory variable is the total catch in tonnes.

Table 5
Spatial autoregressive regressions.

Dependent variable	(1) Conflict	(2) Conflict	(3) Conflict	(4) Fatality
Industrial catch	1.365***			
	(0.382)			
Non-industrial catch		1.063***		
		(0.189)		
Total catch			0.728***	0.102***
			(0.134)	(0.022)
λ (spatial lag)	1.288***	1.264***	1.191***	2.429***
	(0.333)	(0.296)	(0.302)	(0.249)
ρ (spatial error)	1.900***	2.279***	2.120***	1.481***
	(0.205)	(0.325)	(0.279)	(0.078)
Observations	742	742	742	742
Province fixed effects	Yes	Yes	Yes	Yes
Instrumented	Yes	Yes	Yes	Yes

Notes: The regressions are estimated by spatial autoregressive 2SLS. The dependent variable is reported in the column head. The catch variable is instrumented with the chlorophyll-based ocean productivity index. The search radius is set at 100 nmi. The heteroskedasticity-robust standard errors are reported in parentheses. Significance at 10%, 5% and 1% levels are indicated by *, **and ***.

between conflict and fish catches in 2015, it cannot fully exclude the possibility that the estimated impact could be biased due to the asynchronous occurrence of conflict and fish catches within the year. We are particularly concerned with the possibility that conflict-prone regions experience large catches towards the end of the year, so that the impact of fisheries on conflict is overestimated. Although this is improbable in practice since conflicts can adversely influence fish catches (Pomeroy, Parks, Mrakovcich, & LaMonica, 2016), further analysis is warranted to ensure that our baseline results are not driven by the asynchronous occurrence of conflict and fish catches within the sample year.

To assess the sensitivity of the fixed effects 2SLS results in Table 4 to the possible issue in the cross-sectional analysis, we replaced the structural equation in (2) with the following equation:

$$conflict_{c,p} = \beta\overline{catch}_{c,2010-2014} + \gamma_p + \varepsilon_{c,p} \quad (5)$$

As in the original equation in (2), the dependent variable $conflict_{c,p}$ refers to the number of conflicts in cell c and province p in 2015, but the explanatory variable $\overline{catch}_{c,2010-2014}$ now denotes the mean quantity of fish caught annually in cell c during the period 2010 to 2014 (i.e., $\overline{catch}_{c,2010-2014} = 0.2 \times \sum_{t=2010}^{2014} catch_{c,t}$). In the first-stage regression, the instrumental variable OP_c was also replaced by the mean ocean productivity between 2010 and 2014. This means that the exogenous variation in oceanographic conditions in 2010–2014 was exploited to explain the conflict patterns in 2015. In this way, all fish catches occurred before any conflict events in 2015. Therefore, the parameter of interest β in (5) estimates a lagged effect of fisheries on conflict.

The results show that the positive impact of fisheries on conflict remains the same for all catch variables (Table 6). The magnitude of impact is also almost identical to the baseline results. For

Table 6
Lagged effects of fisheries on the number of conflicts.

Dependent variable	(1) $Conflict_{2015}$	(2) $Conflict_{2015}$	(3) $Conflict_{2015}$
Industrial $catch_{2010\text{-}2014}$	9.285** (4.109)		
Non-industrial $catch_{2010\text{-}2014}$		1.588*** (0.413)	
Total $catch_{2010\text{-}2014}$			1.356*** (0.367)
Observations	739	739	739
Province fixed effects	Yes	Yes	Yes
Instrumented	Yes	Yes	Yes

Notes: The regressions are estimated by 2SLS. The dependent variable is the number of conflicts in 2015. The explanatory variable is the mean quantity of fish caught in the period 2010 to 2014. The catch variable is instrumented with the mean chlorophyll-based ocean productivity index from 2010 to 2014. The search radius is set at 100 nmi. The Conley-HAC standard errors (Conley & Molinari 2007) are reported in parentheses. Significance at 10%, 5% and 1% levels are indicated by *, **and ***.

Table 7
Lagged effects of fisheries on the number of conflicts within the year.

Dependent variable	(1) $Conflict_{m7\text{-}m12}$	(2) $Conflict_{m7\text{-}m12}$	(3) $Conflict_{m7\text{-}m12}$
Industrial catch	4.836** (2.382)		
Non-industrial catch		0.809*** (0.210)	
Total catch			0.693*** (0.189)
Observations	742	742	742
Province fixed effects	Yes	Yes	Yes
Instrumented	Yes	Yes	Yes

Notes: The regressions are estimated by 2SLS. The dependent variable is the number of conflicts during July to December in 2015. The catch variable is instrumented with the chlorophyll-based ocean productivity index during January to June in 2015. The search radius is set at 100 nmi. The Conley-HAC standard errors (Conley & Molinari 2007) are reported in parentheses. Significance at 10%, 5% and 1% levels are indicated by *, **and ***.

example, a unit increase in mean annual catch in a cell between 2010 and 2014 increased the number of conflicts in 2015 within 100 nmi of the cell by 1.4 cases. These results suggest that an increase in fish catches in recent years leads to an increased number of conflicts in adjacent areas as much as higher catches in the same year do.

