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Research

Evidence of spatial competition, over resource scarcity, as a primary driver of conflicts between small-scale and industrial fishers

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ABSTRACT. Accounts of fishing conflicts have been rising globally, particularly between small-scale and industrial vessels. These conflicts involve verbal or physical altercations, and may include destruction of boats, assault, kidnapping, and murder. Current scholarship around industrial/small-scale fishing conflicts theorizes them as a form of resource conflict, where fish scarcity is the dominant contributor to conflict and competition. Alternatively, conflicts may be driven by spatial competition, concentrating where there are increased encounters, unrelated to resource status. Current policies to address these conflicts focus on enforcing the separation of small-scale and industrial vessels; however, this broad spatial separation has yet to be evaluated for deterring conflicts. Here we employ a novel spatial analysis to estimate the locations of industrial/small-scale conflicts at sea in Ghana, West Africa. Using data from narrative reports over the period of 1985 to 2014, we combine qualitative information on depth and shoreline indicators to analyze conflict locations. We find virtually all expected conflict locations (98%) occurred within the zone meant to exclude industrial vessels, and conflicts concentrated primarily around major ports. Our results suggest conflicts are likely more related to spatial patterns of vessel presence than patterns of resource use. These findings suggest a critical need for evidence-based and contextual information on the drivers of fisheries conflicts, rather than continued reliance on assumptions of resource scarcity. They also suggest that nuanced policies that reduce vessel encounter and clarify exclusive spatial rights may be more important in responding to these conflicts than approaches designed to broadly separate fleets or increase fish stocks.

Key Words: *artisanal; coastal fisheries; intersectoral fishing conflict; West Africa*

INTRODUCTION

The utilization, study, and governance of marine resources occur primarily on land (Allison and Bassett 2015, McCauley et al. 2016), yet it is the interactions that occur “at sea” that matter most for marine resource sustainability and governance. Conflicts between fishing vessels are some of the most significant outcomes of these interactions at sea, and embody the evolving landscape of marine resource exploitation, competition, trade, and governance (Bavinck et al. 2014, Urbina 2015, Spijkers et al. 2019, Mendenhall et al. 2020). These conflicts involve verbal or physical altercations between individuals on separate fishing vessels, and accounts of these conflicts have been rising globally, particularly between small-scale fishing boats and more capitalized industrial vessels (Azad and Pamment 2020, Gunasekera 2021, Hunt 2021, Onyango 2021). In addition to the increasing prevalence of conflicts, evidence also indicates these conflicts are growing more severe in many locales, involving destruction of small-scale boats, assault, abandonment at sea, and murder (Fairlie 1999, Bavinck 2005, Environmental Justice Foundation 2007, Pomeroy et al. 2007, Dahlet et al. 2021). These conflicts represent a major threat to small-scale fishing lives and livelihoods (Environmental Justice Foundation 2005, 2012, BBC News 2016), and have been implicated in piracy and a host of human rights abuses, especially where governance is already weak (Murphy 2007, Brashares et al. 2014, FishWise 2014, Sumaila and Bawumia 2014, Glaser et al. 2019).

Many small-scale fishers report that competition and conflicts with industrial boats represent one of the greatest threats to their fishing livelihoods (Kura et al. 2004, Salayo et al. 2006, JALA 2007, Environmental Justice Foundation 2021). Even when these industrial/small-scale fishing conflicts are not violent or illegal, they can result in damage to equipment and/or loss of fishing opportunities. Conflicts thus have economic, health, and psychological costs for small-scale fishing communities, and households that rely on catches for income, employment, and food security (Kura et al. 2004, Sumaila 2018). Furthermore, considering current global trends in rising fisheries exploitation, “per capita” fish consumption, exports (FAO 2020), and climate change (Cheung et al. 2009, Pinsky et al. 2018, Sumaila et al. 2019), this inter-sectoral competition and conflict is expected to intensify (Miller et al. 2013). Previous studies of small-scale fisheries have explored the role of diverse environmental phenomena (e.g., climate change, pollution; Islam and Tanaka 2004, Lam et al. 2012, Campbell and Hanich 2014), and social phenomena (e.g., war, migration; Jorion 1988, Binet et al. 2012, Gaynor et al. 2016, Seto et al. 2017) in altering small-scale fishing dynamics. However, relatively little research has explored competition and conflict between small-scale and industrial vessels, and their environmental, social, and economic consequences. This dearth of research is understandable, considering the logistical challenges associated with conducting empirical work on conflicts that occur intermittently at sea (Bennett et al. 2001, DuBois and Zografos 2012). Diverse

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institutions, from fisher associations to non-governmental organizations, have designed monitoring and reporting programs to document these conflicts and better understand their characteristics; however, such programs often require substantial operating funds and mobile technologies that are not always consistently available (Environmental Justice Foundation [date unknown], Salayo et al. 2006). Despite this lack of empirical evidence, the importance of these conflicts to fishing households is critical to understand, in order to take seriously the claims of small-scale fishers and to equitably and sustainably manage fish resources (Kura et al. 2004, Menon et al. 2013).

