# Property Rights to the (Linear) Ocean in Customary International Law

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**Abstract.** I model the ocean as a line, or an array of lines, and show how the most profound change in property rights in human history, creation of the Exclusive Economic Zone, emerged as an equilibrium in customary international law. In a symmetric ocean, I find that customary law codifies efficient Nash equilibria, and steers countries away from inefficient Nash equilibria. The model also identifies the trigger for this change in property rights—access to nearshore fisheries by foreign fleets—and the reason choice of a particular limit, like the current 200-mile zone, is arbitrary. In an asymmetric, regional sea, I find that the scope of the EEZ is determined by the relative power of coastal and distant water states, and need not be efficient. Finally, I find that proposals to nationalize the seas or ban fishing on the high seas are neither efficient nor supportable as equilibria in customary law.

**JEL Codes:** K33, F55, Q22

**Key words:** customary international law, exclusive economic zone, fisheries

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## 1. Introduction

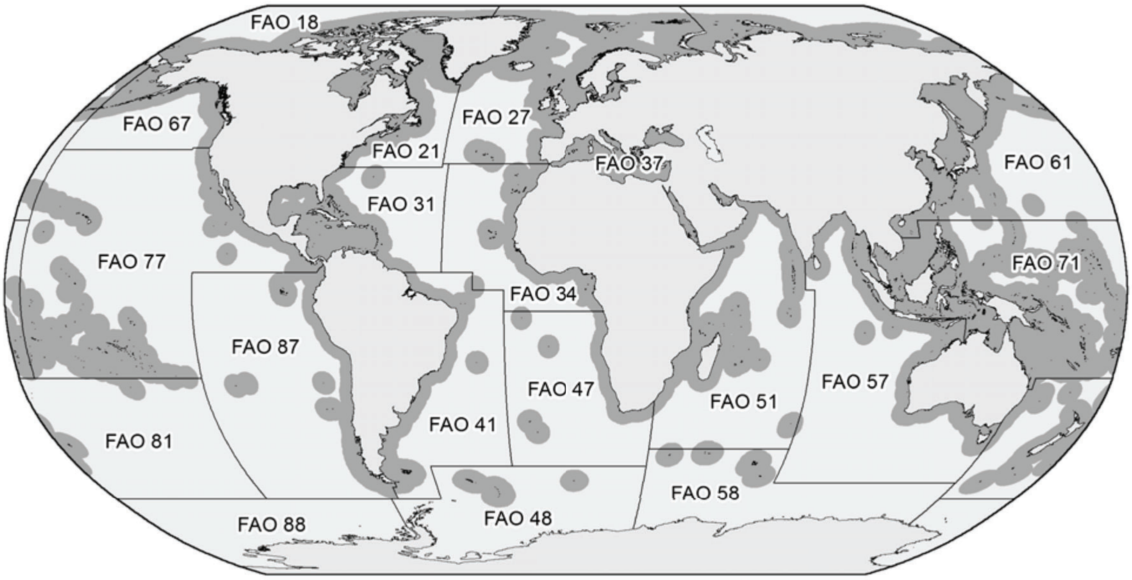
Collective action at the international level is aided by two kinds of institution, customary international law and treaties. Custom determines the rules of the game; treaties address specific issues. Custom applies universally; treaties apply only to the countries that consent to be bound by them. Custom emerges spontaneously; treaties are constructed deliberately. Custom changes rarely; treaties are negotiated and renegotiated all the time. A substantial literature has modeled treaties as devices for achieving collective action, implicitly taking customary law as given.[1] By contrast, though a few papers have used game theory to interpret custom, the question of how to model this institution remains unsettled. In this paper I model an important and unusually clear example of customary law: creation of a new kind of property right to the world's ocean, the exclusive economic zone.

The world's EEZs, shown in Figure 1, make up about 40 percent of the world's ocean and almost 30 percent of the Earth's surface.[2] When first established, about 99 percent of the world's commercial catch was taken within these zones (today, about 97 percent).[3] Creation of the EEZ marks one of the most significant developments in the history of property rights, and yet the origins and consequences of this event have been largely neglected by economists. How and why did the EEZ come to be adopted? Why was it set at 200 nautical miles rather than some other value? Do EEZs increase rents or merely redistribute them? Recently, more radical changes in property rights have been proposed as a (partial) remedy to persistent overfishing, from complete closure of the ocean to a ban on high seas fishing.[4] Could these proposals be

[1] For example, the extensive literature on international environmental agreements (for a recent survey, see de Zeeuw 2015) implicitly assumes (see Barrett 2003) that compliance is a given—an assumption that is consistent with the customary principle known as *pacta sunt servanda* (treaties are to be kept).
[2] This map also shows fishing areas in regional seas, a geography I study later in the paper.
[3] http://www.seaaroundus.org.
[4] Englander (2019) shows that unauthorized fishing is 80% lower just inside the EEZ boundary compared with just outside of it, implying that EEZs are enforced (though not uniformly) and thus valuable. The extent to which EEZs have aided conservation is unknown.

supported as equilibria of the ocean property rights game? Would rents increase if they were? In this paper I develop a model capable of answering these questions.