To further address the potential issue with the asynchronous occurrence of conflict and fish catches within the sample year, we re-estimated equation (2) using higher frequency data for ocean productivity and conflicts.[17] More particularly, we replaced ocean productivity (OP_c) and the conflict variable ($conflict_{c,p}$) with ocean productivity from January to June in 2015 ($OP_{c,p,m1\text{-}m6}$) and the number of conflicts from July to December in the year ($conflict_{c,p,m7\text{-}m12}$), respectively. This means that in the first-stage regression, we effectively predicted the catch variation that is attributed to ocean productivity during the first half of the year. The predicted catch variable was then used to explain the conflict patterns in the second half of the year. In this way, we limited the possibility that the baseline results are driven by the asynchronous occurrence of conflict and fish catches.

The positive impact of fisheries on conflict is confirmed for all catch variables in this analysis (Table 7). For example, a unit increase in total catch due to the ocean productivity shock during the beginning of the year increased the number of conflicts by 0.69 cases in the second half of the year. The magnitude of the estimated impact here is approximately half of the baseline results, while this is expected because the analysis accounts for only half of the conflicts in the sample; that is, the mean number of conflicts within 100 nmi of each cell from July to December (5.45 cases) is about half of the mean number of conflicts throughout the year (11.34 cases).

5.5. Conflict persistence

An additional concern in literature is the persistence in conflict, suggesting that present conflicts may be influenced or driven by the legacy of preceding conflicts, which may result in bias in estimates of the relationship between fisheries and conflict (Bazzi & Blattman, 2014; Beck & Katz, 2011). To address this concern, we collected conflict data for 2016, and replaced the structural equation in (2) with the following equation:

$$conflict_{c,p,2016} = \rho conflict_{c,p,2015} + \beta catch_{c,2015} + \gamma_p + \varepsilon_{c,p} \qquad (6)$$

The dependent variable, $conflict_{c,p,2016}$, denotes to the number of conflicts in cell c and province p in 2016. The explanatory variable, $catch_{c,2015}$, refers to fish catches that occurred in 2015. We also included $conflict_{c,\ p,2015}$, which represents the lag of $conflict_{c,p,2016}$, to control for the potential persistence of conflict. In this way, we limit the possibility that the baseline results are driven by the persistent effect of conflicts that occurred in previous year.

The positive impact of fisheries on conflict is confirmed for all catch variables in this analysis (Table 8). For example, a one-unit increase in total catch during 2015 increased the number of conflicts by 0.25 cases in 2016. However, the estimated impact is only one-fifth of the baseline. One possible explanation for the lower magnitude of the estimated impact is the presence of an intertemporal correlation between the conflict variables, with the estimated persistence parameter (ρ) being around 0.6.

5.6. Catch anticipation and anomalies

Another concern regarding the use of cross-sectional data is that our baseline estimate may be influenced by catch levels that were anticipated before the 2015 study period. For example, areas with historically high catch levels may be common knowledge across regions. This anticipation can lead to an overestimation of the impact of fish catches on conflict in 2015 as such a relationship may be driven by changes that took place before 2015 (e.g., population growth through migration). To address this concern, we

Table 8
Persistence in conflict.

Dependent variable	(1) $Conflict_{2016}$	(2) $Conflict_{2016}$	(3) $Conflict_{2016}$
$Conflict_{2015}$	0.588*** (0.031)	0.607*** (0.016)	0.604*** (0.018)
Industrial $catch_{2015}$	1.467* (0.826)		
Non-industrial $catch_{2015}$		0.307** (0.131)	
Total $catch_{2015}$			0.254** (0.110)
Observations	742	742	742
Province fixed effects	Yes	Yes	Yes
Instrumented	Yes	Yes	Yes

Notes: The regressions are estimated by 2SLS. The dependent variable is the number of conflicts in 2016. The explanatory variable is the quantity of fish caught in 2015. The catch variable is instrumented with the chlorophyll-based ocean productivity index. The search radius is set at 100 nmi. The Conley-HAC standard errors (Conley & Molinari 2007) are reported in parentheses. Significance at 10%, 5% and 1% levels are indicated by *, **and ***.

[17] Ocean productivity index is available at the monthly frequency, and conflict data are recorded with event dates. On the contrary, annual catch is the highest frequency available for fisheries data (see Sections 3.1-3.3).

re-estimated equation (2) using the catch anomaly, which is defined as the deviation of catch from long-term mean of a given cell c, divided by its long-run standard deviation, where the long-run period is considered from 1950 to 2015.[18] The catch anomaly in cell c for 2015 is calculated using the following equation:

$$anomalies_c = \frac{catch^*_{c,2015} - \overline{catch}^*_{c,1950-2015}}{STD\left(catch^*_{c,1950-2015}\right)} \quad (7)$$

where $catch^*_{c,2015}$ is the detrended catch in cell c in 2015, $\overline{catch}^*_{c,1950-2015}$ is the long-term mean of the detrended catch for 1950 to 2015, and $STD\left(catch^*_{c,1950-2015}\right)$ is the standard deviation of the detrended catch for the same period.[19]The catch anomaly allows us to eliminate the potential anticipatory effect because it uses variation in catches relative to the long-term average, which is less likely to be anticipated (Barrios, Bertinelli, & Strobl, 2010; Muñoz-Díaz & Rodrigo, 2004).