Scholarship around industrial/small-scale fishing conflicts often theorizes them as a form of resource conflict, in that scarcity of fish resources is the dominant contributor to conflict and competition (DuBois and Zografos 2012, Pomeroy 2016). Within this framing, one hypothesis suggests that these conflicts occur because of the spatial expansion of small-scale fishing grounds, wherein small-scale fishers respond to locally dwindling stocks by expanding effort and fishing farther afield, thus overlapping in time and space with industrial vessels further from shore (FAO 2013, Mallory 2013, Brashares et al. 2014, Park et al. 2020). Another hypothesis suggests that resource conflicts are the result of industrial vessel incursion into inshore areas reserved for small-scale fishing; here, industrial vessels respond to declining catches by targeting increasingly shallow fishing grounds and fishing illegally in nearshore areas (Platteau 1989, Bavinck 2005, Kolding et al. 2014, Doumbouya et al. 2017). Alternatively, DuBois and Zografos (2012) provide a third hypothesis, differentiating between resource competition, that implies that vessels are targeting the same stocks, and spatial competition, which occurs whether or not the vessels are pursuing the same stocks. This hypothesis suggests that conflicts may not be related to scarcity-induced resource competition at all, but instead be driven by spatial competition, and therefore concentrate where there are increased encounters between small-scale and industrial vessels, unrelated to resource status (Diallo 1995, DuBois and Zografos 2012).

An essential first step in mitigating these conflicts is understanding conflict location. It is critical to identify and analyze the specific areas where conflicts occur to formulate fisheries policies in general, and conflict management approaches in particular, as well as to investigate the dominant factors driving conflict patterns. Current policies to address intersectoral conflicts at sea focus primarily on enforcing the spatial separation of small-scale and industrial vessels (Belhabib et al. 2019). These spatial approaches take different forms, but all delineate inshore areas as "exclusion zones" reserved for small-scale fishers, whilst deeper grounds further offshore remain available for industrial exploitation. However, this broad spatial separation has yet to be evaluated as a strategy for addressing or deterring conflicts, and the design and implementation of these approaches may vary widely. Improving our understanding of the spatial dynamics of these conflicts is imperative for designing evidence-based and appropriate policy responses.

We employ a novel spatial analysis to estimate the locations of industrial/small-scale conflicts at sea, to better understand potential conflict drivers, and related mitigation strategies. Our study was conducted in Ghana, West Africa, where small-scale fishing communities with some of the highest reliance on fish for food and income (FAO 2020) converge with extensive industrial fishing activity (Mullié 2019). Multiple publications have highlighted the importance of conflicts between small-scale and industrial fishers in Ghana (Mullié 2019, Ameyaw et al. 2021, Environmental Justice Foundation 2021), and the government utilizes a well-established inshore exclusion zone (IEZ) that is well-known by small-scale and industrial fishers. Using data from narrative reports on intersectoral conflicts at sea over the period of 1985 to 2014, we combined qualitative information on depth and shoreline indicators to conduct an analysis of conflict locations. Based on this spatial analysis, we explored support for alternative hypotheses for the drivers of conflicts at sea. If conflict is driven by resource competition via expansion of small-scale fishing grounds (H1), conflicts should primarily occur beyond the inshore exclusion zone reserved for small-scale fishers. If conflict is driven by resource competition via nearshore incursion of industrial fleets (H2), conflicts should primarily occur within the inshore exclusion zone on the continental shelf, where target species tend to aggregate. If conflict is driven by spatial competition, distinguished by Dubois and Zografos (2012) as unrelated to direct competition for resources (H3), conflicts should primarily occur near ports where there is high vessel traffic. Although we note that in some cases these drivers may collectively contribute to conflicts, we consider the three hypotheses as supported by distinct spatial trends. Finally, we recommend potential improvements to conflict management and governance, based on our insights into their spatial pattern.

METHODS

We drew on historical records (1985–2014) from national fisheries data systems to understand spatial patterns of small-scale/industrial conflict at sea in Ghana. We defined small-scale and industrial fishing vessels according to domestic Ghanaian criteria outlined in the Ghana Fisheries Act 625 of 2002, considering "artisanal" within the small-scale sector, and aggregating both "semi-industrial" and "industrial" vessels within the industrial sector (Government of the Republic of Ghana 2002, Nunoo et al. 2014, Ameyaw et al. 2021). Although the Ghana Fisheries Act 625 of 2002 officially codified the IEZ in its current form, some form of IEZ was formally used at least as early as 1991 (Government of the Republic of Ghana 1991, Kwadjosse 2018, Alabi-Doku et al. 2020), and was likely used informally prior to its codification. With this in mind, we consider the IEZ rule to apply to all cases, but note the possibility that the IEZ may not have officially applied to the 23 cases that occurred before 1991.

We compiled records from the Ghana Ministry of Fisheries and Aquaculture Development (MOFAD) Offices in Tema, Takoradi, and Accra, Ghana, as well as archives in Tema and Takoradi. Records represent cases from all four coastal regions in Ghana (Western Region, Central Region, Greater Accra Region, and Volta Region), which fishers submitted to the two Arbitration Committees—quasi-governmental institutions charged with arbitrating incidents at sea—located in Tema and Takoradi; descriptions of case characteristics are included in Table A1.1. Because the data only reflect those cases that were brought to the Committees, it is likely that a larger number of conflicts at sea occurred but were never reported (GNCFC and NAFPTA 2018).

It is also possible that the issue of reporting may bias data toward cases that are more proximal to Arbitration Committee locations, although there were reported conflicts from a diversity of locations along the entire coastline, regardless of proximity to committee locations (Table A1.1; Fig. A1.1). Cases were considered discrete units as they were reported to the Arbitration Committees, though in some cases, multiple petitioners or multiple accused parties were named in a single case. The full set of records included a wide range of information, from simple date and time data to comprehensive narrative information from conflict participants as well as administrative and official documentation from Ministry officials, fishing companies, and Arbitration Committee members (Table A1.2).