**Figure 1: Exclusive Economic Zones**




Source: http://www.seaaroundus.org/catch-reconstruction-and-allocation-methods/

The model incorporates two novel features: (i) a geography of the ocean, its fisheries, and the economics of their exploitation; and (ii) the institutional setting in which property rights to the ocean come to be established.

I take the original, static representation of the fishery developed by Gordon (1954), which the literature subsequently developed in a dynamic direction (beginning with Scott 1955), and set it in a spatial context. Most dynamic fisheries models have zero spatial dimension, and thus ignore the aspect of a fishery that is critical for understanding the emergence and evolution of property rights. For simplicity, I ignore dynamics (stocks in my model should be interpreted as steady state values), and model the ocean as a line (one dimension), or an array of lines, situated in a circle (a two-dimensional plane). Coastal states are assumed to be symmetric, and represented by homeports (points) spaced equidistantly around the circle. I model three types of fishery—nearshore, offshore, and highly migratory—and assume that their stocks are distributed uniformly on the line or lines corresponding to their range. States choose fishing effort (fleet size), as usual, and distance, a new variable. Fishing a greater distance is more costly, but provides access to a larger share of a given stock.

I first solve the model assuming freedom throughout the seas. I then suppose that coastal states have exclusive jurisdiction out to a given distance from their homeports, the current situation. Finally, I let coastal states *choose* this property right. If states choose a value of zero, the equilibrium is freedom on the seas. If they choose a positive value, the equilibrium is an EEZ, possibly coupled with a high seas area.

Property rights to the ocean are established in customary law and not by individual choice alone. How to model customary law is the second critical feature of my model.

A customary law exists if states behave in accordance with the law, and do so in the belief that they *are legally obligated to behave in this way* (Bodansky 1995). Because custom is founded in beliefs, lawyers have debated whether it exists let alone whether it has real effects. Goldsmith and Posner (1999) argue that behaviors consistent with self-interest have been misinterpreted as customary law. They also argue that, being the product of a decentralized process, custom is incapable of solving multilateral collective action problems. Norman and Trachtman (2005), by contrast, contend that customary law sustains efficient equilibria in a repeated prisoners' dilemma.[5]

To determine whether custom has real effects, I distinguish behavior supported in customary law from non-cooperative behavior. In some situations, consistent with Goldsmith and Posner (1999), I find that custom coincides with Nash behavior. In other situations, like Norman and Trachtman (2005), I find that custom supports an equilibrium that is mutually preferred by all countries to the Nash equilibrium. This

[5] The difficulty with this approach is distinguishing behavior supported by custom from behavior that could also be supported by non-cooperative behavior.

is for a symmetric ocean. In a regional sea in which coastal and distant water states vie to define the EEZ's scope, I find that the interpretation that wins out is determined by the relative power of these antagonists and need not be efficient. My model thus offers a more complex reading of customary law than the previous literature.

A theory of property rights to the ocean must not only explain why the EEZ emerged when it did, but why a regime of freedom of the seas prevailed previously. My model shows that, absent customary law, countries would have nationalized the seas. Choice of a regime of freedom of the seas thus reflects the restraining influence of custom.

Why did the three-mile limit give way to a 200-mile EEZ? Why was the change adopted in one fell swoop rather than inched up incrementally? Verdier and Voeten (2014) argue that customary law changes in response to a "tipping" behavior that is sensitive to heterogeneous preferences. In my model, the trigger for change is different and simpler. I find that changes in custom occur abruptly when the value of an exogenous variable crosses a critical threshold. Below the threshold, one property rights regime is adopted (freedom of the seas); above it, another is adopted (the EEZ). The variable that causes this shift is entry by foreign fleets—a result that, as I shall explain, agrees with the historical record.

Another fascinating feature of the EEZ is that its precise value, 200 miles, finds no justification in ecology, economics, or (as I explain later) legal precedent. In my model, choice of a particular value is arbitrary: the equilibrium EEZ established in customary law is either zero or a strictly positive value that is bounded but indeterminate and chosen for its "focal" qualities (Schelling 1960).

Customary law also underpins the other choices in my model, distance and effort. The custom of "freedom of navigation" allows fishing vessels to travel throughout the seas. The custom of "freedom of fishing" allows countries to apply effort as they please in the high seas. I find that freedom of navigation is efficient when property rights are established in customary law. By contrast, freedom of fishing leads to inefficiency.

Why not limit the right to fish in customary law? Optimal effort is stock-specific and dependent on numerous conditions. It cannot be reduced to a simple, universal rule. Instead, effort is decided by regional fisheries management organizations. However, a country can avoid having to comply with RFMO rules by not becoming a member. The UN Fish Stocks Agreement limits the right to fish within an RFMO's territory to RFMO members only, but this restriction applies only to the parties to *this* agreement. Custom could universalize the restriction, but doing this would only shift the burden of free rider deterrence to the RFMOs, whose weak governance makes enforcement difficult.[6] Here, I ignore RFMOs and assume that states are free to choose their effort.

