When Fish Attract Pirates: Why High-Intensity Piracy Concentrates in High-Volume Fisheries Contexts

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ABSTRACT

The relationship between fisheries conditions and maritime piracy is often framed through scarcity: lower fisheries production is expected to coincide with higher piracy intensity, while stronger fisheries outcomes should reduce piracy risk. This study reassesses that assumption by examining whether fisheries-related conditions are associated with piracy exposure after accounting for socioeconomic, political, deterrence, and opportunity covariates. Using Mahalanobis distance matching, the analysis compares low-piracy observations with observations of median exposure and high exposure to piracy (the top quartile). The results provide limited support for a general scarcity interpretation. Statistically robust differences appear primarily under high piracy exposure, while the median-exposure observations do not differ consistently from the low-exposure controls. More importantly, the clearest differences are concentrated in artisanal fisheries rather than across fisheries outcomes broadly. This suggests that fisheries matter less as indicators of deprivation than as sources of mobilisation capacity, as they provide maritime skills, small-vessel experience, coastal knowledge, and labour pools that facilitate piracy.

KEYWORDS: maritime piracy; fisheries; artisanal fisheries; Mahalanobis distance matching; piracy intensity; mobilisation capacity; quasi-experimental design; piracy risk

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INTRODUCTION

Maritime piracy is frequently linked to coastal livelihoods and the fishing economy, yet the empirical evidence for this link remains mixed, and the underlying mechanisms remain contested. Some studies argue that declining fisheries production heightens piracy risk by eroding legal income opportunities, whereas others find weak or inconsistent relationships once broader political and economic conditions are considered (DAXECKER & PRINS 2013; JIANG & LAFREE 2023). A further complication is measurement. Fisheries-piracy studies often rely on aggregated and unevenly reported fisheries indicators, thus obscuring differences between industrial, artisanal, subsistence, and recreational sectors. Yet piracy recruitment is frequently linked to fishing communities, maritime skills, small-vessel experience, and local sea knowledge (FRÉCON 2005, 2006; DAXECKER & PRINS 2013; DENTON & HARRIS 2021; PHAYAL ET AL. 2026). Without subsector-level measures, it remains unclear whether piracy is associated with fisheries scarcity, the overall fisheries scale, or the specific sectoral structures that provide maritime labour and operational capability.

This study reassesses the fisheries-piracy relationship with two aims. First, it evaluates whether fisheries indicators (spanning conventional FAO totals, per-capita measures, and Sea Around Us reconstructed series) differ across piracy-exposure statuses after accounting for the major confounders identified in the piracy literature. Second, it tests whether any association is concentrated in particular fishing-sector segments (e.g. the industrial, artisanal, subsistence, and recreational segments) rather than appearing uniformly across aggregate measures. This sectoral focus is central to understanding the competing explanations in the literature. If piracy is driven primarily by scarcity and livelihood erosion, there should be evident differences in terms of lower fisheries outcomes among piracy-exposed observations even after balancing structural correlates. If piracy is driven by industrial encroachment and displacement, as suggested by work emphasising industrialisation and conflict in fisheries systems, then this should plausibly be reflected in industrial fishing measures (levels or shares) or in patterns consistent with industrial dominance relative to small-scale sectors (TEH & PAULY 2018; DESAI & SHAMBAUGH 2021). By contrast, if piracy in high-risk areas depends more on mobilisation capacity and the availability of maritime skills, then the clearest differences should be in the artisanal segment, which most directly corresponds to small-vessel operations and fishing-community labour pools, as discussed in qualitative accounts (FRÉCON 2005; DAXECKER & PRINS 2013; PHAYAL ET AL. 2026).

Empirically, the study reaches two key findings. After the balancing of the observations on lagged governance capacity, macroeconomic pressures, deterrence proxies, and maritime trade exposure using a Mahalanobis-distance full matching within one year, most of the fisheries indicators do not robustly differentiate piracy-exposed observations from comparable controls when the above median piracy level is used as the treatment group. However, when the level of piracy is defined as high-intensity exposure (the top quartile of annual incidents), a greater total artisanal fisheries volume emerges as a consistent correlate, surviving a conservative multiple-testing correction across the full set of fisheries measures. The remainder of the paper presents the rationale for these conclusions: it reviews the literature on piracy, describes the data sources and the matching-based design used to construct the comparable piracy and non-piracy observations, and presents the balance diagnostics and design-based comparisons that underpin the inference. Finally, it discusses the findings and situates them in the current literature.

LITERATURE REVIEW

The research on fisheries production and piracy largely indicates that scarcity in the fisheries sector is associated with higher levels of piracy. Jiang & LaFree (2023) suggest that in the South China Sea, increased fisheries production is associated with fewer attacks, whereas in East Africa, low fish production is associated with more piracy incidents. At the same time, Daxecker & Prins (2013) suggest that low fisheries production is associated with increased piracy incidents and demonstrate that rises in fisheries production decrease opportunities for piracy. Better income opportunities for fishermen also reduce piracy (AXBARD 2016). Increases in fisheries prices are also correlated with decreases in piracy (PRINS ET AL. 2017). Nevertheless, one study found that in Southeast Asia, increases in fisheries production are correlated with increases in piracy (DIXON 2025). Frécon (2005) views pirates as individuals from the fisheries sector since they already possess an expertise of the seas. It is also widely accepted that pirates often have backgrounds in fishing (DAXECKER & PRINS 2013; FRÉCON 2006) and that individuals from fishing communities also engage in piracy (PHAYAL ET AL. 2026). Shocks to fisheries are also associated with piracy. Plankton abundance used as an instrumental variable for fish capture production shows that negative plankton shocks decrease fish capture production and increase the risk of piracy (Flückiger & Ludwig 2015).

Nevertheless, the fisheries data have been criticised because, on the one hand, for some states a substantial portion of their fish catch is not reported (Denton & Harris 2021) and, on the other hand, in some cases the primary contributors to this figure are not accounted for. Some piracy research uses fisheries data but does not distinguish among the contributions of different groups to the total value. Daxecker & Prins (2013) do not differentiate between small-scale fishermen and large-scale fishery companies in their work. This is an essential distinction because research on fishing in Southeast Asia has demonstrated that there, industrial fishing has overtaken small-scale fishing, and there has been a conflict between small-scale fishermen and industrial fishing operators (Teh & Pauly 2018). These industrial operators can destabilise the fisheries catches of small-scale fishermen (Desai & Shambaugh 2021). This is directly linked to overcapacity (which leads to overfishing), whereby there are too many fishers relative to fish; particularly in Southeast Asia, the effectiveness and implementation of overfishing policies are questioned (Pomeroy 2012). Overfishing can affect local communities that depend on fishing for their livelihoods (ibid.), and logically, if their livelihoods are affected, they may, in turn, resort to piracy, given their existing skills. Overfishing has been identified as a problem in regions such as Southeast Asia (Cruz-Trinidad 2003; Desai & Shambaugh 2021; Long 2003; Salayo et al. 2008; Silvestre et al. 2003). Research indicates that the depletion of fishing stocks caused by overfishing could result in less resilient fishing communities and persistent piracy (Desai & Shambaugh 2021).