Conflict reports were not explicitly georeferenced, so to determine the probable location of each conflict, we relied on reported narrative information on both the depth and village waters where a conflict occurred (Table A1.1). A total of 380 out of 1063 records contained this information; although the remaining records have potential for additional quantitative and qualitative studies, we utilized the 380 with potential for spatial analyses. We created 50 nm sea space polygons to distinguish the local waters off the coast of each village. We then used these polygons to assign the depth values from the bathymetry raster to a village location based on their spatial overlap. This resulted in a list of spatially explicit points that had both depth and village sea space designation. For each recorded conflict, we used Python v.2.7.3 to assign a point for all locations that met both depth and location criteria. We then performed a kernel density analysis to create a map of probable historical conflict locations, weighting each point by the probability it represented a true conflict location (assuming equal probability of all potential locations for a given conflict). A radius of 10 km was calculated through a standard algorithm in the ArcGIS Kernel Density tool. This algorithm uses the unweighted distance of each point to another and the calculated mean center of the population to derive a standard distance. This radius also took into account the resolution of the bathymetric data that was used to derive potential conflict locations (Esri n.d., Silverman 1986). The resulting depiction represents the relative density of conflict throughout the study region.

To evaluate our hypotheses about the drivers of conflict, we explored predicted conflict intensity by quantifying its overlap with various spatial features of interest. First, we created 10 km and 20 km buffers from the ports in Sekondi, Takoradi, and Tema, the three locations in Ghana where industrial vessels can access shore. Second, we used the 75 m isobath as a proxy for the continental shelf. Although neither geological nor legal definitions of the continental shelf stipulate specific depths or distances from shore (Dodds 2010, Rothwell and Stephens 2010, Pinet 2011, Long 2012), continental shelves are typically at < 150 meters depth and in Ghana the continental shelf is usually at < 75 meters depth (Koranteng 2001, Pinet 2011). Finally, we also considered two measures representing the IEZ in Ghana, where industrial vessels are prohibited from fishing, and fishing rights are reserved for small-scale fishers (Government of the Republic of Ghana 2002). Despite the clear legal definition of Ghana's IEZ as the farthest limit of either the 30-meter isobath or the 6 nm offshore limit (Government of the Republic of Ghana 2002), the government, fishers, and other parties oftentimes use the 30-meter depth contour as a proxy. We therefore calculated two IEZ polygons: the first represented the 30-meter isobath used by the Government of Ghana as proxy for the IEZ (henceforth referred to as 30-m isobath), and we created the second based on bathymetry and distance to shore, to provide a more accurate representation of the IEZ as defined in the Ghana Fisheries Act 625 of 2002 (henceforth referred to as IEZ). Information on all spatial data layers is available in Table A1.3.

To understand how conflict intensity varied with these spatial features, we calculated isopleths of the predicted conflict locations, ranging from 50% (the core zone of conflict) to 99% (the comprehensive zone of conflict), at 5% increments. Isopleths are spatial polygons that represent the smallest area containing a given percentage of all probable conflict locations (as determined through the weighted kernel density estimation). Conflict intensity thus decreased as isopleth percentage increased. We then calculated the percentage of each of these isopleth polygons that overlapped with each of the spatial features defined above (10 km from port, 20 km from port, continental shelf, 30-m isobath, and IEZ). We used ArcGIS v.10.2 to create all original data layers and both ArcGIS and R v.4.1.1 to perform spatial analysis.

RESULTS

We found that there were 380 conflict reports for which location data were available, and there were between one and 30 potential locations associated with each conflict (mean = 4.89, standard deviation = 4.59; Fig. A1.2). The predicted zone of conflict extended along the entire coast of Ghana (Fig. 1), with the comprehensive conflict zone (99% isopleth) encompassing an area of 15,616 km². The core conflict zone (50% isopleth) had a much smaller area of 1330 km², suggesting a high degree of clustering, because half of the probable conflict locations fell within < 10% of the area of the comprehensive conflict zone (Fig. 2; Fig. A1.3).

Virtually all expected conflict locations occurred within the IEZ (98%), and the vast majority (81%) occurred within the 30 m isobath (Fig. 2). The core zone of conflict (50% isopleth) falls entirely within both the IEZ and the 30-m isobath. There was also complete overlap between the conflict zone and the continental shelf (Fig. 2).

Conflicts at sea were concentrated primarily around major fishing ports, with 51% of the comprehensive zone of conflict (99% isopleth) falling within 10 km of ports, and 61% falling within 20 km (Fig. 2; Fig. A1.3). This pattern is even stronger when considering the core conflict zone (50% isopleth), of which 78% falls within 10 km of ports, and 98% within 20 km. In general, conflict intensity increases when in proximity to ports (Fig. A1.3). Predicted conflicts show some additional clustering separate from ports, but areas representing the core zone of conflict are substantially smaller (Figs. 1 and 2).

DISCUSSION

Using qualitative historical records on conflicts at sea in Ghana, we mapped and examined potential conflict locations and explored the implications of these spatial patterns for conflict theory and management. Our results indicate that ports represent conflict hotspots because of spatial overlap between industrial and small-scale vessels (H3). The strong clustering of conflict near ports suggests that intersectoral conflicts are shaped less by simple notions of resource scarcity, or "too many fishers chasing too few

Fig. 1. Predicted spatial patterns of conflict between small-scale and industrial fishing vessels for (A) the entire study region along the coast of Ghana. This predicted conflict density was based on narrative information on conflict location as reported in historical conflict records (1985-2014). Insets show the areas around (B) the Tema port and (C) the Takoradi/Sekondi ports.