The results show that the positive impact of fish catches on the number of conflicts remains the same for all catch variables (Table 9). More specifically, a one-unit increase in total catch anomaly in 2015 increased the number of conflicts by 23.6 cases for the year. The positive impact of catch anomaly on conflict remained consistent for all catch variables. These results suggest that a region where fisheries catch deviated positively from the long-term average was more inclined to experience conflict than other regions.

5.7. Level of violence

The analysis also examined whether fisheries have a consistent positive effect on conflicts involving different levels of violence. To that end, we first categorized each conflict event as one of three types according to the level of violence as defined by ACLED. We then re-estimated equation (2) for fixed effects 2SLS, replacing the dependent variable with each conflict type in turn (Table 10). Using different levels of violence in conflicts, we intend to disentangle the mechanisms through which increased fish catches affect conflict. In theory, fish catches may be associated with conflict in all levels of violence; however, the magnitude of such a conflict-fisheries relationship would be sensitive to the level of violence involved in the conflict. The results indicate that the total catch coefficient is positive and statistically significant for all types of conflict, but the magnitude of this effect varies for the different types. Type I (protests, riots and strategic development) is the least violent and has the largest estimated coefficient; specifically, there were 1.2 additional cases of Type I conflict for each additional thousand tonnes of catch. In contrast, the most violent conflicts (Type III) returned the lowest magnitude (0.079).

5.8. Regional differences

To investigate whether the impact of fisheries on conflict differed by region, we re-estimated the model with a subsample of four development regions as classified by the National Development Planning Agency of Indonesia. These regions are different in terms of the exploitation status of important commercial stocks and the way coastal resources are managed (Halim et al., 2019; MMAF, 2017; Muawanah et al., 2018). For example, fishing intensity is generally higher in western regions where fisheries are more industrialised than eastern regions where small-scale fisheries account for a significant share of total production (Figure 2). The subsample analysis thus allows us to assess how these regional differences in resource status and management systems are associated with the way in which fisheries influence conflict patterns. The results confirm the positive impact of fisheries on the number of conflicts for all regions (Table 11). However, the magnitude of that impact was about 20% higher in western regions than in the east; the greatest impact was in Region B, where the national capital region returned the highest concentration of conflicts.

Table 9
Effects of catch anomalies on conflict.

	(1)	(2)	(3)
Industrial catch anomalies	32.658* (19.400)		
Non-industrial catch anomalies		18.414*** (5.820)	
Total catch anomalies			23.568** (9.351)
Observations	742	742	742
Province fixed effects	Yes	Yes	Yes
Instrumented	Yes	Yes	Yes

Notes: The regressions are estimated by 2SLS. The dependent variable is the number of conflicts. Catch anomalies are calculated based on Equation (7). The catch anomaly variable is instrumented with the chlorophyll-based ocean productivity index. The search radius is set at 100 nmi. The Conley-HAC standard errors (Conley & Molinari 2007) are reported in parentheses. Significance at 10%, 5% and 1% levels are indicated by *, **and ***.

5.9. Illegal, unreported and unregulated (IUU) fishing

We also assessed the impact of IUU fishing by replacing catch variables with IUU catch variables. IUU fishing is a major contributor to overfishing in Indonesian waters, posing a serious threat to the sustainable use of fisheries resources (Resosudarmo & Kosadi, 2019). This means that if overfishing and increased competition over declining resources were an important driver of the fisheries-conflict relationship, we would expect to see a greater impact of IUU fishing on conflict than non-IUU fishing. The regressions with IUU catch variables show that all types of IUU fishing have a positive impact on the number of conflicts at the 1% significance level (Table 12). As shown in the baseline estimation of non-IUU fishing, a unit increase in industrial IUU fishing in a given cell also had a greater impact than non-industrial IUU fishing on the number of conflicts in adjacent areas. However, the relative impact of industrial and non-industrial IUU fishing differed from the baseline estimation; that is, the impact of industrial IUU fishing increased moderately when compared to the baseline estimate while the impact of non-industrial fishing was almost four times greater than that of its non-IUU counterpart.

6. Discussion

These results show that oceanographic conditions directly affect fisheries production in Indonesia and that the resulting higher fish catches fuel violent conflict in coastal areas. According to our estimates, the number of conflict events in Indonesia increases by 15% with every 10% increase in total catch. This positive relationship between conflict occurrence and fish catch is apparent both in nearshore and offshore fisheries as far as 100

[18] For this analysis, we collected annual catch data from 1950 to 2015 from Global Fisheries Landings v4.0.

[19] Instead of using catch in levels, we calculated anomalies based on detrended catches. This is because fisheries catches in both the industrial and non-industrial sectors in Indonesia have consistently increased since 1950 (see Appendix, Figure D1). This means that calculating the catch anomaly based on the mean catch in levels is misleading since the anomaly almost always increases over time. To overcome this, we first detrended the series by regressing catch on year dummies (i.e., $catch_{c,t} = \sum \beta^t year_t + \varepsilon_{c,t}$) and then used the residuals as the detrended catch variable (i.e., $catch^*_{c,t} = \hat{\varepsilon}_{c,t}$). The detrended catch is presented in Appendix Figure D2.

Table 10
Catch landings and conflict by conflict types.