IUU (illegal, unreported and unregulated) fishing is often discussed as well. Harmful and destructive fishing is associated with increased piracy (ibid.). Jesperson & Henriksen (2022) point out that establishing a causal relationship between piracy and IUU is complex because the conditions that often give rise to IUU are also conducive to piracy. But although there is no causal relationship between IUU and piracy, a correlation between them exists (ibid.). Nevertheless, Phayal et al. (2024) find that where IUU declines, piracy is likely to occur. Furthermore, Phayal et al. (2026) suggest that IUU may be driving piracy in Indonesia. Denton & Harris (2021) also indicate a connection between piracy and IUU, as increases in IUU drive piracy. Nevertheless, caution is warranted when attributing an increase in piracy to IUU because patrols that deter IUU may also deter piracy (Jesperson & Henriksen 2022), which suggests that it is not necessarily IUU that causes piracy but rather a lack of deterrence. However, Desai & Shambaugh (2021) show that IUU increases piracy. Additionally, when the figures are assessed subsectorally and as including unreported fish catch values, piracy is positively correlated with industrial fish catches and negatively correlated with artisanal and subsistence fish catches (Denton & Harris 2021). But in the Gulf of Guinea, IUU risk is not correlated with piracy (Jesperson & Henriksen 2022). Furthermore, recently, the Sea Around Us Project has introduced a new set of reconstructed fisheries data that are divided according to sub-sector contributions and reported and unreported reconstructions. Research by Denton & Harris (2021) using these data has found a statistically significant association between industrial fishing catches and piracy.

Shipping traffic density is frequently mentioned in the literature on maritime piracy but is often presented as merely a background context. Higher shipping traffic density consistently correlates with increased piracy incidents, and the literature highlights that maritime zones heavily traversed by vessels are especially prone to piracy (Fan et al. 2023; Galgano 2024; Psarros et al. 2011). A survey study also indicates that individuals engage in piracy due to the abundance of available ships (Phayal et al. 2026). Additionally, areas with higher levels of shipping density are more prone to piracy, as more than 80% of the attacks since 1991 were in the regions with the highest levels of vessel traffic (Fan et al. 2023). This also aligns with research on crime hotspots, which shows that areas with high road network density tend to experience higher crime levels; this observed correlation between infrastructure density and crime has been well established in the urban context, and offers a useful parallel for understanding the relationship between shipping lane density and maritime piracy (Zhang et al. 2020). Daxecker & Prins (2013) also found that greater regional trade is associated with increased hijacking.

Socio-economic conditions are widely recognised as key drivers of maritime piracy. The research consistently shows that piracy is closely linked to adverse economic pressures, including unemployment, declining fish prices, reduced fisheries production, and competition from IUU fishing, all of which diminish legal income opportunities for coastal populations and push individuals, especially those in the fisheries sector, toward piracy (Chen et al. 2023; Daxecker & Prins 2013, 2021; Sumaila & Bawumia 2014; Young & Valencia 2003). Evidence from Somalia and Southeast Asia further demonstrates that reductions in fish stocks, employment, and production significantly increase the likelihood and frequency of pirate attacks, whereas improvements in fisheries outputs and rising labour costs reduce piracy incentives (Di Salvatore 2018; Flückiger & Ludwig 2015; Hastings 2012; Jablonski & Oliver 2013; Jiang & LaFree 2023; Tominaga 2018). Nevertheless, other research shows no correlation between piracy and fish values (Daxecker & Prins 2015b). Fieldwork in Southeast Asia similarly shows that individuals involved in piracy often come directly from the fisheries and maritime transport sectors (Frécon 2005; Phayal et al. 2026), and that weak state capacity, government debt, wealth disparities, economic stagnation, and inadequate enforcement heighten the vulnerability to attacks (Bizouras 2013; Hu et al. 2023; Vagg 1995). Taken together, the literature highlights that deteriorating socio-economic conditions play a central role in shaping piracy risk and must be accounted for in analyses of maritime piracy attacks.

Institutional conditions are central to understanding where and why maritime piracy emerges. Weak state capacity, fragile governance, permissive political environments, and a limited judicial or enforcement capability consistently appear as enabling factors in the academic literature. Empirical studies show that permissive institutional settings intersect with economic pressures on states to facilitate recruitment and serve as safe havens for pirate groups (Daxecker & Prins 2013; Pérouse de Montclos 2012). State fragility is generally associated with higher piracy risk (Daxecker & Prins 2013; Desai & Shambaugh 2021; Dixon 2025); however, this relationship is non-linear, as there is evidence of an inverted U-shape in which piracy increases with fragility only up to a certain point, after which the extreme institutional collapse becomes too chaotic and infrastructure-poor to sustain organised maritime crime (Daxecker & Prins 2013; De Groot et al. 2011; Tominaga 2018). This aligns with findings indicating that weak governance alone does not maintain piracy, as sustainable operations require functioning infrastructure, predictable corruption, and logistical support (Daxecker & Prins 2021; Desai & Shambaugh 2021; Di Salvatore 2018; Sumaila & Bawumia 2014). Consequently, piracy is unlikely in completely failed states (Daxecker & Prins 2015b). Regional assessments, particularly those of the Gulf of Guinea, further demonstrate that piracy thrives where permissive political conditions coincide with socioeconomic deprivation, legal and judicial weaknesses, and a favourable maritime geography, while a limited institutional capacity undermines the securitisation process intended to counter piracy (FIORELLI 2014; PIEDADE 2016). Subnational analyses similarly show that piracy tends to occur in areas where local governance is present but weak, and that have enough infrastructure and corruption to support its operational needs; the organised attacks in Nigeria and Somalia are in neither in the most remote nor the most urbanised locations, which underscores the importance of local political and economic capacities (DAXECKER & PRINS 2021). Overall, institutional and governance conditions structure the opportunity environment in which piracy develops and persists, and must therefore be accounted for when analysing pirate activities.

The state's role in deterring piracy is directly linked to state fragility. Research shows that military bases tend to prevent piracy (DESAI & SHAMBAUGH 2021). Research also shows that the government's capacity to project power influences pirates' decisions (DAXECKER & PRINS 2015A) and a lack of state capability equates to a lack of deterrence (TOWNSLEY & OLIVEIRA 2015). One way to assess deterrence is to use law enforcement presence as a proxy. The presence of law enforcement indicates a likelihood of punishment, as with its presence, the chances of offenders being caught increase (BOIVIN & NOGUEIRA DE MELO 2023). Aben & Fontanel (2019) highlight that while military expenditure is a key indicator, it alone cannot fully measure a state's power. Even though military expenditure as a share of GDP is an imperfect measure of state power (IBID.), it remains the most widely available cross-national indicator that plausibly captures states' deterrence capacities in comparative research. Accordingly, military expenditure as a share of GDP is best interpreted as capturing defence effort or the prioritisation of defence relative to national resources rather than as a complete measure of deterrence on its own (IBID.).

Consequently, the choice of variables reflects the literature review. Therefore, the question remains: are fisheries (either overall or within a particular fisheries subsector) associated with piracy after controlling for other factors that affect piracy?

THEORETICAL EXPECTATIONS AND HYPOTHESES

The literature on fisheries and piracy points to a relationship that is theoretically important but empirically unsettled. The existing studies generally agree that piracy is connected to coastal livelihoods, maritime opportunity structures, and weak governance, but they differ on why fisheries matter: whether because they reflect scarcity, displacement, illegal fishing pressures, or the availability of maritime skills. In accordance with this, this study tests three competing expectations: a scarcity and livelihood-erosion expectation, an industrial encroachment and displacement expectation, and a mobilisation-capacity expectation.

The first expectation follows from work that links piracy to deteriorating legal income opportunities. If fisheries are central to coastal livelihoods, then declining fish production, a weak fishing income, or adverse shocks to fisheries should increase the incentives for individuals to engage in piracy. Low fisheries production is associated with higher piracy (Daxecker & Prins 2013), while better income opportunities for fishermen reduce piracy (Axbard 2016). Similarly, higher fish prices are associated with lower piracy (Prins et al. 2017), and negative plankton shocks, which reduce fish capture production, increase piracy risk (Flückiger & Ludwig 2015). Additionally, lower fisheries production is associated with piracy in some regional contexts (Jiang & LaFree 2023). From this perspective, piracy is primarily a livelihood response: when legal fishing opportunities deteriorate, individuals with limited economic alternatives become more likely to turn to maritime crime.