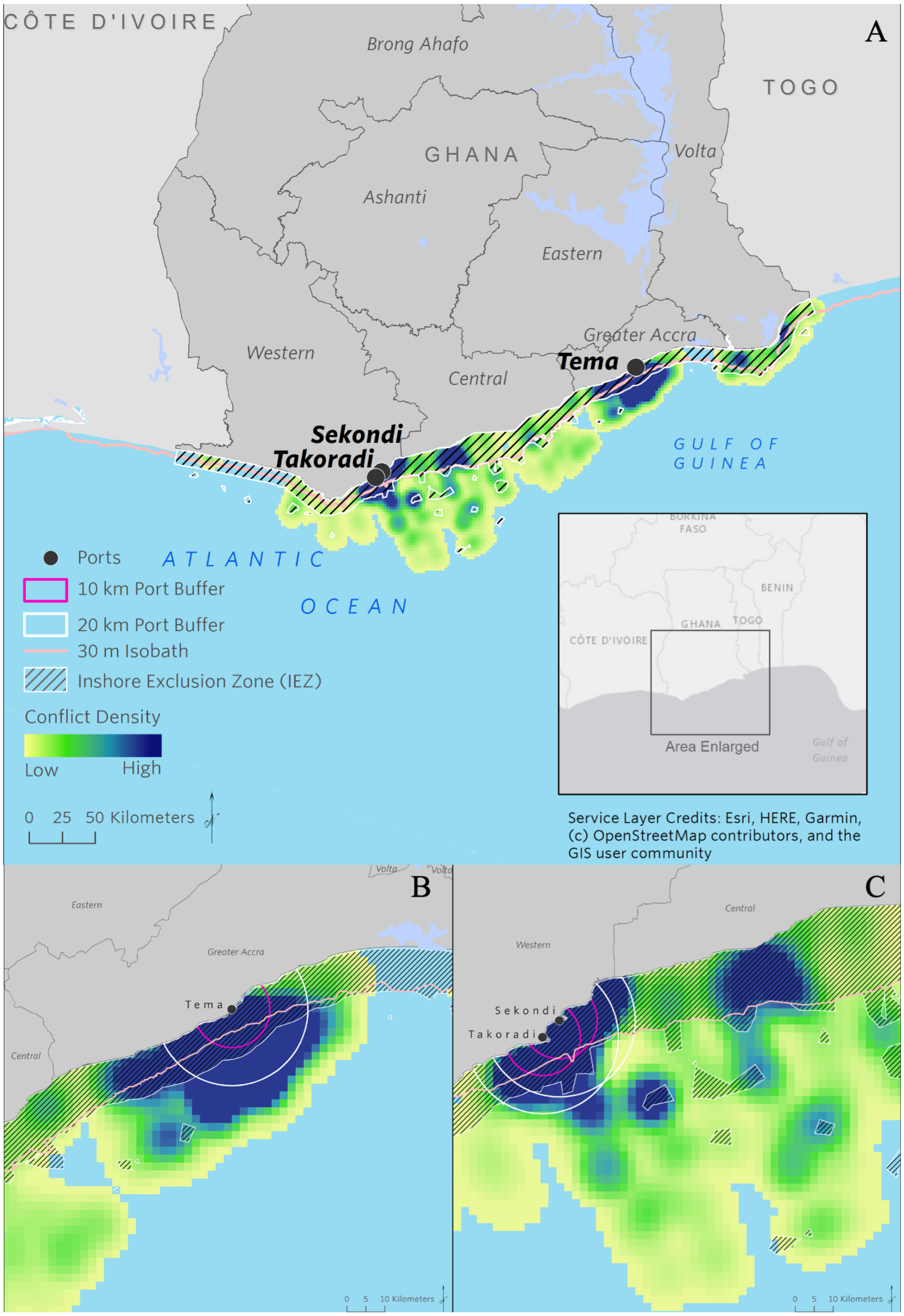
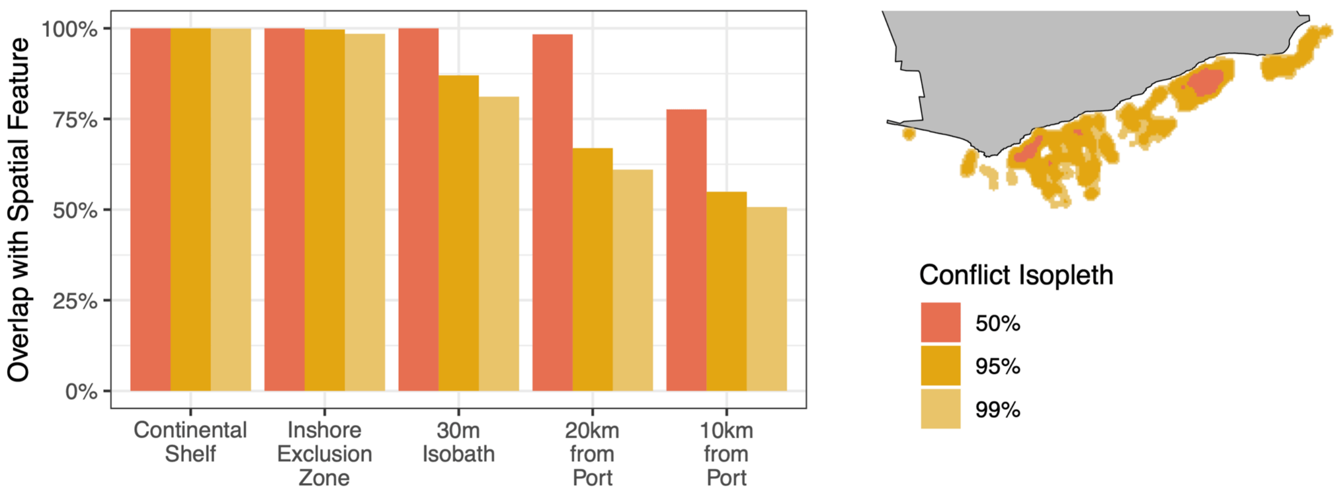