	Type I: Protests, riots and strategic development	Type II: Violence against citizens	Type III: Battles, explosions and remote violence
Total catch	1.203***	0.219***	0.079**
	(0.322)	(0.083)	(0.033)
Observations	742	742	742
Province fixed effects	Yes	Yes	Yes
Instrumented	Yes	Yes	Yes

Notes: The regressions are estimated by 2SLS with the province fixed effects. The catch variable is instrumented with the chlorophyll-based ocean productivity index. The dependent variable is reported in the column head. The search radius is set at 100 nmi. The Conley-HAC standard errors (Conley & Molinari 2007) are reported in parentheses. Significance at 10%, 5% and 1% levels are indicated by *, **and ***.

Table 11
Regional differences in the impact of fisheries on the number of conflicts.

		Western Indonesia		Eastern Indonesia	
		Region A	Region B	Region C	Region D
		(1)	(2)	(3)	(4)
Panel A: Regression results					
Total catch		2.037***	2.148***	1.782***	1.672***
		(0.503)	(0.535)	(0.513)	(0.452)
Observations		273	474	500	526
Province fixed effects		Yes	Yes	Yes	Yes
Instrumented		Yes	Yes	Yes	Yes
Panel B: Development region					
Region	Central city	Province			
Development Region A	Medan	Aceh, North Sumatra, West Sumatra, Riau, Riau Islands			
Development Region B	Jakarta	Jambi, South Sumatra, Bengkulu, Bangka Belitung Islands, Lampung, Banten, Special Capital Region of Jakarta, West Java, Central Java, Special Region of Yogyakarta, West Kalimantan			
Development Region C	Surabaya	East Java, Bali, Central Kalimantan, North Kalimantan, East Kalimantan, South Kalimantan			
Development Region D	Makassar	West Nusa Tenggara, East Nusa Tenggara, West Sulawesi, South Sulawesi, Southeast Sulawesi, Central Sulawesi, Gorontalo, North Sulawesi, Maluku, North Maluku, Papua, West Papua			

Notes: The regressions are estimated by 2SLS with the province fixed effects for the sub-sample of each development region. The four development regions are categorised based on the National Development Planning Agency of Indonesia. The catch variable is instrumented with the chlorophyll-based ocean productivity index. The dependent variable is the number of conflicts. The search radius is set at 100 nmi. The Conley-HAC standard errors (Conley & Molinari 2007) are reported in parentheses. Significance at 10%, 5% and 1% levels are indicated by *, **and ***.

Table 12
Impact of IUU fishing.

	(1)	(2)	(3)
Industrial IUU catch	8.336***		
	(2.954)		
Non-industrial IUU catch		6.397***	
		(1.536)	
Total IUU catch			3.620***
			(0.936)
Observations	742	742	742
Province fixed effects	Yes	Yes	Yes
Instrumented	Yes	Yes	Yes

Notes: The regressions are estimated by 2SLS with the province fixed effects. The catch variable is instrumented with the chlorophyll-based ocean productivity index. The Conley-HAC standard errors (Conley & Molinari 2007) are reported in parentheses. The dependent variable is the number of conflicts. Significance at 10%, 5% and 1% levels are indicated by *, **and ***.

nmi from the coast. Our results indicate that the influence of increased fish catches on conflict is not confined to coastal areas but can spill over into neighbouring regions, extending its impact to adjacent territories. Our results also show that, although Indonesian fisheries are dominated by non-industrial small-scale fishing boats (FAO, 2021), industrial fisheries are associated with four times more conflict events than non-industrial fisheries, possibly because industrial fishing boats are larger and are equipped with more modern gear (e.g., trawl, purse-seine). While these technological advances have increased the productive capacity of fishing industries, they have also raised concerns about detrimental impacts on marine ecosystems (Pauly, Froese, & Palomares, 2000; Pichegru et al., 2012; Thurstan, Brockington, & Roberts, 2010).

The same pattern is evident in regional differences in the fishery-conflict relationship; an increase in fish catches in western regions affects the conflict occurrence 20% more than that in eastern regions. Fisheries in Indonesia's western regions are more industrialized and more intensively exploited, with less scope for further development (FAO, 2021). Additionally, fisheries management in Indonesia focuses mainly on industrial fisheries, but individual catches are not restricted by total allowable catches or quota systems. Similarly, small-scale fisheries are only weakly regulated (Halim et al., 2019). However, the impact of non-industrial fisheries and those in eastern regions is generally weaker, possibly because they provide food and livelihood security directly to the country's vast coastal communities.

Our findings indicate a strong association between fisheries and conflicts in development region B, which may be directly related to the presence of Jakarta within this region. In 2015, a significant proportion (22%) of conflict events, particularly protests, occurred in Jakarta. As the capital of Indonesia, Jakarta is the centre for creating and implementing fisheries policies and regulations (Dudayev, Hakim, & Rufiati, 2023; Sunoko & Huang, 2014). Fishers and coastal communities may hold protests in Jakarta to influence these policies and demand better support for the fishing industry. High population density is another possible factor contributing to the pronounced relationship between fisheries and conflicts around Jakarta. As people migrate to the city seeking improved economic opportunities, resource competition escalates, leading to unfavourable fishing conditions in nearby coastal areas (Batubara, Kooy, & Zwarteveen, 2018). These conditions result in increased conflicts among resource users.