This logic produces a clear empirical expectation. If piracy is driven by scarcity and livelihood erosion, piracy-exposed observations should display lower fisheries outcomes than comparable non-exposed observations after balancing for broader structural conditions. This should be visible not only in the aggregate fisheries production, but also in per-capita measures or reconstructed catch indicators that better approximate the availability of fishery resources relative to population. Moreover, if scarcity is the dominant mechanism, the association should not be confined only to one productive subsector. It should appear more broadly across fisheries indicators that capture the declining economic opportunities in coastal economies.

H1: *The Scarcity Hypothesis: High-piracy-exposure observations are expected to have significantly lower fisheries outcomes than low-piracy-exposure observations.*

The second expectation emphasises industrial encroachment, overfishing, and displacement. The related argument does not assume that piracy follows from low fisheries production in general. Instead, it suggests that the structure of fisheries matters. Industrial fishing can displace or undermine small-scale fishing communities, intensify competition over maritime resources, and generate conflict between local fishers and larger operators. This is especially relevant in Southeast Asia, where industrial fishing has overtaken small-scale fishing in several contexts and where conflicts between small-scale and industrial fishing actors have been documented (TEH & PAULY 2018). Industrial operators may also destabilise catches for local communities, while overcapacity and overfishing weaken the resilience of fishing-dependent populations (POMEROY 2012; DESAI & SHAMBAUGH 2021). Related work on illegal, unreported, and unregulated fishing also suggests a connection between destructive fishing practices, weakened livelihoods, and piracy; nevertheless, the causal relationship remains difficult to establish because weak deterrence can enable both IUU fishing and piracy (DENTON & HARRIS 2021; JESPERSON & HENRIKSEN 2022; DESAI & SHAMBAUGH 2021; PHAYAL ET AL. 2026).

This produces a different empirical expectation. If piracy is driven primarily by industrial encroachment and displacement, piracy-exposed observations should be associated with industrial fishing, either through higher industrial catches or higher industrial shares. The mechanism is not simply that overall fisheries volumes are low, but that industrialised extraction changes the distribution of benefits and costs within the fishing economy. Under this expectation, industrial fishing should be more strongly associated with piracy exposure than aggregate catch measures alone.

H2: *The Industrial Encroachment Hypothesis: High-piracy-exposure observations are expected to show stronger differences in industrial fishing levels or industrial shares than low-piracy-exposure observations.*

The third expectation concerns mobilisation capacity. The related argument begins from a different premise. Piracy requires more than grievances or poverty. It also requires practical maritime capabilities: knowledge of local waters, familiarity with boats, navigation skills, small-vessel handling, access to maritime labour, and community-level networks that can support illicit activity. Qualitative accounts frequently describe pirates as individuals connected to fishing communities or maritime transport sectors because they already possess the skills and sea knowledge necessary for piracy (FRÉCON 2005, 2006; DAXECKER & PRINS 2013; PHAYAL ET AL. 2026). From this perspective, fisheries may matter not because they are declining, but because some fishing sectors provide the human and operational resources through which piracy becomes feasible.

The mobilisation-capacity expectation is therefore distinct from both the scarcity and the industrial encroachment expectation. It does not predict that piracy should be highest where fisheries are weakest. Nor does it necessarily predict that piracy should be most closely tied to industrial fishing. Instead, it expects the association between piracy and fisheries to be strongest in the fishing subsector most closely linked to small-vessel operations, local sea knowledge, and coastal labour pools. Artisanal fisheries are theoretically important for this reason. They involve small-scale maritime activity, regular engagement with nearshore waters, and community-based labour structures that correspond more closely to the operational requirements of piracy than aggregate fisheries production or industrial catches. If piracy depends on mobilisation capacity, piracy-exposed observations should therefore differ most clearly in artisanal fisheries measures.

***H3:** The Mobilisation-Capacity Hypothesis: High-piracy-exposure observations are expected to show the clearest differences in artisanal fisheries outcomes relative to low-piracy-exposure observations.*

These three expectations imply different observable patterns. The scarcity expectation predicts lower fisheries outcomes among piracy-exposed observations. The industrial encroachment expectation predicts stronger associations with industrial fishing levels or shares relative to small-scale sectors. The mobilisation-capacity expectation predicts that piracy exposure should be most clearly associated with the artisanal segment, where the relevant maritime skills, vessels, and labour pools are concentrated.

DATA AND METHODS

The piracy data was obtained from the Maritime Piracy Location and Event Dataset (MPLED), which records maritime piracy incidents between 1978 and 2020. Additional variables measuring governance, container port traffic, GDP per capita, unemployment rates, inflation, military spending, population, and capture fisheries production were sourced from the World Bank's World Development Indicators (WDI) database using the WDI function in R. Additional fisheries data were obtained from the Sea Among Us database (PAULY ET AL. 2020). Due to missing observations across several indicators, the final analytic sample has variables for 2000–2019 for each country-level observation, totalling 1199. Table 1 describes the variables used in this research. Furthermore, fisheries areas representing ordinary coastal subdivisions or integrated island regions were reassigned to the given sovereign country whereas remote island territories and distant EEZ areas were excluded from the analysis because their fisheries production may not reflect the mainland coastal economy linked to piracy dynamics.

TABLE 1. VARIABLE DESCRIPTIONS

Variable	Source	Description
Piracy Exposure	MPELD	Coded as binary, representing the piracy exposure status for a country in a given year i.e. 0 = No (Control); 1 = Yes (Treatment)
Piracy Incidents	MPLED	Number of piracy incidents [used in the robust model]
Total Fisheries SAU	(Pauly et al. 2020)	Quantity of fisheries in tonnes
Total Fisheries FAO	World Bank	Quantity of fisheries
Fisheries Per Capita	World Bank	Quantity of fisheries per capita
Industrial Fisheries	(Pauly et al. 2020)	Quantity of industrial fisheries in tonnes
Subsistence Fisheries	(Pauly et al. 2020)	Quantity of subsistence fisheries in tonnes
Artisanal Fisheries	(Pauly et al. 2020)	Quantity of artisanal fisheries in tonnes
Recreational Fisheries	(Pauly et al. 2020)	Quantity of recreational fisheries in tonnes
Share of Industrial Fisheries	(Pauly et al. 2020)	Per cent share of industrial fisheries
Share of Subsistence Fisheries	(Pauly et al. 2020)	Per cent share of subsistence fisheries
Share of Artisanal Fisheries	(Pauly et al. 2020)	Per cent share of artisanal fisheries
Share of Recreational Fisheries	(Pauly et al. 2020)	Per cent share of recreational fisheries
Fisheries Exposure	(Pauly et al. 2020)	Coded as binary, representing the level of fisheries exposure status for a country in a given year; i.e. 0 = No (Control); 1 = Yes (Treatment) [used in the robust model]
Population	World Bank	Total population

Unemployment rate	International Labour Organisation (ILO)	The International Labour Organisation unemployment rate
Container port traffic	UN Conference on Trade and Development (UNCTAD)	The number of standard shipping containers (TEUs) moved between land and sea transport at a port
Governance	World Bank	The mean of the 6 Worldwide Governance Indicators (voice and accountability; political stability and absence of violence/terrorism; government effectiveness; regulatory quality; rule of law; control of corruption)
Inflation	IMF	Inflation rate as per the consumer price index
GDP per Capita	World Bank	Gross domestic product per capita measured in US dollars and adjusted for the reference year 2015
Military spending	Stockholm International Peace Research Institute (SIPRI)	Military expenditure by country as a percentage of the gross domestic product

Based on the literature, we used a matching approach to compare high-piracy-exposure observations with low-piracy-exposure observations that were similar across the key observable covariates (unemployment, inflation, GDP per capita, container port traffic, governance, and military spending). This allowed us to assess whether differences in fisheries indicators persisted after accounting for major economic, institutional, and security-related factors.