Fig. 2. The association of conflict between small-scale and industrial fishers with spatial features of interest (continental shelf, Inshore Exclusion Zone (IEZ), 30-m isobath, and port proximity) off the coast of Ghana. The overlap value on the y-axis corresponds to the percentage of each predicted conflict isopleth (50%, 95%, and 99%) that falls within the polygon associated with each spatial feature. Isopleths are spatial polygons that represent the smallest area containing a given percentage of all probable conflict locations, as determined through weighted kernel density estimation. The inset map illustrates the spatial distribution of the 50%, 95%, and 99% conflict isopleths along the coast of Ghana (land shown in gray).



fish" (Pauly 1990, Pomeroy et al. 2016), and shaped more by vessel encounter between the two sectors. Furthermore, it suggests that rules around navigation in the IEZ may be essential to the success of spatial management, and potentially more important in reducing these conflicts than rules controlling only for fishing.

Although this study does not preclude the possibility of resource decline (Lazar et al. 2020), there is little indication that areas near ports are disproportionately targeted for fishing, or that scarcity would be more prevalent in the hotspots identified in this study. Because industrialized fishing vessels are restricted to berthing within these larger ports, but small-scale fishing effort is dispersed throughout the coastline, it is far more likely that these conflicts would aggregate near ports because of increased industrial vessel presence. In fact, Ghana has approximately 300 small-scale fish landing sites distributed throughout the coast, and according to the 2016 frame survey, only 10% of small-scale fishing vessels are based in one of the three towns with large port facilities (Dovlo et al. 2016). It is important to note that resource competition may be expected to occur in other areas or time periods of target species concentration (e.g., seasonal spawning areas, migration corridors). However, only areas with a clear and consistent physical association (e.g., continental shelf) were utilizable in this study, and future research is needed to understand fine-scale spatiotemporal dynamics of resource conflict in relation to fish distribution.

We also found some evidence that resource competition via nearshore incursion of industrial fleets (H2) shapes conflict. Almost all predicted conflict locations occurred on the continental shelf and within the inshore exclusion zone that is restricted for small-scale fishers, suggesting that incursion by industrial fleets (H2) is a more likely driver of conflict than the expansion of small-scale fishing grounds (H1). Because virtually all conflicts in the analysis fell within the IEZ, this indicates strong support for the fact that conflicts predominantly occur within the area restricted for small-scale fishers, and are not related to expanded small-scale effort. This understanding can assist in the design and monitoring of marine regulations, and enforcement strategy of these spatial zones. IEZs are defined in a multitude of ways in different contexts, from simple distance metrics from shore (e.g., Liberia; Government of Liberia Ministry of Agriculture 2011), to connected GPS coordinates (e.g., Sierra Leone; Government of the Republic of Sierra Leone 2017), to composite indicators combining multiple variables (e.g., Ghana; Government of the Republic of Ghana 2002). Additionally, these spatial zones may indicate a range of prohibited activities (e.g., fishing, navigation), excluded actors, and special conditions or exemptions (Belhabib et al. 2019). The concentration of conflicts on the continental shelf suggests that shelf location should be a critical component in the design of exclusive zones. Using a simple distance from shore metric may be sufficient if it encompasses the full continental shelf area, but where continental shelves extend beyond these distances (as in the case of Senegal, Cameroon, and many others), there may be substantial conflicts that are unaddressed by the existing spatial rules (Fig. 2). Furthermore, beyond the design of these rules, the knowledge of conflict prevalence on the continental shelf may help to more effectively target prevention, monitoring, and enforcement efforts, if conflicts are more concentrated within these areas.

Spatial governance of ocean areas (e.g., marine spatial planning, marine protected areas, etc.) is a fundamental and growing component of ocean governance for coastal states (Roberts et al. 2005, Lorenzen et al. 2010). In Ghana, the IEZ is one of the oldest and most well-known of any restricted zones, and small-scale fishers are aware of, and often adamant about, the importance of this zone in preserving their fishing rights. However, although the Ghana Fisheries Act 625 of 2002 prohibits industrial and semi-industrial vessels fishing in the IEZ, it allows for navigation, and makes exceptions in the case of (a) permitted semi-industrial vessels targeting cephalopods, and (b) fishing vessels exempted by the Director of Fisheries (Government of the Republic of Ghana 2002). Therefore, it is not possible for small-scale fishers to know the full legal status of industrial vessels in the IEZ at the time of their interaction and potential conflict. Although these exemptions are not considered common practice, cases of exemptions are also not publicly available, and adding another layer of opacity for both fishers and fisheries officers. This ambiguity creates a potential misalignment between what may be the actual legal status of an industrial vessel in the IEZ and the perception of illegal behavior by small-scale fishers, who see themselves as having exclusive rights to inshore fishing areas. Therefore, the existence of these exceptions and exemptions may in fact exacerbate intersectoral conflicts, as they create the perception of exclusive spatial access for small-scale fishers, but fail to fully separate the fleets and impair the ability of both small-scale and industrial fishers to know with certainty the legality of industrial presence in this zone. Furthermore, any spatial monitoring and enforcement of this area by government or third parties requires knowledge not only of industrial vessel presence, but also activity (i.e., fishing versus navigation), and potential special status at that time. As such, methods of monitoring and enforcement that rely heavily on remote sensing (e.g., AIS, VMS, drones) are unlikely to be able to determine legality of activity without supplemental information. It may also prove challenging for fisheries officers involved in interdictions to validate in real time whether an industrial vessel has an active exemption, creating an added layer of uncertainty to the monitoring and enforcement of the IEZ.