In addition to explaining the past, my model can be used to evaluate proposals for changes in property rights. One radical proposal is to extend today's EEZ to its maximum extent, eliminating the high seas entirely (Hannesson 2011b). Though this would end free access by distant water states, I find that it would also limit access by coastal states and, depending on the spatial distribution of the fishery, have no effect on their incentive to overfish. Another radical proposal is to retain the current EEZ and ban fishing on the high seas (Global Oceans Commission 2014). Contrary to previous studies (White and Costello 2014; see also Sumaila *et al*. 2015), I find that that such a ban is the worst of all property rights remedies. Like the other proposal, it fails to limit overfishing by coastal states. In addition, by imposing a tougher restriction on where these states may fish, it increases their costs even more. I find that neither proposal can be supported as an equilibrium in customary law.

In the sections that follow, I provide a brief history of property rights to the ocean, and then present and solve the model. I first solve for effort and distance assuming freedom of the seas (the historical situation) and a given, positive EEZ (today's situation). I then derive property rights equilibria in customary law and compare

[6] Under the "objections" procedure, for example, any party may decide unilaterally not to be bound by a majority decision.

these to their Nash counterparts. From there, I examine how coastal and distant water states vie to establish property rights in a regional sea, and evaluate the proposal to close the high seas. I conclude by summarizing the main results.

## 2. Emergence of a New Property Right

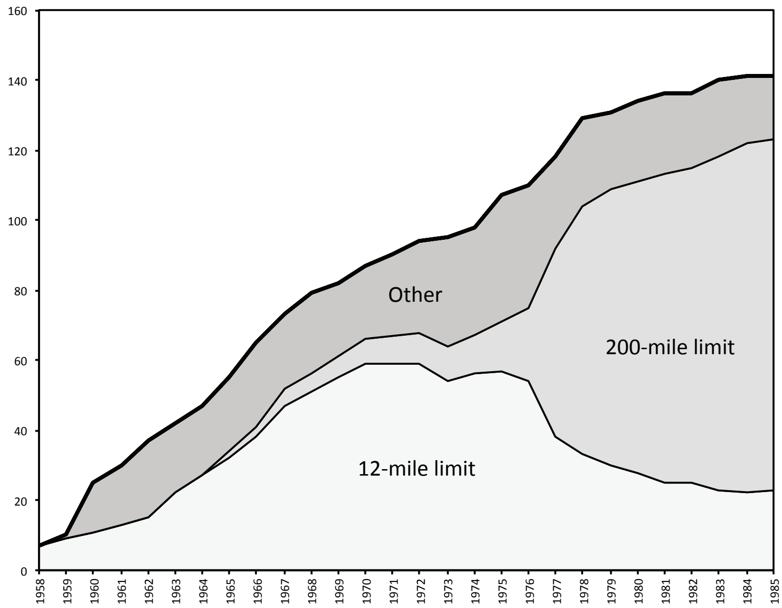
The EEZ emerged out of a process whereby a coastal state would assert an exclusive right to fish beyond its traditional, three-mile territorial sea, and other states would respond either by recognizing the claim, usually by asserting the same right, or by acquiescing to, or denouncing, it. Contemporaneous with these developments, property rights to the ocean were discussed in a series of Law of the Sea conferences. These were complementary processes. Spontaneous behavior by countries acting unilaterally revealed dissatisfaction with the status quo ante, whereas the conferences coordinated choice of a new rule and facilitated negotiation of a grander bargain over related issues, such as access to resources beyond the continental shelf. Ultimately, the 200-mile limit came to be codified in the Law of the Sea treaty, adopted in 1982. However, "[i]t is at the very least arguable that [the EEZ was] established… in general customary law *before* [my emphasis] it was adopted in the final [Law of the Sea] Convention text" (Lowe 2013: 204). Certainly, the EEZ was enshrined in customary law before this agreement entered into force in 1994. Though the United States has yet to ratify the Law of the Sea Convention, by proclaiming a 200-mile conservation zone in 1976, upgraded to a 200-mile EEZ in 1983, the US affirmed the existence of the EEZ in customary law (Henkin 1984: 1564).

Figure 2 shows the number of fisheries-related property rights claims made over time, separated into three categories, 12-miles, 200-miles, and "other."[7] As the aggregate of these claims (shown by the dark line) increases during the period, the figure reveals growing dissatisfaction with the traditional three-mile territorial sea. At the

[7] The figure reports the most extensive claim to a fisheries zone by each state. For example, if a state claimed both a 12-mile territorial sea and 200-mile EEZ, the figure shows only the latter limit.

first Law of the Sea Conference in 1958, a number of countries proposed a 12-mile exclusive fisheries zone. Over time, more and more countries agreed, and by 1972 it looked as if a 12-mile limit might become law. By 1979, however, backing for the 12-mile limit had eroded, whereas support for a 200-mile limit had grown ten-fold (the US declared a 12-mile exclusive fishing zone in 1966 but changed this to a 200-mile zone in 1976).[8] In just a few years, property rights to the world's oceans flipped. At the start of the decade, a three-mile territorial limit prevailed; by the end, a 12-mile territorial sea coupled with a 200-mile EEZ had taken its place.