Following Stuart's (2010) definition of matching, this study equated the treatment and control groups as closely as possible on the observed covariates while assessing whether there was a significant difference in fisheries outcomes between the groups. The treatment was a binary country-year piracy-status indicator coded from the annual median number of piracy incidents: for each year, a country was coded as 1 if its piracy-incident count exceeded the year's median across all the countries, and as 0 otherwise. To assess how the fisheries activity differed for piracy-exposed and non-exposed country-years across the competing fisheries datasets (FAO/WDI totals, Sea Around Us indicators, and per-capita measures), fishing-sector segments (industrial, artisanal, subsistence, recreational), and reported and unreported fisheries volumes, and also to improve the comparability between the treated and control observations, the analysis used Mahalanobis distance matching (MDM). MDM was selected because, unlike propensity score matching (PSM), it reduces imbalance, model dependence, and bias (King & Nielsen 2019).

To limit model dependence arising from reliance on particular model specifications, we employed full matching using the Mahalanobis distance as implemented in MatchIt (method = "full", distance = "mahalanobis"). We implemented Mahalanobis distance matching on covariates consistently identified as confounders in the piracy literature, including governance, socioeconomic conditions (inflation, GDP per capita, unemployment), deterrence capacity (military spending), and maritime trade exposure (container port traffic). Inference was then based on between-group comparisons in the matched sample. To avoid cross-year comparisons and global-period confounding, we enforced exact matching on year (exact = ~ year). We imposed calipers (0.5 SD) on standardised covariates to rule out poor matches and reduce reliance on extrapolation. Matching covariates were lagged using the previous available country-year observation rather than contemporaneous values in order to balance pre-treatment characteristics and limit contemporaneous feedback; because observations from 2001 were unavailable for one variable in the complete-case sample, the first retained post-lag year was 2002. The fisheries indicators were not included in the matching stage because they were the outcomes of interest. Balance was assessed using standardised mean differences (SMD) and distributional diagnostics, with <0.1 SMD as a benchmark.

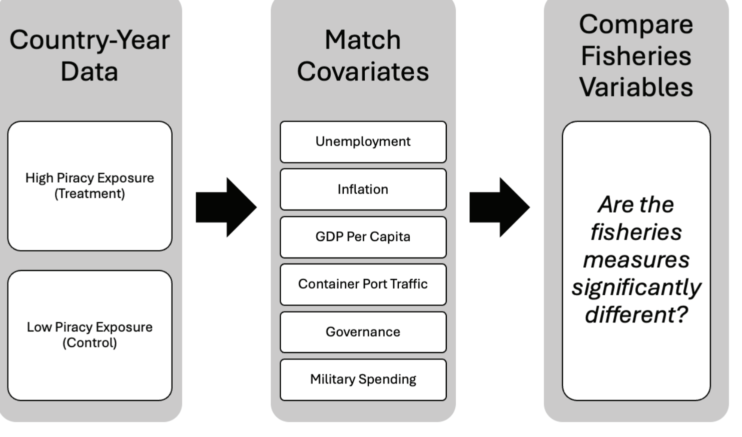
After matching, we compared the fisheries indicators across the piracy-status groups. In the matched sample, we conducted design-based t-tests (svyttest) using the matched weights and country-clustered standard errors to assess whether the fisheries indicators differed for observations with above-median piracy (treatment) and those with at-or-below-median piracy (control). Estimates from this design were interpreted as covariate-adjusted differences in fisheries indicators by median piracy status rather than as evidence of a causal effect in either direction. To ensure the robustness of our p-values, we controlled for the familywise error rate (FWER) using the conservative Bonferroni method and reported the adjusted p-values (CHEN ET AL. 2017). The Bonferroni adjustment significantly reduces the probability of type I errors, i.e., incorrectly rejecting the null hypothesis (IBID.); in other words, incorrectly concluding that there is a difference between the treatment and control groups when there is no difference between them.

The significance level (α) used in this study is 0.05. The FWER was calculated as $1 - (1 - \alpha)^m$, where m was the number of tests being performed. Therefore, $\text{FWER}=1 - (1 - \alpha)^{23} = 0.69$ or 69%. Thus, there was a

69% probability of obtaining at least one false-positive result. After using the Bonferroni correction method $\frac{\alpha}{k}$, where k was the number of tests, the Bonferroni-corrected α is $\frac{0.05}{23}\alpha = 0.00217$. The new FWER using the Bonferroni-adjusted alpha was $1 - (1 - 0.00217)^{23} = 0.04873$ or 4.9%. Consequently, by adjusting the significance level using the Bonferroni method, the FWER was reduced to approximately 5%. The less stringent Benjamini-Hochberg (BH) p-value were also provided as a comparison.

We then repeated the full procedure using an alternative piracy-status definition based on within-year piracy intensity, coding a country-year as 1 if the country's piracy-incident count fell in the top quartile (the top 25%) of the countries in that year, and 0 otherwise. Figure 1 presents the matching process.

FIGURE 1. THE OVERVIEW OF THE MATCHING PROCESS



RESULTS

THE MAIN FINDINGS

After matching, all the control variables were balanced to below 0.1, as shown in Figures 2 and 3. Tables A1 and A3 in the appendix show the full diagnostics. The total number of observations in the dataset is 1199; after lagging, it is 1114.

FIGURE 2. POST-MATCH STANDARDISED MEAN DIFFERENCES OF COVARIATES (MEDIAN)

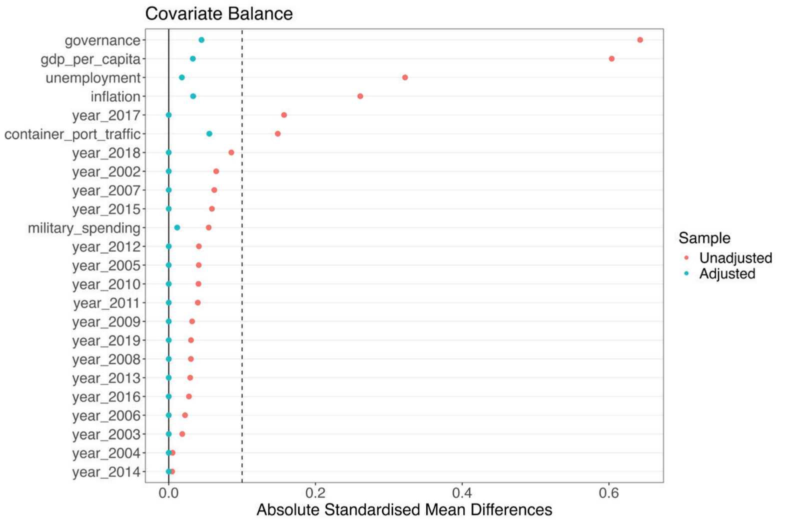
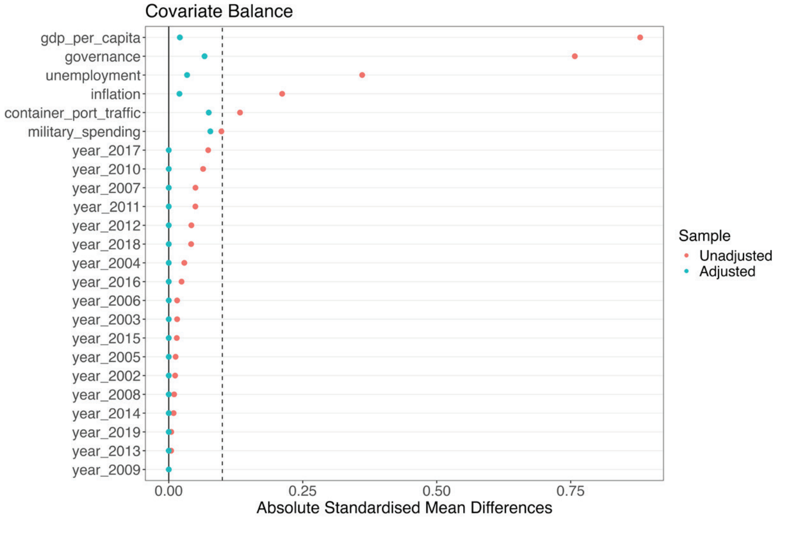