It is not possible to determine whether industrial and semi-industrial vessels identified in this study were engaged in illegal activity, which is often cited as a contributor to fisheries conflict (Belhabib et al. 2019). However, the numerous case narratives describing industrial fishing in the IEZ, combined with the extremely high proportion of conflicts that occurred within the IEZ make it unlikely that all conflicts in this zone were attributable to navigation, or to vessels with exempt status (Pauly et al. 2013, Debrah et al. 2018, Ameyaw et al. 2021). This analysis is, however, able to compare conflicts at sea in the IEZ as outlined in the Fisheries Act with conflicts at sea within the 30-meter contour line most often applied by governing agencies. In our analysis, over 2.5 times as many potential conflict locations were included in the IEZ than the 30-m isobaths (Fig. 1). Therefore, how an IEZ is described within legislation, and how it is interpreted by fishers and managers, has considerable implications for monitoring and enforcement. In this case, it is likely that many of these potential conflict locations were in fact located within the IEZ, but were not perceived as such. For example, in both conflict hotspots near Tema and Takoradi, the 6 nm offshore limit extends substantially farther than the 30-m isobath (Fig. A1.3), indicating that managers applying the 30-m isobath rule would omit a large number of conflicts actually located in the IEZ from their consideration in monitoring and enforcement.

Although this study found that existing spatial management approaches (e.g., the IEZ) are inadequate to fully separate industrial and small-scale fleets and prevent conflicts at sea, some spatial methods are useful when they are well-designed. Our analysis suggests that IEZs should be designed with a few key factors in mind. First, the IEZ should fully encompass those areas traditionally fished by small-scale fishers, and be congruent with where small-scale fishers believe their exclusive rights to exist. These should be without exceptions and exemptions that might exacerbate frustrations by small-scale fishers, create uncertainty for fisheries officers, and obscure monitoring and enforcement efforts (GNCFC and NAFPTA 2018, Belhabib et al. 2019). Second, the IEZ should establish clear and conservative rules regarding navigation. The concentration of conflicts near ports suggests industrial vessels navigating are equally or more involved in conflicts when navigating than while fishing. Therefore, it is imperative to implement clear policies and obvious on-the-water indicators for where industrial vessels are allowed to navigate within the IEZ for the purposes of berthing. These rules should also be conservative, only allowing industrial vessels in narrow and well-defined areas for navigation, rather than throughout the IEZ. This relates to the need for clear and incontrovertible rights for small-scale fishers; if industrial activity may be exempt because of navigation or special status, the exclusive right of small-scale fishers is thrown into confusion. Implementation of effective rules pertaining to navigation is a key step in ensuring clarity and confidence on the part of small-scale and industrial fishers, as well as fisheries officers and enforcement agencies. Third, the IEZ should be legible to both small-scale fishers and industrial vessels, and strongly incorporate factors relating to the continental shelf. This study demonstrates that where the IEZ uses factors that are difficult to apply at sea, especially by small-scale fishers (e.g., 6 nm from shore), those factors are likely to be sidelined or ignored in favor of more interpretable factors (e.g., 30 m depth; Mullié 2019). With this in mind, and considering the strong concentration of conflicts on the continental shelf, we suggest that the IEZ should rely more heavily on depth indicators, which are legible at sea by both small-scale and industrial fishers (GNCFC and NAFPTA 2018). Together, these factors will improve the potential of spatial management to prevent and deter intersectoral conflicts, and better equip fisheries managers and monitoring, control, and surveillance officers to interpret and enforce the rules in these zones.

Whereas the design factors above may improve the ability of IEZs to address these conflicts, social and institutional approaches will be particularly important, as the different cultures and political economies of these two fleets are of central importance. Institutions and actors that are able to bridge the divides between industrial and small-scale "sea tenure" systems (Cordell 1989, Kolding et al. 2014) will be critical in avoiding conflictual interactions at sea. Similarly, institutions that can mediate these conflicts on land and displace the "action arena" from sea space and into appropriate onshore fora will be key (Ratner et al. 2013). These institutions will require high levels of perceived legitimacy and low enough transaction costs to be seen as a viable alternative to conflict in sea space for both industrial and small-scale actors. The particular form that these institutions may take, and their relative complexity, will depend on a number of contextual factors including whether fleets are foreign or domestic, migratory or sedentary, mixed species or specialized, and many other factors.

CONCLUSION

We found that industrial/small-scale conflicts at sea occur largely within the IEZ reserved for small-scale fishers, and within this zone, they are concentrated near ports. These findings support claims by Ghanaian small-scale fishers regarding the incursion of industrial boats (GNCFC and NAFPTA 2018, Mullié 2019, Ameyaw et al. 2021), and additionally bring into question the dominant framing of these conflicts as a simple resource conflict, wherein fishers instinctively compete and conflict over the limited resources of fish. If this were the case, we would expect conflicts to concentrate most in areas of high fishing pressure or low fish availability. Instead, the concentration near ports suggests that conflicts are shaped more by the disproportionate presence of industrial vessels in these areas than by disproportionate presence of small-scale vessels, or by increased fishing pressure by either fleet. We also find no evidence for the hypothesis that conflicts are driven by the expansion of small-scale fishing into industrially fished areas beyond the IEZ. Together, these findings suggest a critical need for evidence-based and contextual information regarding the drivers of conflicts between small-scale and industrial fishers, rather than a continued reliance on assumptions of resource scarcity (Scholtens and Bavinck 2018). This also suggests that nuanced policies designed to reduce vessel encounter and clarify exclusive spatial rights may be equally or more important in responding to these conflicts than approaches designed to broadly separate fleets or increase fish stocks (Fisher et al. 2018).