Our results also show an association between favourable oceanographic conditions and increased IUU fishing, which results in a greater number of conflict events in surrounding areas. Importantly, IUU fishing has a greater impact on conflict occurrence (by a factor of about 2.4) than non-IUU fishing, further reinforcing the link between fisheries conditions and conflict, as IUU fishing is considered a major threat to resource sustainability and maritime security in Indonesian waters (Resosudarmo & Kosadi, 2019). Recent studies (Axbard, 2016; Flückiger & Ludwig, 2015) have shown that incidence of sea piracy increases with decreased fishing returns, and our results also align with existing observations that conflict patterns in coastal areas reflect increases in environmental degradation and resource competition (Muawanah et al., 2012).

Civil conflicts in Indonesia involve different levels of violence, ranging from relatively peaceful public protests to armed battles (Raleigh et al., 2010). Our results show the causal impact of fishing on all types of conflict, which suggests that no single factor predominantly explains the underlying mechanisms. Previous theoretical and empirical studies have identified multiple ways in which natural resources affect conflict. However, contrary to some earlier studies (Maystadt & Ecker, 2014; McGuirk & Burke, 2020; Miguel et al., 2004) we found no evidence that Indonesian fisheries prevent conflict by providing sufficient rewards to increase the opportunity cost of fighting; instead, our results suggest that increasing fish catches fuel conflict in surrounding areas. This may reflect the current overexploitation of important species in Indonesian waters (MMAF, 2017) and the fact that the non-exclusivity of fisheries resources serves to diminish their long-term benefits.

In the present context, there are at least three other channels that may be at play in the relationship between fisheries and conflict in Indonesia. First, increased fish catches in a given location may be associated with increased inequality of access to the benefits of natural resources. In light of the state's weak fisheries management capacity, frustrations around inequitable access to resource rents may fuel violence in local communities. Grievances of this kind have triggered civil conflicts in Indonesia, exacerbated by inequalities related to income, employment and political opportunity (Barron et al., 2009). Previous studies have also reported cases of local disputes around territorial claims and resource allocation that eventually escalated into violent communal conflict (Aragon, 2001). Second, an increase in fish catches supported by favourable oceanographic conditions may enhance the financial feasibility of insurgency in the short term; in a related context in Africa, lucrative rents from a mining site improved the financial capacity of fighting groups to fuel violent conflict (Berman et al., 2017). Third, the relationship between fisheries and conflict may be driven through changes in fish prices. For example, higher ocean productivity and resulting greater fish landings can lead to a decrease in fish prices. While this may benefit consumers, the decline in prices could negatively impact the income of fishing operators, despite a higher catch volume. This resource-driven economic disparity has the potential to intensify socio-economic tensions and contribute to conflict within communities (Lessmann & Steinkraus, 2019).

It is important to note that Indonesia's unique geography, as an archipelago with an extensive coastline and a significant coastal population, can play a crucial role in the relationship between fisheries and conflicts through a wide range of channels, including socio-economic, environmental, and political factors (Andrews et al., 2021; Hendrix & Glaser, 2011; Pomeroy et al., 2016). In addition to this, there are other potential reasons that our study found a robust fisheries-conflict linkage in Indonesia, including the scale of fisheries production (the world's 2nd largest producer), high reliance on fish as a source of animal protein intake (>50%), and the co-existence of both industrial and non-industrial fishing vessels (FAO, 2018; Muawanah et al., 2018).

This means that our findings are particularly pertinent to countries and regions where fisheries play a critical role in providing food and income. This is not a situation exclusive to Indonesia or limited to developing countries, as evident from the consistent increase in the global population relying on fish as the most accessible source of animal protein, as well as per capita fish consumption over the past decades (FAO, 2020). Moreover, the co-existence of industrial and subsistence-oriented fishing entities is prevalent in both developed and developing countries (Watson, 2017). Considering these anecdotes, we envisage that our study provides valuable insights into the fisheries-conflict relationship for other countries and regions. However, it is important to note that the mechanisms through which fisheries affect terrestrial conflict may differ across countries and regions, depending on their geographical and other features. Therefore, a useful avenue for future research is to explore these variations.

7. Conclusions

Inappropriate resource management potentially poses a major threat to the social and political stability of resource-dependent states and regions. Previous studies have uncovered a causal relationship between violent conflict and non-renewable resources such as oil and diamonds, but little is known about this issue in marine contexts. To bridge this gap, the present study provided a geographically disaggregated analysis to assess the impact of fisheries exploitation on the onset of violent conflict in Indonesia. To that end, we constructed a unique sample of grid cell data at 1×1 degree resolution. Exploiting the exogenous variation in oceanographic conditions, our results confirmed a quantitatively relevant positive relationship between fish catches and conflict. According to our analysis, offshore fishing up to 100 nautical miles from the coast effectively explains conflict patterns in Indonesia's coastal areas. Our results further show that the fisheries-conflict relationship is especially strong in the case of industrial and illegal fishing, which is a significant source of socio-ecological concern in Indonesia. Possible channels through which increased fish catches may fuel conflict include mounting competition for declining fish stocks, conflicting claims regarding territorial user rights, socioeconomic inequality and empowerment of armed insurgents.