FIGURE 3. POST-MATCH STANDARDISED MEAN DIFFERENCES OF COVARIATES (TOP QUARTILE)



The Median

Based on our piracy median designation, there were 636 control and 478 treated observations. Since we used matching without replacement, we had 203 observations in the control group and 188 in the treated group. Table 2 gives an overview of the sample sizes.

TABLE 2. SAMPLE SIZES

Sample	Control	Treated
All	636	478
Matched (ESS)	160.23	188
Matched	203	188
Unmatched	433	290
Discarded	0	0

Figure A1 in the appendix shows that for some fisheries variables, the standardised mean differences before and after we matched the covariates remained large, but this alone does not establish a statistical significance. The design-based t-tests (bootstrapped with 10,000 replications) indicated differences at the $p<0.05$ level for some variables (including the total volume of artisanal fisheries, the total volume of reported artisanal fisheries, the fisheries volume from the FAO). However, after adjusting for multiple comparisons across the 23 fisheries indicators using the Bonferroni procedure, these differences were no longer statistically distinguishable from zero. Accordingly, we interpreted the evidence as insufficient to conclude that the fisheries indicators differ by median piracy status once multiple comparisons are taken into account. Table A2 in the appendix shows the full results.

The Top Quartile

Based on our top quartile piracy designation, there were 857 instances of control and 257 treated observations. Since we used matching without replacement, we had 232 observations in the control group and 127 in the treated group. Table 3 gives an overview of the sample sizes.

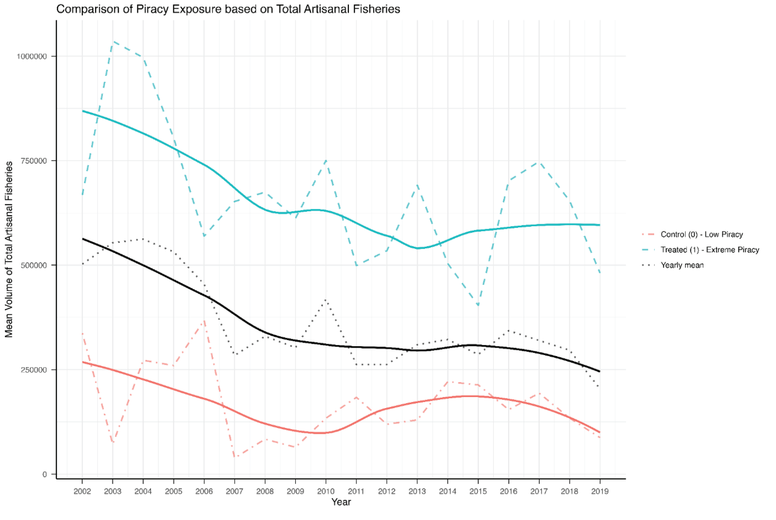
TABLE 3. SAMPLE SIZES FOR THE TOP 25

Sample	Control	Treated
All	857	257
Matched (ESS)	155.72	127
Matched	232	127
Unmatched	625	130
Discarded	0	0

Figure A2 shows the standardised mean differences of all the fisheries variables before and after we matched the covariates. The design-based t-tests (with a bootstrapping of 10 000 replications) for the top-25% piracy specification indicated differences at the $p<0.05$ level for the total volume of artisanal fisheries, the total volume of reported artisanal fisheries, the share of unreported fisheries, the share of reported fisheries, the total volume of fisheries (FAO), the volume of reported fisheries, the total volume of fisheries (SAU), and the total volume of subsistence fisheries. However, after the controlling of the error rate across the 23 fisheries indicators using the Bonferroni procedure, only the differences in the total volume of artisanal fisheries were statistically distinguishable. Accordingly, we interpret this as evidence that only the total volume of artisanal fisheries differs by piracy status after multiple comparisons are adjusted for. The results show that the total volume of artisanal fisheries remains significantly higher in the treatment group (the highest-intensity piracy group) than in the control group. In the weighted matched sample covering 2000 to 2019, the average treatment effect on the treated (ATT), defined as the average difference in artisanal fisheries output between the treated observations (piracy_top25 = 1) and their matched controls (piracy_top25 = 0), indicates that the country–years in the top quartile of piracy intensity have, on average, 450 643 more tonnes of artisanal fisheries output than the comparable non-top-quartile country–years within the same year. Table A4 in the appendix shows this result.

After matching on key covariates and comparing countries with above-median piracy levels to those with below-median levels in the same year, we found no significant differences in their fisheries outcomes. In other words, there is no evidence from this analysis that countries' fisheries conditions differ systematically based on whether their piracy level is above or below the median for the given year. However, for the top quartile, the total volume of artisanal fisheries is higher in the treatment group. That is, in a high-intensity piracy setting, the countries in the top quartile of piracy incidents for each given year have a higher total artisanal fisheries volume than those not in the top quartile. Figure 4 visualises the differences. The thicker smoothed lines represent locally estimated scatterplot smoothing (LOESS) trends, which are included to show the longer-term direction of change in the mean total artisanal fisheries for each group. Additionally, Table A5 in the appendix shows the matched sets.

FIGURE 4. THE ANNUAL MEAN VOLUMES OF ARTISANAL FISHERIES BY TREATMENT AND CONTROL GROUP



The Sensitivity Analysis

Rosenbaum sensitivity analyses were conducted to assess how robust the findings are to potential hidden bias from unobserved covariates. The first Rosenbaum sensitivity analysis indicates that the matched association between high piracy and total artisanal fisheries is robust to substantial hidden bias. Specifically, Figure 5 shows that the result remains statistically significant up to $\Gamma = 6.5$. The Rosenbaum result does not show that an omitted variable exists. Rather, it shows that any omitted variable capable of overturning the finding would need to be strongly associated with both a high-piracy status and the total artisanal fisheries volume. In this case, the required hidden bias is large since the unobserved factor would need to increase the odds of high-piracy classification by a factor of approximately 6.5 within the matched comparison groups. This represents a large degree of hidden bias by conventional standards in observational social science research, where Γ values of this magnitude are generally interpreted as evidence of a strong robustness to unobserved confounding (KEELE 2010).