These intersectoral conflicts represent a major challenge to small-scale fishing lives and livelihoods, and in many places are more of a threat than other much more cited issues of climate-induced migrations, overfishing and local depletions, and pollution. Effectively addressing them will require tapping into the core legitimacy of different fishing communities and their claims, rather than a simple line on a map.

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Data Availability:

Data for this study are owned by the Government of Ghana Ministry of Fisheries and Aquaculture Development (MOFAD) and may be requested through official government channels.

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Appendix 1. Supplementary information.

Table A1.1: Coded data from Incident at sea database.

Incident at Sea Database		
Field	Range	Notes
Conflict Code	TA/TM + numerical	TA indicates records found in Takoradi, TM indicates records found in Tema, and numerical is arbitrary unique ID
Date	1985-2014	Dates with limited resolution (e.g. only month or year) were only included in analyses of available information
Time	00:00-23:00	Transformed to 24-hour clock time
Depth	10m-91m	Transformed to meters from abesem, feet, and fathoms
Incident location	1. Aboadze 2. Abuesi 3. Accra 4. Ada 5. Adina 6. Adjoa 7. Aflao 8. Ahwiam 9. Ampatano 10. Ampenyi 11. Anloga 12. Anomabo 13. Apam 14. Ashamang 15. Atiteti 16. Atorkor 17. Axim 18. Azizanya 19. Biriwa 20. Blekusu 21. Brenu Akyinim 22. Butre 23. Cape Coast 24. Cape Three Points 25. Chorkor 26. Dixcove 27. Egya 28. Elmina 29. Fete 30. Funko 31. Fuveme 32. Half Assini 33. Kafudzidzi 34. Keta 35. Komenda 36. Korle Gonno 37. Kpone 38. Labadi 39. Miamia 40. Moree 41. Mumford 42. New Amanful 43. Ngyiresia 44. Ningo 45. Nkotompo 46. Nungua 47. Nyanyano 48. Osu 49. Otuam 50. Prampram 51. Sakumono 52. Saltpond 53. Sarfa 54. Sekondi 55. Senya Beraku 56. Shama 57. Takoradi 58. Tegbi 59. Tema 60. Teshie 61. Volta Estuary 62. Winneba 63. Woe	Refers to associated village waters where incident occurred

Table A1.2: Sample of information included in records of conflicts between small-scale and industrial vessels in Ghana, as documented in reports.

Case ID	Depth	Village Associated Waters	Other info
TA005	N/A	N/A	06/16/2007; "settled amicably"
TA019	16 fathoms	Ampatano	12/05/1994; damaged set net
TA143	14.5 fathoms	Aboadze	2/13/1999; damaged set net; "After casting our net we sighted a boat from East towards our net as Southwest. We have 8 markers on the net. All indications made to the boat to change her course failed. By then our second canoe was at where they were passing and they also told them that there is a net there so they should return but they failed and rather started throwing crabs at them. They run through the net and went away without minding us. After hauling our net we went home."
TM050	27 feet	Apam	12/19/2009; [vessel name] compensated the fishermen; damaged set net; Estimated costs GH 485.00
TM269	7.5 fathoms	Nungua	09/27/2000; 6:00:00 AM; damaged drift gillnet; "we made an attempt to chase the boat with paddles but since it could not yield any result we decided to come ashore and inform the chief fisherman"
TM728	N/A	N/A	03/20/1997; Estimated damages GH 3,662,530.00

Table A1.3: Information on the sources of data layers included in spatial analysis.

Layer	Data type	Data source
Exclusive Economic Zone (EEZ)	Shapefile	VLIZ (2014). Maritime Boundaries Geodatabase, version 8. Available online at http://www.marineregions.org/. Consulted on 2016-05-25.
Village locations	Shapefile	Generated from conflict at sea database and Google maps (n=102)
Village seaspace polygons	Shapefile	Generated by calculating midpoints between villages village locations connected to a polygon buffer layer 50 nm from the coastline
Bathymetry	Raster (30-arc second grid cells)	General Bathymetric Chart of the Oceans (GEBCO)
30-meter depth contour	Line shapefile	Hɛn Mpoano project
Inshore exclusion zone (IEZ)	Shapefile	Generated by determining the areas within Ghana's exclusive economic zone (EEZ) that meet either criteria: 1) within 6 nm from shore OR 2) less than 30 m depth