**Figure 2: Claims to a 200-Mile Exclusive Economic Zone**




Source: Compiled using data from Smith (1986).

It might appear from Figure 2 that support for the 200-mile limit was less than universal well into the 1980s, as some states continued to claim 12-miles and others a different value altogether. However, custom doesn't *require* that coastal states claim an EEZ; it merely *permit*s them to do so. States claiming a 12-mile zone at this time

[8] The figure shows formal claims. At the Law of the Sea negotiations in 1974, 110 states supported the 200-mile limit, eight opposed it, and 23 expressed no opinion (Alexander and Hodgson 1975).

were really claiming a 12-mile territorial limit and *no* EEZ. Why would a state forego an EEZ? Most states bordering the semi-enclosed Mediterranean feared that if they declared an EEZ, other Mediterranean states would make a reciprocal claim, forcing each to fish only within its own EEZ (Ijlstra 1992: 180). This explains why France and Spain declared an EEZ on their Atlantic coasts but not, until recently, in the Mediterranean.[9] Even now, only five out of 18 Mediterranean states have declared an EEZ in this sea. Finally, the reason states assert an EEZ in the "other" category is due to their geography.[10] For example, the sea separating Sweden from its neighbors is less than 400 miles in every direction, constraining Sweden to an EEZ of less than 200 miles. In sum, by the late-1970s, states claimed a 200-mile EEZ when doing so was feasible and desirable, a shorter EEZ when an EEZ was desirable but a 200-mile limit infeasible, and no EEZ when an EEZ was undesirable.

Though Figure 2 ends in 1985, the situation today looks much the same. Of the 149 member-states of the United Nations with a coastline, 113 have declared a 200-mile EEZ, 21 a 12-mile territorial sea and no EEZ, and 15 an EEZ of between 12 and 200 miles for reasons of geography.[11] The 200-mile limit established in the mid-to-late-1970s remains the customary rule today.

Why did freedom of the seas prevail previously? A different regime could have been chosen. Indeed, centuries ago, a different regime *was* chosen. The 1494 Treaty of Tordesillas divided the world along a meridian 370 leagues west of the Cape Verde Islands, assigning the eastern half to Portugal and the western half to Spain, and strongly implying "that the two sovereigns owned the seas within their respective spheres" while retaining the right of innocent passage (Pardo 1984: 9). It was not until the early seventeenth century that the principle of *mare clausum* (closed sea)

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[9] France proclaimed a Mediterranean EEZ in 2012. Spain initially protested against this move, but then reversed its position, declaring its own Mediterranean EEZ in 2013.
[10] Under the Law of the Sea Convention, archipelagic states may claim an EEZ beyond 200-miles, subject to certain restrictions, when the distance separating their islands exceeds this amount.
[11] In 1985, there were 159 UN members. Today, there are 193. Data for the current status of maritime claims are from https://www.cia.gov/library/publications/the-world-factbook/fields/283.html.

came to be challenged by its opposite, *mare liberum* (free sea), and not until the eighteenth century that the cannon-shot rule, which later became the three-mile territorial sea, "predominated, and claims to large areas of sea faded away" (Brownlie 1990: 234). In my model, the Nash equilibrium sustains a closed sea regime of the type claimed by Portugal and Spain, whereas customary law sustains a regime either of freedom of the seas (no EEZ) or of an EEZ coupled with a free high-seas.

The process of establishing an EEZ began when US President Harry S. Truman issued a proclamation on September 28th, 1945, asserting the right of the US to establish fisheries conservation zones "in those areas of the high seas contiguous to [its] coasts," due to a concern about "the inadequacy of present arrangements for the protection and perpetuation of the fishery resources" in these seas. Critically, Truman went on to acknowledge the "right of *any* [my emphasis] State to establish conservation zones off its shores in accordance with" the same principles, virtually announcing that his claim, to be considered legitimate, had to be accepted in customary law.

Though Truman's proclamation opened the door to a change in property rights, the US did not make a specific claim at this time. Chile moved first in this game, declaring a 200-mile "exclusion zone" in 1947, as "Chile's infant whaling industry found itself threatened by ever increasing levels of competition from efficient distant water whaling fleets" (Hollick 1977: 497). Peru and Ecuador quickly followed Chile's lead, wanting also "to protect their fishing fleets" at a time when "the prospect of American tuna fishing in waters off their shores was growing" (Hollick 1977: 499). Later, all three countries consolidated their claims in the Santiago Declaration of 1952, but other countries refrained from joining them, and the US opposed their claims. At this point, claims to a 200-mile zone were just claims, not law.