FIGURE 5. THE GAMMA VALUE

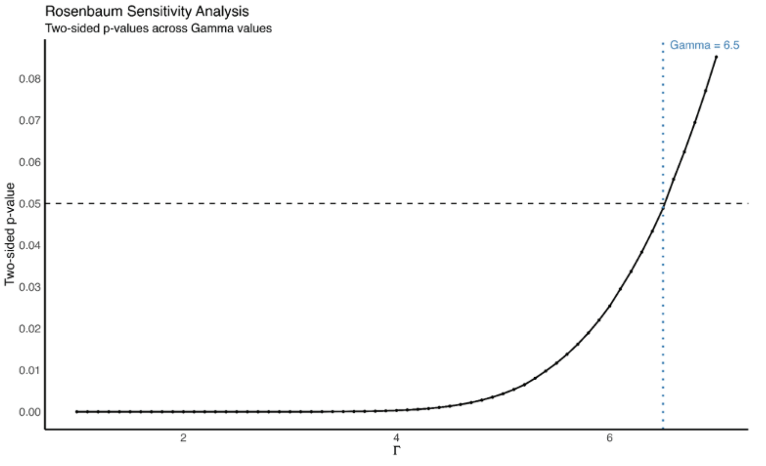
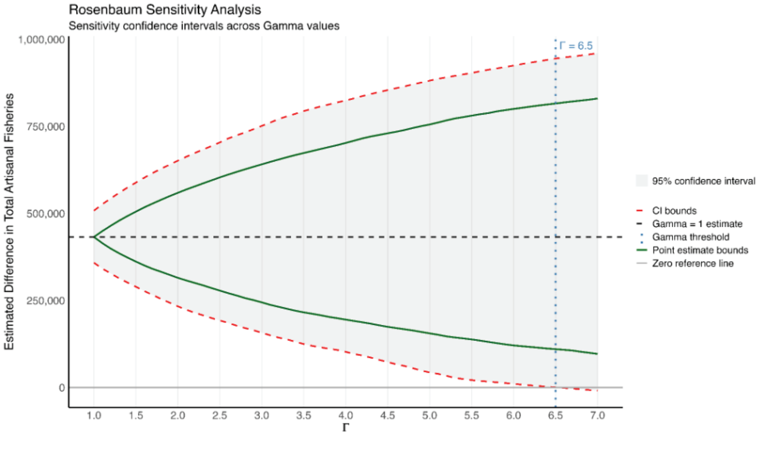


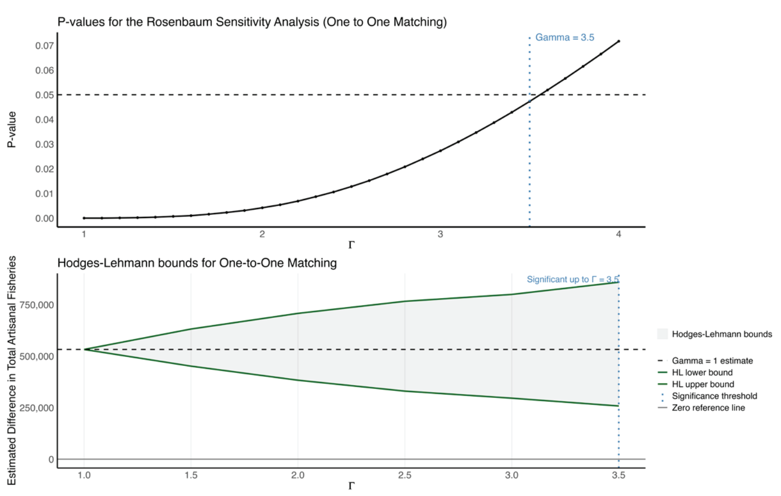
Figure 6 visualises this sensitivity result by showing how the Rosenbaum confidence intervals change as Γ increases. As stronger levels of hidden bias are assumed, the confidence interval widens, indicating greater uncertainty around the estimated difference in total artisanal fisheries between high-piracy and lower-piracy country-years. The interval remains above zero until approximately Γ = 6.5, after which zero becomes a plausible value. This marks the point at which the estimated difference is no longer statistically distinguishable from zero.

FIGURE 6. THE ROSENBAUM SENSITIVITY CONFIDENCE INTERVALS ACROSS Γ VALUES.



An additional sensitivity check was conducted using a different specification (one-to-one nearest-neighbour matching). This paired specification was used to assess whether the observed difference in total artisanal fisheries between high- and low-piracy country-years remains robust to an alternative matching procedure and to increasing assumptions about hidden bias. This second Rosenbaum sensitivity results show that the Wilcoxon signed-rank p-value remains below the 0.05 threshold until approximately Γ = 3.5, becoming non-significant shortly after this point (Figure 7a). The corresponding Hodges-Lehmann confidence interval results (Figure 7b) show that the Hodges-Lehmann estimated difference remains positive across the plotted sensitivity range. These results suggest that the one-to-one matched comparison is robust to moderate hidden bias, although its sensitivity threshold is lower than that of the full-matching specification.

FIGURE 7A. THE ROSENBAUM SENSITIVITY RESULTS (TOP); 7B. THE HODGES-LEHMANN ESTIMATED DIFFERENCE (BOTTOM)



The Robustness Test

A bootstrap resampling with 5,000 replicates was conducted to assess whether the matched difference between high- and low-piracy country-years remained stable across repeated samples. Table 4 shows the bootstrap results, indicating a consistent positive difference in total artisanal fisheries, with a mean estimated difference of 452,134 and a median of 450,232. The 95% bootstrap interval ranged from 335,787 to 576,742, remaining entirely above zero, and all the bootstrap estimates were positive. This suggests that the observed difference between the high- and low-piracy groups is not driven by a small number of unstable matched observations.

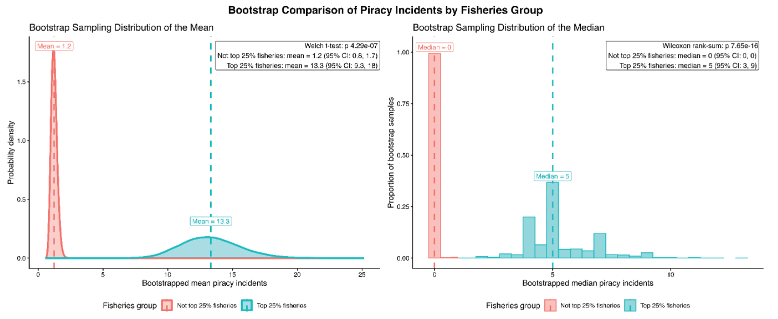
TABLE 4: THE BOOTSTRAP ROBUSTNESS CHECK FOR FULL MATCHING

Replicates	Mean estimate	Median estimate	95% bootstrap CI	Positive estimates	Mean matched N	Mean ESS treated	Mean ESS control
5,000	452,134.00	450,231.60	[335,787]; [576,742]	100.00%	280.6	103.8	85.5

Note: The estimate is the weighted mean difference in total artisanal fisheries between high piracy and lower-piracy country-years. The confidence interval is the 2.5th and 97.5th percentile of the bootstrap distribution. ESS refers to the effective sample size after matching weights.

To further assess the robustness of the findings, an alternative matching specification was conducted using the total artisanal fisheries as the treatment and control, and the number of piracy incidents as the outcome. The total artisanal fisheries variable was coded as 1 for country-years in the top quartile and 0 for country-years outside the top quartile. The covariates used in the main matching specification were retained, with a calliper of 0.5 applied to all covariates except unemployment, for which a calliper of 0.4 was used to achieve an acceptable balance. The full balance diagnostics are reported in Table A7. The matching procedure retained 174 treated observations and 110 control observations. Figure 8 presents the matched comparison between the country-years in the top quartile of the total artisanal fisheries and the otherwise comparable control country-years. The country-years in the top fisheries quartile recorded a mean of 13.3 piracy incidents, compared with 1.2 incidents in the control group. The median difference is also clear: the top-quartile fisheries country-years recorded a median of 5 piracy incidents, while the control group recorded 0. Overall, this suggests that the high-fisheries country-years experienced substantially more piracy incidents than the comparable country-years outside the top fisheries quartile, with a mean difference of 12.1 incidents and a median difference of 5 incidents.