We draw three possible policy implications based on our empirical analysis. First, we show that changes in fisheries conditions impact the wider community beyond those directly involved in fishing. It has long been accepted that economic performance in the fishing sector is affected by inherent variations in the marine environment (Hjort, 1914) and by incentives for overfishing (Warming, 1911). By implication, improved fisheries management that curb overfishing and prevents stock depletion offers benefits that extend beyond resource user groups to society as a whole. Second, our analysis suggests that the Indonesian government's current regulatory focus on large fishing vessels above 30 GT is sensible in terms of conflict mitigation, as adequate management of these vessels is imperative to break the link between fisheries and conflict. Finally, this study bolsters the case for monitoring and reducing illegal fishing in Indonesian waters, whether by industrial or small-scale operators. This aligns with recent evidence of a link between illegal fishing and maritime crimes that lead to social unrest, including piracy, trafficking and smuggling (Mackay et al., 2020; Vince, Hardesty, & Wilcox, 2021).

Our study is not without limitations, and some caveats need to be considered. First, we used cross-sectional data for 2015 due to the availability of conflict, catch, and ocean productivity data for the same year. Although we carried out additional analyses to show that our results are not sensitive to the asynchronous occurrence of conflict and fish catches, one avenue for further research is to address the current research questions using panel data when such data become available. We found that the estimated effect of fisheries is consistently higher in regressions with province fixed effects than without them, suggesting that the omission of unobserved regional differences was controlled in the model. We additionally provided a plausible exogeneity test (Conley, Hansen, & Rossi, 2012) to show that our results are robust to potential violation of the exclusion restriction assumption. However, panel data allow researchers to exploit cross-sectional and time series variations in conflict and fisheries catches, and this may enable a stronger identification of the causal link between fisheries and conflict.

Second, there are potential measurement errors in catch data that were constructed based on multiple sources, including information provided by governments, international organisations, and AIS. The use of alternative fisheries data may be a possible way to reduce the problem of potential measurement errors. For example, Indonesia's Vessel Monitoring System (VMS) tracks vessel locations. Although VMS data do not contain catch information or are publicly available (Watch, 2017), they would provide accurate locations of fishing activities. Moreover, vessel movement information based on AIS and VMS data can be used to identify the presence of fishing activities and determine the type of fishing being conducted (Merten, Reyer, Savitz, Amos, Woods, & Sullivan, 2016).

Third, our data exhibits a relatively low representation of fisher groups directly involved in conflict events in Indonesia during 2015. This could be due to various reasons, including the inclination of small-scale fishers to engage in diverse livelihood activities and their exclusion from official fisher group registries. Consequently, identifying the connections between fish catches and fisheries-related conflicts comprehensively, while distinguishing them from other types of conflict, becomes challenging when relying solely on ACLED data. Exploring alternative data sources and approaches, such as conducting text analysis of news articles and social media data (Maerz & Puschmann, 2020), could provide an alternative avenue to enhance our understanding of the potential links between fish catch and conflicts.

CRediT authorship contribution statement

Yifan Lu: Conceptualization, Methodology, Data curation, Formal analysis, Visualization, Writing – original draft, Writing – review & editing. **Satoshi Yamazaki:** Conceptualization, Methodology, Writing – original draft, Writing – review & editing.

Data availability

Data and code are available at https://github.com/ylu27/FishtoFight.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A

Fig. A1.

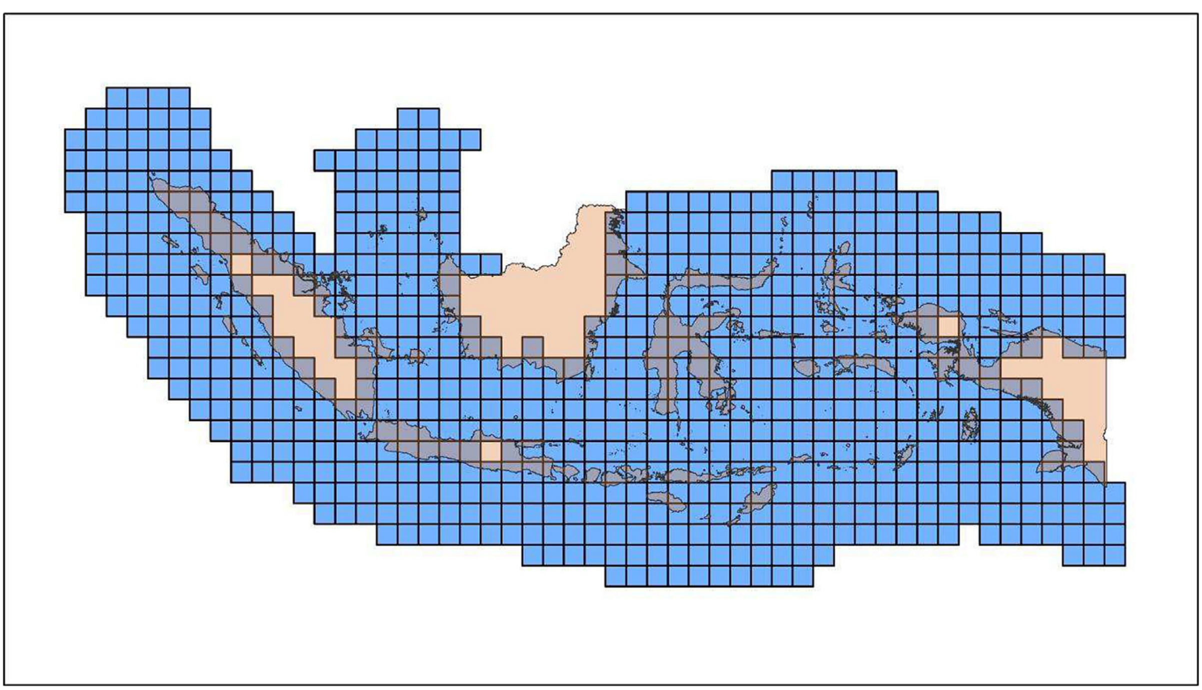

Fig. A1. Cell sample.