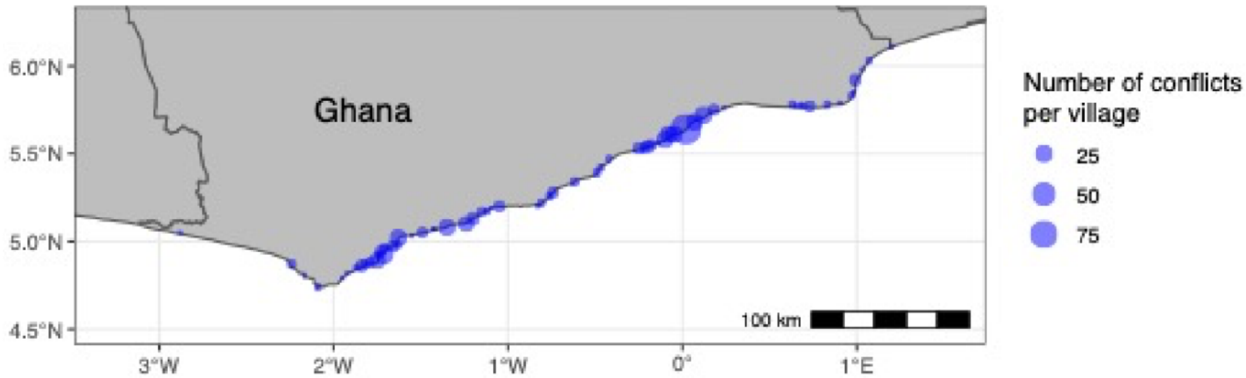

Fig. A1.1: Map of associated Ghanaian villages in whose waters conflicts occurred. The size of the point is indicative of the number of cases that were submitted for conflicts in those villages' waters. The map includes the n=380 conflicts included in this analysis.

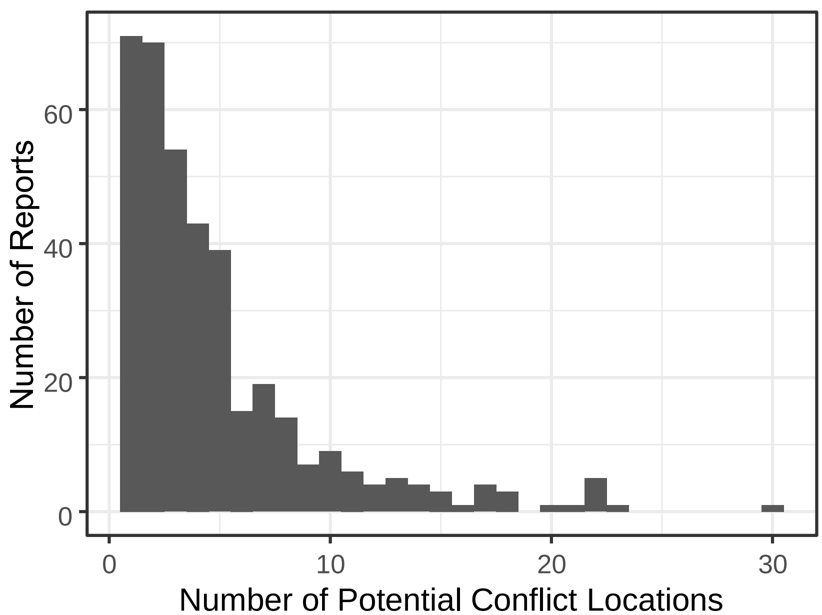

Fig A1.2: Histogram of the number of potential conflict locations for all reports (n=380). Many reported conflicts had multiple potential locations, given that spatial information was not explicit, but rather included information on nearby village and water depth.

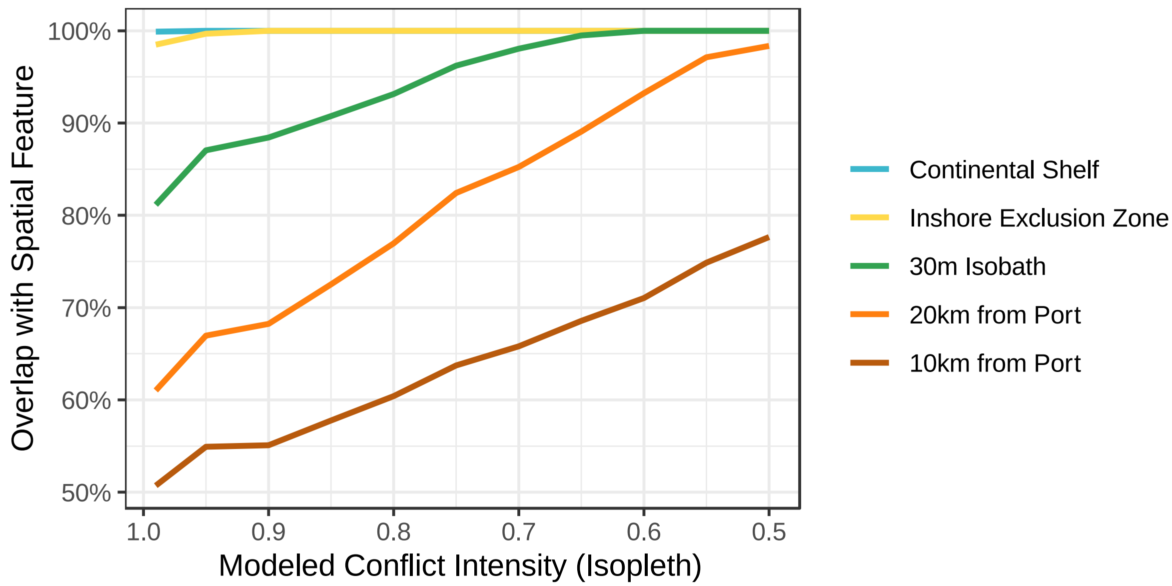

Figure A1.3: Spatial patterns of conflict between small-scale and industrial fishers in Ghana. This figure illustrates the relationship of conflict intensity (as estimated by calculating the 50%-99% isopleths at intervals of 5%) with spatial features of interest (continental shelf, IEZ, isobath, and port distance). Conflict intensity decreases as the isopleth percentage increases. Overlap on the y-axis corresponds to the percentage of each predicted conflict isopleth that falls within the polygon associated with each spatial feature.