Inspired by these early moves, Iceland declared a four-mile fishery limit in 1952, followed by a 12-mile limit in 1958 and a 50-mile limit in 1972, out of fear that "overfishing by foreign fleets was depleting a natural resource on which [Iceland's] economy depended for survival" (Mitchell 1976: 128). Having fished in these waters for centuries, the United Kingdom protested; but because the two countries resolved their disputes through bilateral agreements, Iceland's claims failed to presage a change in custom. In 1972, however, Kenya introduced draft articles on the concept of an "Exclusive Economic Zone" to the UN Committee on the Seabed, and after that more and more countries began asserting a 200-mile limit. By the time Iceland did so in 1975, provoking a third Cod War with the United Kingdom, customary law seemed ready to tip. The final blow came in 1976, when countries attending the fourth session of the Third Law of the Sea Conference recognized the right of coastal states to establish an EEZ. Indeed, even the United Kingdom, which had strongly opposed Iceland's 200-mile claim, extended its own Exclusive Fisheries Zone from 12 to 200 miles in 1977. Within a year or two, property rights to the world's oceans had undergone an unprecedented and abrupt regime shift.

Why 200 miles and not some other number? The choice can be traced to Chile's initial claim, a focal point. But why did Chile choose 200 miles? It turns out that, for Chile's purposes, "the distance finally adopted could as easily have been 50 or 300 miles as 200 miles" (Hollick 1977: 495). The idea of declaring a limit originated with a Chilean whaling company, hoping to block distant water fleets from whaling near Chile's coast. The company only desired a 50-mile zone, but its legal counsel believed that, for reasons of legitimacy, a claim had to be grounded in legal precedent. The precedent they chose was the 1939 Declaration of Panama, an agreement adopted after the outbreak of World War II to keep the waters off of the Americas "free from the commission of hostile acts." In preparing for these talks, the US Department of State drew a map showing a 300-mile security zone. Using a pencil, President Franklin D. Roosevelt then modified the map, adding eleven small "x" marks to the zone's outer boundaries, labelling these from "A" to "L" (intentionally or unintentionally, skipping "D"), and drawing "straight lines with a ruler between those points."[12] As a consequence, the breadth of the security zone now ranged from 300 to 500 miles

[12] See https://history.state.gov/historicaldocuments/frus1939v05/map-panama. The declaration is at https://history.state.gov/historicaldocuments/frus1939v05/d60.

(Armanet 1984: 29). After some further tweaking, Roosevelt's proposal was adopted in the Declaration, but identified only by its coordinates. Rather than accept the linear configuration, or convert it to a single value, the whaling company relied on a map appearing in a Chilean publication, which mistakenly showed the security zone as extending only 200 miles (Armanet 1984: 29). Chile's President, Gabriel González Videla, then adopted this limit without fact checking. The 200-mile limit ultimately established in customary law was thus the product of a sequence of judgements and errors. However, it sufficed to serve as the universal EEZ because, consistent with the theory developed later, a "correct" value neither existed nor was needed.

## 3. Model

My model is grounded in the classic Gordon-Schaefer static model of a fishery (Gordon, 1954; Schaefer, 1954), which the literature subsequently developed in a dynamical direction.[13] In this paper, I develop it in a spatial direction.

In the standard model, the fishery inhabits a point. Previous papers modified this model by allowing the fishery to comprise a multiple points or "patches" (Sanchirico and Wilen 1999, 2005), linked by diffusion equations that describe the movement of fish between points. White and Costello (2014) and Finus and Schneider (2015) adapted this approach to ocean fisheries, letting some "patches" represent EEZs and a residual one the high seas. However, these models lack a true geography. I model the ocean as a line, or an array of lines, placed in a two-dimensional plane, on which are situated coastal states' "homeports."[14]

[13] Scott (1955) emphasized the need to model dynamics, an approach that was later developed rigorously by Clark and Munro (1975), Clark (1976), and others. Munro (1979) and Levhari and Mirman (1980) were the first to model the transboundary management problem as a non-cooperative game, though they focused on the dynamics of competition between only two players; for reviews of the more recent literature, see Bailey, Sumaila, and Lindroos (2010) and Hannesson (2011a). My model was inspired by Hotelling's (1929) classic paper on competition on "Main Street," though in my model the players choose distance, not location.

[14] Though it might seem more natural to model the ocean in two (or even three) dimensions, the results would then be sensitive to the assumed shape of the ocean.

Herrera et al. (2016) also place the fishery on a line, but without reference to the players' territories. In their (dynamic) model, states choose effort along different sections of a line (and at different points in time), guided by such considerations as where the preponderance of fish are located and their assumption that individual effort is costlier where total effort is greater. They show that states have incentives to forgo fishing within some sections so as to shift stocks to neighboring areas, increasing rents. They also show that, as the number of countries exploiting a fishery increases, these "no fish" sections shrink and eventually disappear. Herrera et al. (2016) call these "no fish" sections "reserves," but they are *de facto,* not *de jure*, reserves. In my paper, property rights are established in law.

As my model is static, stocks are best interpreted as steady state values.[15] Finus and Schneider (2015) also employ a static model. White and Costello (2014) and Herrera et al. (2016) use dynamical models, but their analyses focus on steady state solutions as well. All of these papers rely on simulations. Here, I derive analytical solutions.