Appendix B

Figs. B1 and B2.

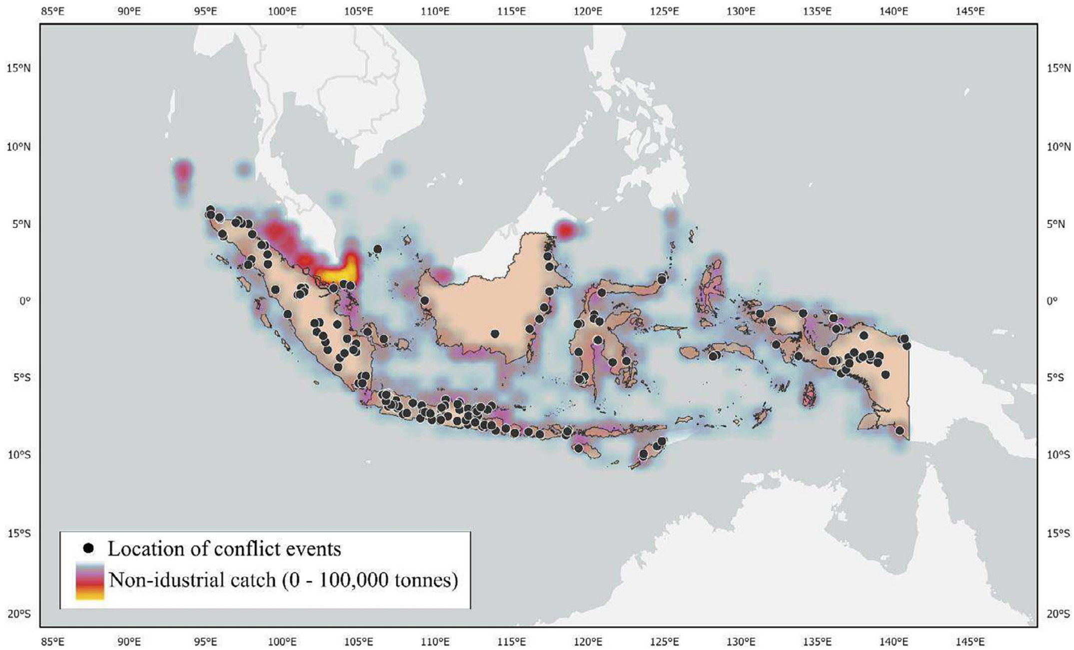

Fig. B1. Geographical distribution of non-industrial catch and conflict events at a 1 × 1 degree cell in Indonesia for 2015.

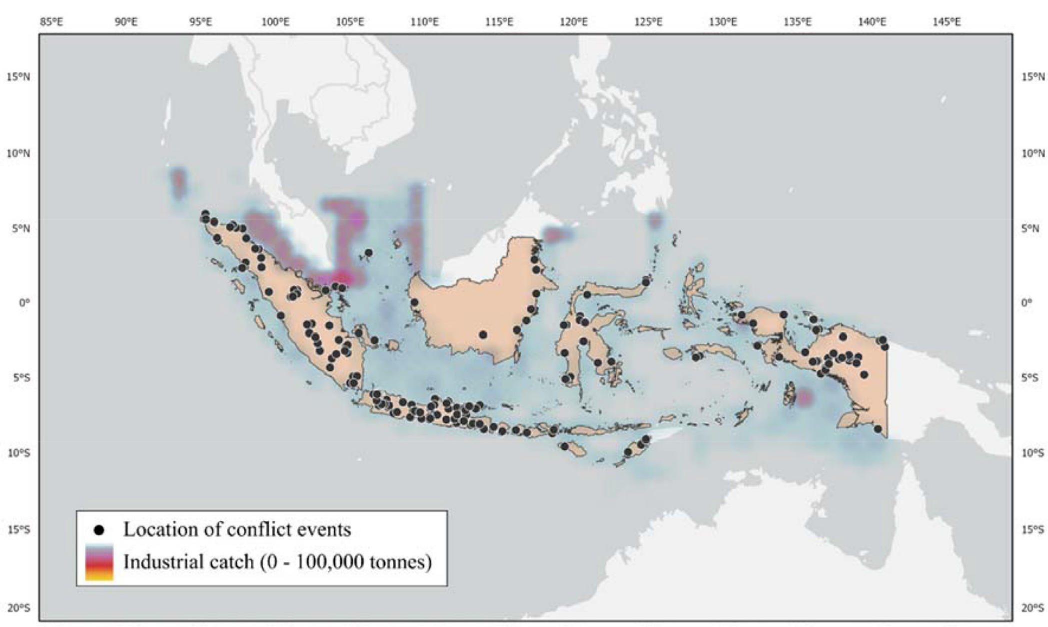

Fig. B2. Geographical distribution of industrial catch and conflict events at a 1 × 1 degree cell in Indonesia for 2015.

Appendix C

Table C1.

Table C1
Correlation of variables.

