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A micro-spatial analysis of opportunities for IUU fishing in 23 Western African countries

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1. Introduction

Illegal, unreported and unregulated (IUU) fishing is one of the biggest and most serious environmental crimes. Global fisheries lose an estimated 11–26 million tons, or roughly one-quarter of the world catch of fish to IUU fishing every year, making the annual economic loss about $11–24 billion (Agnew et al., 2009). This means 108,000 pounds (approximately 49 metric tons) of wild-caught fish are lost *every minute* to IUU fishing (Pew Charitable Trusts, 2013). Approximately three billion people depend on fish as a source of food and nutrition (FAO, 2016), and fish are the main source of protein for approximately one billion people worldwide (OECD, 2014). IUU fishing not only significantly impedes the development and sustainable management of the fisheries around the world, but it also severely undermines the global efforts to reduce malnutrition and hunger in developing countries. Considering that globally 94% of commercial fish are harvested within exclusive economic zones (EEZs) of coastal countries (SAUP, 2014), these economic losses directly impact these countries.

The Western African coast hosts some of the most fertile fishing grounds in the world (Ighobor, 2017). It encompasses the Canary and Benguela upwelling systems - the two ecosystems that maintain one of the world's most productive tuna fishing grounds (Daniels et al., 2016). This region is also among the regions in the world most affected by illegal fishing (Doumbouya et al., 2017): nearly 40% - the highest level worldwide, of all the fish caught in this region is illegal (Doumbouya et al., 2017; Agnew et al., 2009). In the European Union Strategy on the Gulf of Guinea, IUU fishing tops human, narcotics and arms trafficking, as one of the top threats in the region, having dominated EU's West Africa agenda since 2014 (Lewerenz and Vorrath, 2015).

By all measures, IUU fishing is a serious crime, however, criminological research on the topic remains relatively scarce. The criminological literature that does exist uses the framework of environmental criminology to empirically test the driving factors of IUU fishing. Petrossian (2015), in her study of 53 countries, found that IUU fishing within the EEZs of these countries is driven by the availability of highly commercial species, and the countries' relative proximity to known ports of convenience. Other studies examined the CRAVED[1] characteristics of commercial fish and crustacean species, and their vulnerability to IUU fishing (Petrossian and Clarke, 2014; Petrossian et al., 2015a), and found that the easily 'concealable', 'removable', 'abundant', as well as 'valuable' and 'enjoyable' species were significantly more likely to be targeted by IUU fishers than their matched controls. Lastly, two criminological studies specifically examined that ports of convenience facilitated IUU fishing by allowing 'concealability' of illegally caught fish that are laundered through these ports (Petrossian et al., 2015b; Marteache et al., 2015). None of these past studies, however, examined the driving factors and opportunity structures for IUU fishing in a micro-spatial context, which is the aim of the current study. Guided by the theoretical assumptions of environmental criminology, this research examines the relevance of micro-spatial predictors of IUU fishing in the exclusive economic zones of 23 Western African countries, and expects that the attributes of these locations, when combined in prescribed ways, create contexts in which certain outcomes are made more likely, and, as such, can predict the spatial preferences of likely motivated offenders.

1.1. Guiding theory: environmental criminology

In their seminal work, "Opportunity Makes the Thief", Felson and Clarke (1998) argued that crime opportunities are a necessary condition for a crime to occur, in other words, crime is largely a product of opportunity. They then laid out ten principles that formed the foundation for three 'opportunity' theories in criminology: the routine activity approach, the crime pattern theory, and the rational choice perspective, all of which belong to the family of theories known as environmental criminology. *The routine activity approach* suggests that for a crime to occur, there must be a convergence in time and space of three elements: a motivated offender, a suitable target, and the absence of a capable guardian (Cohen and Felson, 1979).

The crime pattern theory (Brantingham and Brantingham, 1993) considers how people move about in space and time. Movement from one area, or node, to another, creates an activity space for the offenders. According to the theory, crime happens when the activity space of a victim or target intersects with the activity space of an offender.

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[1] The CRAVED acronym was proposed by Clarke (1999) to explain the characteristics of products that make them attractive to thieves. The products that are easily concealable, removable, available, valuable, enjoyable and disposable are more likely to be stolen, according to this theft model.

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Importantly, they suggest that the journey to crime is typically very short - offenders generally don't travel far from these nodes and paths to commit crimes (also see Rossmo, 2000, for a discussion of the literature on this).

Lastly, *the rational choice approach* (Cornish and Clarke, 1987) assumes that offenders make rational decisions structured by the social, environmental and situational variables. Offenders prefer to commit crime in environments that provide high rewards, as well as minimal risk and effort.

It is important to note that the above-mentioned theories focus on explaining the *crime events* in the context of the immediate environment in which these events unfold (Wortley and Townsley, 2016). These theories focus on explaining the interaction between the motivated offender and the opportunities for crime commission created by the environment. As such, these theories focus on crime problems, rather than offenders' criminal dispositions that may lead them to commit a crime.

Environmental criminological theories have the following important five premises: (1) crime is always a choice; (2) opportunity plays a significant role in crime; (3) crime is highly concentrated (in time and space, among offenders and victims) where the opportunities are greatest; (4) all crime can be reduced if measures that reduce crime focus on reducing the opportunities for crime; (5) to be successful, any prevention measure should be tailored toward highly specific forms of crime and take into consideration the unique opportunity structures and facilitating conditions that assist the crime commission.