Like all the other papers mentioned here, my model is symmetric (though later I consider an important asymmetric situation). Specifically, the ocean is drawn with reference to a circle of length $L$ ($L > 0$), on which reside $n$ coastal states, each of which is represented by a different point, with the points being spaced equidistantly from one another (the distance between any two neighboring countries is thus $L/n$).

An important assumption concerns the spatial distribution of the stock(s) of fish in relation to this circle. I consider three types of fishery, illustrated in Fig. 3 under the arbitrary assumption that $n = 4$:

[15] A dynamic counterpart to my model would involve not patches but a single population, with fish diffusing from line segments of higher to lower concentration, without preference for direction, as in Fick's first law (Fickian diffusion is equivalent to random walk in the continuous limit). Fick's second law describes how concentrations change with time and can be used to solve for the steady state distribution, which will be uniform on a circle of finite circumference. Biased diffusion would give a different distribution, as in Herrera et al. (2016). See also Okubo and Levin (2001).

1. A single *highly migratory* stock, distributed uniformly on $L$, represented by the circumference of the circle; see Fig 3a. The uniformity assumption holds roughly for species like tuna (Block *et al*. 2005), which are caught both inside and outside today's 200-mile EEZ (Schiller et al. 2018). Note that this distribution can also be interpreted as representing transboundary stocks shared by a subset of countries in a regional sea (such as anchoveta, shared by Chile and Peru), as $n$ can be any positive integer value; Palacios-Abrantes et al (2020) show that most harvested species are fished from shared stocks.

**2.** A single *offshore* stock, consisting of $n$ straight lines, or spokes, each of length $w$, $w \in (0, r_0)$, which radiate out from the center of the circle with radius $r_0$ in the direction of each country's homeport; see Fig 3b. Offshore stocks include toothfishes, found in deep waters, the only commercially-important species harvested exclusively outside the current EEZ (Schiller et al. 2018). They also include species like cod and halibut, found in relatively shallow, offshore waters, like the Flemish Cap in the Northwest Atlantic. If the EEZ exceeds $r_0 - w$, then the offshore stock will be a "straddling stock."

3. $n$ biologically independent and spatially separate *nearshore* stocks, distributed uniformly on the circle, beginning at each state's homeport and extending in a clockwise direction to a distance, $s$, $s \in (0, L/n)$; see Fig 3c. These fish are normally found between the shore and the limit of the continental shelf, which extends, on average, about 30 nautical miles from shore, but can stretch beyond the current, 200-mile EEZ. This is where the primary producers, plankton, obtain their nutrients due to upwelling, supporting the world's most productive fishing grounds, including the Southeast Pacific Anchoveta Fishery. Nearshore stocks that extend beyond the current EEZ, such as the "nose" and "tail" of the Grand Banks fishery, are also "straddling stocks."

## Figure 3: Three Linear Fisheries

Figure 3a: The Highly Migratory Fishery

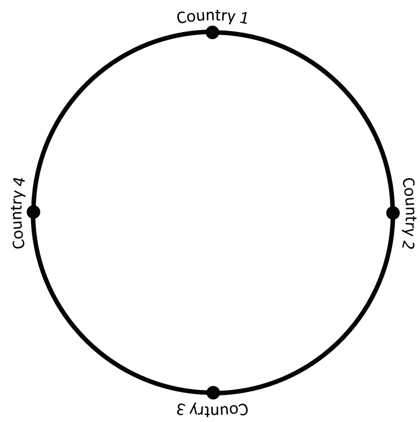



Figure 3b: The Offshore Fishery

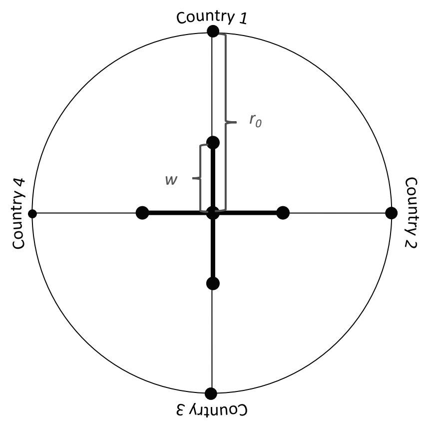
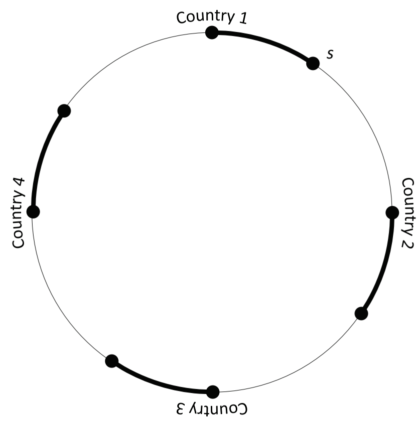



Figure 3c: The Nearshore Fishery



Notice that, as $w \to r_0$, the distinction between offshore and highly migratory stocks blurs. Though situated differently in the two-dimensional plane, with or without an EEZ, both stocks are the common property of all coastal states.