	Conflict	Conflict (50nmi)	Conflict (100nmi)	Conflict (150nmi)	Conflict (200nmi)	Fatalities (100nmi)	Catch	IND-catch	NID-catch	IUU	IND-IUU	NID-IUU	OP
Conflict	1.0000												
Conflict (50nmi)	0.4054	1.0000											
Conflict (100nmi)	0.2995	0.7503	1.0000										
Conflict (150nmi)	0.2488	0.5620	0.8241	1.0000									
Conflict (200nmi)	0.2372	0.4484	0.6553	0.8671	1.0000								
Fatalities (100nmi)	0.2189	0.2698	0.3735	0.3300	0.2738	1.0000							
Catch (‘000)	0.1845	0.1943	0.2329	0.2010	0.1779	0.1840	1.0000						
IND-catch	0.0957	0.1183	0.1587	0.1471	0.1303	0.0958	0.8590	1.0000					
NID-catch	0.2094	0.2119	0.2457	0.2072	0.1833	0.2086	0.9680	0.7030	1.0000				
IUU	0.1857	0.1812	0.2233	0.1952	0.2013	0.1504	0.8216	0.7090	0.7937	1.0000			
IND-IUU	0.1358	0.1259	0.1676	0.1520	0.1767	0.0790	0.5966	0.6011	0.5340	0.9206	1.0000		
NID-IUU	0.2026	0.2077	0.2370	0.1988	0.1742	0.2117	0.9026	0.6461	0.9371	0.7991	0.5009	1.0000	
OP	0.1543	0.1595	0.2163	0.1993	0.1917	0.1405	0.3999	0.3170	0.4001	0.3582	0.2765	0.3683	1.0000

Appendix D

Fig. D1.

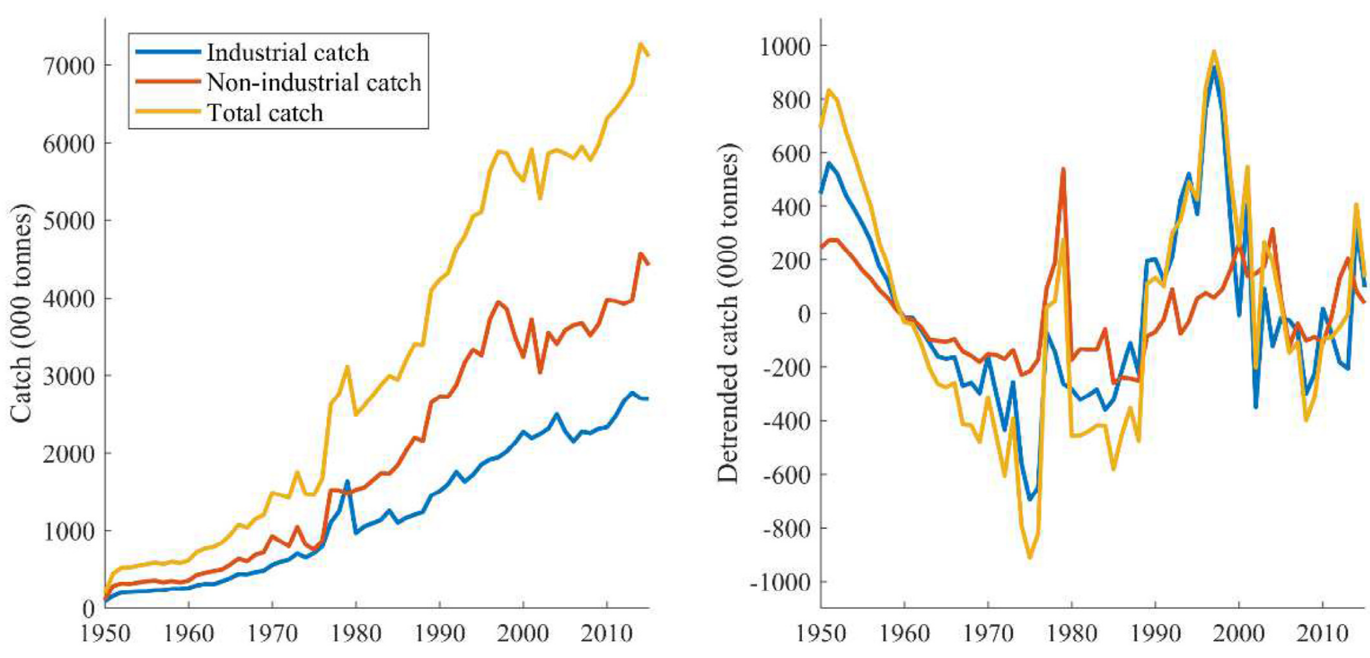

Fig. D1. Fisheries catch and detrended catch in Indonesia from 1950 to 2015.

Appendix E

Table E1.

Table E1
Poisson IV with a control function estimator.

	(1)	(2)	(3)
Industrial catch	0.652***		
	(0.219)		
Non-industrial catch		0.143***	
		(0.029)	
Total catch			0.118***
			(0.025)
Observations	742	742	742
Province fixed effects	Yes	Yes	Yes
Instrumented	Yes	Yes	Yes

Notes: The regressions are estimated by Poisson IV with control function estimator. The catch variable is instrumented with the chlorophyll-based ocean productivity index. The dependent variable is the number of conflicts. The search radius is set at 100 nmi. The heteroskedasticity-robust standard errors are reported in parentheses. Significance at 10%, 5% and 1% levels are indicated by *, **and ***.

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