FIGURE 8. THE BOOTSTRAP COMPARISON OF PIRACY INCIDENTS



DISCUSSION

Using Mahalanobis-distance matching and a conservative family-wise error control across 23 fisheries indicators, we find no robust fisheries differences between the above-median piracy observations and the matched controls. Overall, the results show that the scarcity hypothesis and the industrial hypothesis are not supported once the core structural correlates of piracy are accounted for. However, the mobilisation-capacity hypothesis is supported, as the artisanal fisheries volume is systematically higher in the most piracy-intense settings. Under a top-quartile (high-intensity) piracy definition, the total artisanal catch remains higher in the treated group even after the Bonferroni adjustment. Substantively, this pattern suggests that the fisheries–piracy link is threshold-dependent: the fisheries metrics do not reliably distinguish "moderate" from "lower" piracy contexts once governance, macroeconomic conditions, deterrence proxies, and maritime trade exposure are comparable, yet the artisanal sector becomes salient where piracy is already concentrated. Therefore, high-intensity piracy countries are systematically associated with neither fisheries scarcity nor industrial encroachment but rather with the total volume of fisheries in the artisanal subsector.

The literature review mainly pointed to fisheries abundance reducing piracy and low production increasing piracy (DAXECKER & PRINS 2013; DENTON & HARRIS 2021; DESAI & SHAMBAUGH 2021; FLÜCKIGER & LUDWIG 2015; JIANG & LAFREE 2023). Our null results under the median split align more closely with studies cautioning against a simple, direct relationship between national fisheries values and piracy (E.G., DAXECKER & PRINS 2015B). Once the key covariates are balanced through matching, most fisheries indicators lose their independent discriminating power, which is consistent with the possibility that some previously reported associations partly reflect shared underlying structural drivers rather than fisheries conditions per se.

At the same time, the positive association between artisanal volume and high-intensity piracy aligns with a different strand of the literature emphasising the occupational and capability foundations of piracy. Prior work argues that pirates often come from fishing communities and possess maritime skills and local sea knowledge (Daxecker & Prins 2013; Frécon 2005, 2006; Phayal et al. 2026). Read in that context, the findings of this research point to the mobilisation-capacity hypothesis for explaining maritime piracy. The existing piracy scholarship has often emphasised scarcity, deprivation, weak state authority, and declining legal opportunities in coastal economies (Daxecker & Prins 2021, 2013). These explanations are important because they help explain why individuals may become willing to participate in piracy. However, motivation alone is insufficient. Piracy also requires the capacity to act. Potential offenders must have access to vessels, maritime skills, local knowledge, operational networks, and the ability to move through the maritime domain. Fisheries production should be understood not only as an economic condition that may decline and produce grievance, but also as an indicator of the maritime resources and capabilities that enable piracy.

Routine activity theory puts forward that crime requires the convergence of likely offenders, suitable targets, and an absence of capable guardians in time and space (Cohen & Felson 1979). In the maritime domain, this means piracy is more likely where potential offenders can access vessels and where the naval, coastguard, state, or private security presence is limited. Fisheries-based actors routinely move through ports, fishing grounds, coastal waters, and maritime transit routes. These are also spaces where maritime targets may become visible and reachable.

Crime pattern theory further clarifies why familiarity matters. Brantingham et al. (2017) argue that offenders are more likely to commit crimes within their awareness spaces: the places, routes, and environments they know through their everyday activity (Browning et al. 2021). Piracy should be understood in similar terms. The maritime domain is not simply an open space where any motivated actor can commit an offence. It is a specialised environment that requires experience and local knowledge. Those who work at sea are more likely to understand where vessels move, when they are vulnerable, how to approach them, and how to flee undetected. Fisheries activity can therefore produce the spatial familiarity needed for maritime crime.

The findings also align with criminal capital theory. McCarthy and Hagan (2001) argue that criminal success depends not only on motivation but also on competence, experience, skills, and useful networks. In the case of piracy, maritime labour can generate forms of capital that are transferrable to illicit activity. A fisher's knowledge of local waters, a boat operator's ability to manoeuvre at sea, or a coastal worker's familiarity with vessel routines may reduce the uncertainty and risk involved in piracy. That is, where maritime skills, vessels, and coastal networks are already concentrated, the threshold for organising piracy may be lower.

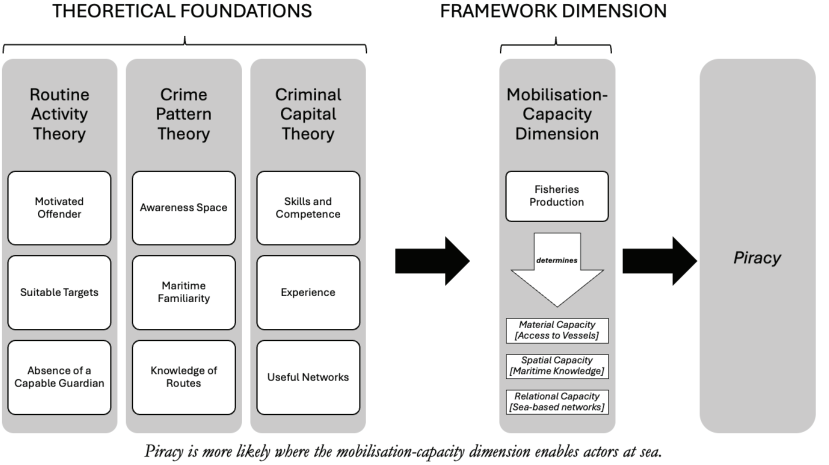
Based on these three theories, mobilisation capacity refers to the practical means through which potential offenders can organise and carry out piracy. It has three main components. The first is material capacity. Piracy requires boats, engines, fuel, equipment, and points of departure and return. Without access to a vessel, the ability to carry out piracy is severely constrained. The second is spatial capacity. Piracy requires familiarity with the maritime environment, including knowledge of routes, tides, currents, landing points, vessel movements, patrol patterns, and escape options. The third is relational capacity. Piracy is rarely carried out by isolated individuals. It usually depends on crews, lookouts, informants, handlers, buyers, and other forms of logistical support. These material, spatial, and relational resources form the operational base of maritime crime. The more these capacities are present, the more favourable the conditions for piracy and the lower the barriers to engaging in piracy.

The mobilisation-capacity hypothesis therefore complements scarcity-based explanations rather than replacing them. Scarcity may help explain why some individuals become willing to offend, but capacity helps explain where that willingness can be converted into action. Ships may provide targets, and weak guardianship may create openings (Cohen & Felson 1979), but offenders must still possess the means to exploit those opportunities. Piracy requires more than economic deprivation. It requires operational access to the sea. Fisheries production is important in this hypothesis because it may capture the density of maritime activity. A higher fisheries production may reflect a larger maritime labour force, more active vessels, more frequent movement through coastal waters, a stronger local knowledge of the sea, and wider networks linked to maritime storage, trade, repair, and transport. These conditions do not automatically produce piracy. However, they may create a setting in which piracy can be more easily organised when suitable targets and weak guardianship are present. High artisanal volumes may be regarded as a proxy for a larger pool of small-vessel operators and maritime labour that can be recruited when opportunity structures and criminal networks are established, which is characteristic of precisely the environments captured by the top-quartile piracy definition.