Obviously, many alternative configurations could be considered. For example, all three fisheries could be represented by a hub and spoke arrangement. As well, different assumptions could be made about their distribution for any linear geography. The assumption of a uniform distribution is the simplest, but any distribution supported on a bounded interval (such as the two-sided truncated normal distribution) could be analyzed within the framework of this paper.[16]

A novel variable in this model is the distance a state travels from its homeport. Denote $i$'s chosen distance $d_i$, and assume (innocuously) that, for highly migratory and nearshore fishery stocks, each state must move in a clockwise direction, starting from its homeport. For these cases, $d_i \in [0, L]$. To harvest an offshore stock, states travel along the line that connects their homeport to the center of the circle and, from there, move along any or all of the other $n$ - 1 line segments radiating out from this point. For an offshore fishery, the economic range for distance is $d_i \in [0, r_0 + w(n-1)]$.

It shall prove convenient to refer to a country's "own" line segment. For highly migratory and inshore fisheries, country $i$'s line segment extends from its own homeport to that of its nearest neighbor, moving in a clockwise direction, and is of length $L/n$. For an offshore fishery, country $i$'s line segment extends from its own homeport to the center of the circle and is of length $r_0$.

For highly migratory and offshore fisheries, denote the stock by $x$. The uniformity assumption implies that the stock available to country $i$, $x_i$, depends on the distance $i$ chooses to fish. For the highly migratory fishery, $x_i = xd_i/L$. For the offshore stock, $x_i = 0$ for $d_i \in [0, r_0 - w]$, $x_i = x(d_i - r_0 + w)/wn$ for $d_i \in [r_0 - w, r_0 + w(n-1)]$,

[16] Herrera et al. (2016) choose a symmetric distribution with a single peak in the center of the line and with zero supports on the ends of the line.

and $x_i = x$ for $d_i \geq r_0 + w(n-1)$. Finally, for nearshore fisheries, denote the stock adjacent (in a clockwise direction) to country *i*'s homeport by $x^i$, the stock adjacent to the homeport of the next country (again, moving in a clockwise direction) by $x^{i+1}$, etc. Then the stock available to *i* in fishery *i + m* is $x_i^{i+m} = 0$ for $d_i \leq mL/n$, $x_i^{i+m} = x^{i+m}(d_i - mL/n)$ for $d_i \in [mL/n, mL/n + s]$, and $x_i^{i+m} = x^{i+m}$ for $d_i \geq mL/n + s$; $m \in \{0,1,\dots,n-1\}$.

For highly migratory and offshore fisheries, country *i*'s harvest, $h_i$, is assumed to depend on *i*'s effort, $E_i$, and the stock available to *i* by virtue of its choice of distance:

$$h_i = \alpha E_i x_i. \tag{1}$$

For nearshore fishery *j*, country *i*'s harvest depends on the stock of fishery *j* available to *i*, by virtue of *i*'s choice of distance, and the effort *i* allocates to *j*:[17]

$$h_i^j = \alpha E_i^j x_i^j. \tag{2}$$

Assuming logistic growth in the stock, and interpreting *x* to be a steady state value, the aggregate harvest in the highly migratory and offshore fisheries is given by

$$h = \sum_{i=1}^{n} h_i = rx\left(1 - \frac{x}{K}\right), \tag{3}$$

where *r* denotes the intrinsic rate of growth of the stock (biology) and *K* is carrying capacity (ecology). For nearshore fishery stocks, we have

$$h^j = \sum_{i=1}^{n} h_i^j = rx^j\left(1 - \frac{x^j}{K}\right) \forall j. \tag{4}$$

[17] To simplify notation, I do not assign a different $\alpha$ to each stock. Nor do I do so for the parameters $r, K, p, c$, and $\gamma$ introduced later in this section.

Substituting and rearranging gives, for the highly migratory fishery,

$$x = K\left(1 - \frac{\alpha}{rL}\sum_{i=1}^{n} E_i d_i\right) \text{ for } d_i \in [0, L]; \tag{5}$$

for the offshore fishery,

$$x = K\left(1 - \frac{\alpha}{rwn}\sum_{i=1}^{n} E_i (d_i - r_0 + w)\right) \text{ for } d_i \in [r_0 - w, r_0 + w(n-1)]; \tag{6}$$

and, for the *j*th nearshore fishery, *j* = 1, … *n*,

$$x^j = K\left(1 - \frac{\alpha}{rs}\sum_{m=0}^{M} E_{j-m}^{j}\left(d_{j-m}^{j} - mL/n\right)\right) \text{for } d_{j-m}^{j} \in [mL/n\,, mL/n + s], \tag{7}$$

where $M$ is the number of coastal states, other than *j*, that fish in the waters adjacent to *j*'s homeport. Here, for any *j*, country *j* – *m* is located *m* line segments away from *j* in a counterclockwise direction. In the model, $M$ is to be determined endogenously.