Consistent with the expectations outlined by these theories, we would expect to find significant concentrations of IUU fishing activities around the micro-environmental opportunity structures that not only reward such activity, but also facilitate easy removal and inconspicuous getaway, lowering the risk of apprehension and the consequent costs of engaging in such activity (Sumaila et al., 2006).

2. Materials and methods

2.1. Study area and units of analysis

This research examines IUU fishing activity within the exclusive economic zones of 23 countries in the Western African coast. The data available on the variables were at the ½ ° × ½ ° latitude and longitude grid cell level, therefore, the units of analysis in this study included a total of 2342 grid cells that were clipped to the exclusive economic zones of these 23 countries.

2.2. Data sources

This study uses a range of geographic and species-specific variables from various sources. This section provides an overview of these data sources and the variables they measure.

Source 1. Aquamaps.org provides data on the natural occurrences of known marine species around the world (Aquamaps, 2017). Using different algorithms and data sources, the species distribution data provided by Aquamaps.org take into consideration such environmental factors as temperature, salinity, water depth, and primary productivity, among others, to estimate the probabilities of a given species occurrence at a ½ ° × ½ ° latitude and longitude grid cell level. The data can be downloaded in a spreadsheet format and converted into an ArcGIS-compatible shapefile format to display the species-specific information on a map. This research uses Aquamaps.org species distributions data for 2016 for all the species used in the models (to be discussed later).

Source 2. The Sea Around Us Project (SAUP) is a scientific research initiative housed at the University of British Columbia. The goal of the project is to provide assessments on fisheries around the world, and their impact on the global marine ecosystems (SAUP, 2017). This research uses EEZ-specific data to identify the commercially harvested species within the EEZs of the 23 countries examined, and the commercial status of these species as of 2016 (which is listed as "commercial for local use", "commercial for use elsewhere", "highly commercial for local use", etc.…). According to Petrossian (2015), countries are most vulnerable to IUU fishing if they have species that are highly commercial internationally. Upon a closer look at the species found within the EEZs of these 23 countries, this research identified a total of 22 such species that were not only commercially harvested species within individual countries in West Africa, but also "highly commercial for use elsewhere" (SAUP, 2017). These species were extracted for analyses in this study (see Appendix A for a list).

Source 3. In their study, Petrossian and Clarke (2014) used multiple data sources to identify species that were most frequently targeted by IUU fishers ($N = 58$) (henceforth, CRAVED species). They also used multiple sources to create risk scores for these CRAVED species. These species were significantly more likely to be caught illegally than their matched controls due to their CRAVED characteristics. The current research extracted a total of 20 species from this list that are commercially harvested in the 23 West African countries examined (not replicating the already identified 22 highly commercial species mentioned above). Some of these species were not highly commercial, however, they were included in the analyses, as it was their overall CRAVED status that distinguished these species from the other 22 highly commercial species identified earlier. Conversely, the highly commercial species initially identified that were also CRAVED species were treated as CRAVED species, as more information could have been obtained about these species (i.e. CRAVED information). Appendix B provides a list of these species, their risk scores, as well as the countries where they are commercially harvested.

Source 4. The Pew Environmental Group (2010) conducted a study examining the worldwide movements of blacklisted fishing vessels from January 2004 through December 2009. During the study period, the research recorded a total of 509 different movements, and these included 425 visits to 140 ports in 71 countries. Data on the number of IUU visits to the ports that are in Western Africa were extracted from the Pew (2010) study. In addition to the 19 Western African ports identified, this research uses two additional ports (Las Palmas de Gran Canaria and Santa Cruz de Tenerif), considering the relative importance of these ports in the region as hubs for transporting fish from Western Africa into Europe. According to past research (Petrossian, 2015; Petrossian et al., 2015b; Marteache et al., 2015), ports of convenience are significant magnets for carrying out and inconspicuously offloading illegal catch, therefore, data on these ports were collected for use in this study.

Source 5. National Geospatial Intelligence Agency (2017) provides data on over 3700 ports around the world. The data are available in a shapefile format and can be downloaded and displayed in ArcGIS. Port location information was obtained from this data source to map out the locations of the 21 ports of convenience (19 West African and 2 Spanish).

Source 6. Global Fishing Watch (GFW), an initiative sponsored by Google, Oceana and SkyTruth, uses open technologies to publicly broadcast Automatic Identification Signals (AIS), a tool that tracks vessel locations via satellites and ground-station receivers from fishing vessels around the world (Global Fishing Watch, 2016). The GFW uses a convolutional neutral network analysis method to extract fishing effort (by number of hours) by gear type and flag country, among other vital information to ensure transparency of the activities of the global fishing industry. The data are available at different resolutions. This research uses the 2016 fishing effort data provided at the ½ ° × ½ ° latitude and longitude grid cell level, as data on species distributions and their probabilities from Aquamaps.org were available at that level of resolution only. Data on the locations of global transshipment activities in 2016, were also provided by Global Fishing Watch (for more information on transshipment data, as well as the methodology of data collection, see Kroodsma et al., 2018).

Source 7. International Transport Workers' Federation is an