This argument is consistent with piracy research that treats the fisheries sector as connected to both opportunity and willingness. Tominaga (2018) shows that fisheries conditions shape the relationship between economic motivation and piracy, while Desai and Shambaugh (2021) demonstrate that piracy is spatially connected to fishing activity and destructive or illegal fishing. Further support for the mobilisation and capabilities mechanism comes from evidence that fishing communities' maritime operations, transnational social ties, and contacts may facilitate criminal mobilisation and be exploited by pirates and traffickers (Beseng & Malcolm 2021). The mobilisation-capacity framework extends this logic by emphasising that fisheries economies may matter not only because of loss, decline, or grievance, but also because they contain the resources, skills, and networks needed to make maritime offending feasible. The result is therefore that piracy will be more likely where motivation, opportunity, and mobilisation capacity intersect. Deprivation may create incentives, suitable vessels may create targets, and weak guardianship may create openings. Yet piracy becomes practically viable only where actors also possess the maritime means to act. Fisheries production is therefore treated as a potential indicator of this mobilisation capacity.

Therefore, the positive association between higher fisheries production and higher maritime piracy is best explained by the fact that fisheries production reflects greater maritime resources, skills, local knowledge, and sea-based networks. Our findings thus reframe the fisheries-piracy relationship. Fisheries are not only a sector whose decline may generate grievance. They may also constitute a reservoir of maritime capacity. Piracy, from this perspective, is most likely where suitable targets overlap with actors who already possess the vessels, knowledge, networks, and operational familiarity needed to act at sea. Figure 9 provides a visual overview of how the mobilisation-capacity dimension is constructed.

FIGURE 9. THE MOBILISATION-CAPACITY THEORETICAL FRAMEWORK



Piracy is more likely where the mobilisation-capacity dimension enables actors at sea.

The results also speak to measurement debates raised in the literature. Fisheries statistics are often criticised for under-reporting and for conflating heterogeneous sectors (DENTON & HARRIS 2021). This motivated our use of the Sea Around Us reconstructed data that disaggregate sectors and reported and unreported components (PAULY ET AL. 2020) alongside the FAO totals. The fact that the sole robust finding appears in the artisanal-level measure rather than being consistent across industrial catches or reported and unreported shares, suggests that sectoral composition matters, but also that national aggregates remain blunt instruments for capturing the mechanisms discussed in IUU and overfishing debates (DESAI & SHAMBAUGH 2021; JESPERSON & HENRIKSEN 2022; TEH & PAULY 2018). Importantly, the Sea Around Us unreported reconstructions are not identical to measures of IUU risk; they only reflect data that are missing from official statistics (ZELLER ET AL. 2016). Consequently, the absence of robust differences in the reported and unreported shares does not resolve the causal complexity noted by prior work as piracy deterrence and IUU deterrence overlap (Jesperson & Henriksen 2022).

The general findings offer three clear implications on the relationship between fisheries production and maritime piracy. First, the scarcity hypothesis is not supported at the country-year level of aggregation once governance, macroeconomic variables, deterrence proxies, and maritime trade exposure are comparable.

Second, the findings invite a careful reconsideration of the industrial encroachment logic often discussed in connection with Southeast Asia (Desai & Shambaugh 2021; Pomeroy 2012; Teh & Pauly 2018). If piracy were primarily a direct response to industrial encroachment, as reflected in national aggregates, we would expect more consistent signals in industrial measures or industrial shares. The absence of robust effects there suggests either: (i) that those dynamics operate at subnational scales not captured in this paper, (ii) that the relevant margin is not tonnage but incomes, prices, enforcement, or conflict, or (iii) that artisanal volume is capturing a different pathway than direct industrial competition (such as capability or nearshore maritime density).

Third, the artisanal fisheries result supports a threshold interpretation of piracy. In general, the factors that differentiate the most piracy-intense contexts from others are not the same as those that differentiate moderate from low piracy. This is consistent with institutional arguments claiming that piracy requires not only hardship but also operational feasibility, i.e. some combination of infrastructure, predictable corruption, and opportunity (Daxecker & Prins 2013, 2021; de Groot et al. 2011; Di Salvatore 2018). In high-piracy-intensity settings, artisanal scale may indicate a larger base of maritime capability that can be mobilised within permissive opportunity structures.

A key contribution of this study is a methodological one. By using Mahalanobis-distance full matching within year, with lagged covariates and calipers, the comparisons are made among country-years that are similar on major confounders highlighted in prior research. This strengthens inference relative to uncontrolled comparisons and reduces reliance on any single parametric model specification; in other words, it reduces model dependence (KING & NIELSEN 2019).

The composition of the matched treated observations in the high-intensity analysis also provides context. The treated group retained under the covariate matching is concentrated in established piracy regions (including Southeast Asia and West Africa), with treated observations such as Bangladesh, the Philippines, Indonesia, Nigeria, Vietnam, and Ghana being matched to controls that are similar on the matched covariates but exhibit a lower piracy intensity (e.g., Sri Lanka, Thailand, Morocco, Senegal, and Tanzania). This reinforces the idea that the artisanal fisheries association is regionally conditioned within the overlap sample and should not be interpreted as a universal or generalisable worldwide phenomenon. It is most plausibly interpreted as follows: within high-risk piracy areas, the scale of the artisanal fisheries sector is associated with piracy intensity, even after accounting for the usual structural correlates.

Several limitations follow directly from the literature and from what our design can and cannot capture. The first relates to aggregation and heterogeneity. Country-level fisheries tonnage may conceal the local mechanisms emphasised in qualitative and subnational piracy research, including fisheries displacement, livelihood disruption, and pirate recruitment (FRÉCON 2005; YOUNG & VALENCIA 2003). Future research should replicate the same design within regions such as Southeast Asia or the Gulf of Guinea, and, where feasible, at subnational levels with the use of geospatial proxies or local indicators to better capture where fisheries conflict and livelihood shocks are experienced.

Secondly, there is the issue of opportunity measurement. The literature repeatedly highlights shipping density as an opportunity structure for piracy (FAN ET AL. 2023; PHAYAL ET AL. 2026; PSARROS ET AL. 2011). Our matching uses container port traffic as a cross-national proxy for maritime trade exposure, though this may not fully capture spatial shipping-lane density, anchorage exposure, or route chokepoints. Incorporating direct shipping-density measures would tighten the alignment between theory and measurement.

Next, there might be unmeasured context-specific confounding variables. Global indices may not capture specific drivers (e.g., insurgency dynamics). As a result, even a strong balance on governance and macro-indicators may not guarantee substantive equivalence across matched sets. This reinforces the appropriate framing of our estimates as covariate-adjusted associations among comparable observations rather than causal effects. Nevertheless, the sensitivity analyses suggest that any unobserved confounder would need to exert a sufficiently strong influence to account for the observed differences between the treatment and control groups.

Finally, there is the limitation of the Bonferroni adjustment's conservative nature. The Bonferroni adjustment strongly limits false positives but to the detriment of statistical power, increasing the risk of false negatives (Type II errors) and making it harder to detect real effects, especially when the number of tests is large. The null findings should therefore be read as 'insufficient evidence of systematic differences', not as definitive evidence of no relationship.

CONCLUSION

This study challenges the straightforward narrative that piracy is a direct function of fisheries scarcity. After balancing the principal covariates emphasised in the literature (governance capacity, macroeconomic pressures, deterrence proxies, and maritime trade exposure), we found that most fisheries indicators do not robustly differentiate piracy-exposed observations from comparable controls. However, we also found that within high-intensity piracy contexts, a greater artisanal fisheries volume is a consistent covariate that particularly aligns with a mobilisation/capability interpretation grounded in the documented fisheries backgrounds and maritime skills of participants in piracy (DAXECKER & PRINS 2015A; FRÉCON 2005; PHAYAL ET AL. 2026). The policy implication is that interventions focused solely on increasing the aggregate catch are unlikely to be sufficient. More credible strategies should pair improvements in governance and enforcement with targeted efforts to strengthen the economic resilience and legitimate livelihood opportunities of artisanal fishing communities in high-risk areas, thereby reducing the conditions under which maritime labour and capabilities can be drawn into piracy.

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