Another important assumption concerns costs. For highly migratory and offshore fisheries, let *i*'s total costs be given by

$$C_i = (c + \gamma d_i)E_i; c, \gamma > 0. \tag{8}$$

For inshore fisheries, costs are given by

$$C_i = \sum_{m=0}^{M} \left(c + \gamma d_i^{i+m}\right) E_i^{i+m}\,. \tag{9}$$

If distance is given, eqs. (8) and (9) reduce to the standard assumption, dating back to Gordon (1954), that costs are proportional to effort (see also Clark 2006). The parameter $c$ represents the fixed cost of fishing effort (the cost of boats sitting in the homeport). The novelty in eqs. (8)-(9) is the spatial dimension.

The assumption that costs are linear in distance seems a natural companion to the assumption that costs are linear in effort. It might be supposed that marginal distance costs are increasing, implying a relation like $C_i = (c + \gamma d_i^\nu)E_i, \nu > 1$. However, though costs must be incurred in keeping vessels at sea for longer, and in traveling greater distances, investments in transshipment and resupply vessels allow owners to avoid "the fuel expenditure and lengthy breaks in fishing required to return to port or their home countries," a cost savings (Tickler *et al*. 2018: 3). Indeed, since 1950, mean distance fished has doubled; today, all parts of the ocean are fished, except for the polar extremes (Tickler et al. 2018).

According to eqs. (1)-(2), to obtain a positive harvest, a state must expend a strictly positive effort over a strictly positive distance. Increases in effort and distance are equally effective in increasing harvests, but (8)-(9) imply that effort is the costlier option. Hence, if a state chooses to fish within a fishery, it will want to fish everywhere within the fishery. Spatial evidence confirms that fishing effort is deployed far and wide, though unevenly (Sala et al. 2018). Seas such as the northeast Atlantic and northwest Pacific, for example, are fished more intensively than the Southern Ocean and central Atlantic, mainly due to variations in net primary productivity (represented by $K$). Another source of variation is the property rights regime. Kroodsma et al. (2018: 905) find that the EEZs of many island-states form "conspicuous 'holes' in the global effort map." This reason for spatial variation is the main focus of my attention.

## 4. The Ocean with no EEZ

Assume to begin that a regime of freedom of the seas prevails, as it did (outside the traditional three-mile territorial limit) prior to the establishment of the EEZ.

### 4.1 The highly migratory fishery

Coastal state $i$'s profit from fishing is $\pi_i = ph_i - C_i$ or, upon substituting,

$$\pi_i^{HM} = p\alpha K E_i \frac{d_i}{L}\left[1 - \frac{\alpha}{rL}\left(E_i d_i + \sum_{j\neq i} E_j d_j\right)\right] - (c + \gamma d_i)E_i. \tag{10}$$

Every country $i$ maximizes (10) by choosing $E_i \geq 0$ and $d_i \in [0, L]$, taking as given $E_j, d_j, j \neq i$. Assuming a symmetric interior solution,

$$E_i^{HM} = \frac{rL}{\alpha(n+1)d}\left(1 - \frac{L(c+\gamma d)}{p\alpha K d}\right). \tag{11}$$

For any positive distance, effort will be positive so long as the term in brackets is positive. This term is increasing in distance. Assuming that it always pays a coastal state $i$ to fish within its own line segment (that is, to choose $d_i \geq L/n$), the term in brackets will be positive provided:

$$\phi > 0, where\ \phi = \left(1 - \frac{(cn + \gamma L)}{p\alpha K}\right). \tag{12}$$

Assuming that (12) holds, and noting that the second order conditions are satisfied, eq. (11) describes the Nash equilibrium effort level for given distance.

Maximization of (10) by choice of $d_i$ yields another first order condition. However, and as noted before, cost function (8) implies that states will always prefer to increase distance rather than to increase effort (which involves a fixed cost). Hence, in a Nash equilibrium, coastal states will fish throughout the ocean: $d^{HM^*} = L$. Substituting this value into (11) then gives each state's Nash equilibrium effort level:

$$E^{HM^*} = \frac{r\theta}{\alpha(n+1)}, where\ \theta = \left(1 - \frac{(c+\gamma L)}{p\alpha K}\right), \tag{13}$$

and $\theta > 0$ by assumption (12).

### 4.2 The offshore fishery

For the offshore fishery, coastal state *i* maximizes

$$\pi_i^{OS} = p\alpha K E_i \frac{(d_i - r_0 + w)}{wn}\left[1 - \frac{\alpha}{rwn}\left(E_i(d_i - r_0 + w) + \sum_{j \neq i} E_j\left(d_j - r_0 + w\right)\right)\right] - (c + \gamma d_i)E_i. \tag{14}$$

As in the highly migratory fishery, it is easy to show that if it pays state *i* to fish anywhere in the offshore fishery, then it will pay *i* to fish everywhere in this fishery: $d^{OS^*} = r_0 + w(n-1)$. Maximizing (14) with respect to effort and substituting gives

$$E^{OS^*} = \frac{r\psi}{\alpha(n+1)}, where\ \psi = \left(1 - \frac{\left[c + \gamma\left(r_0 + w(n-1)\right)\right]}{p\alpha K}\right). \tag{15}$$

It is easy show that $\psi > 0$ provided that it always pays a country to fish within its own line segment.

### 4.3 The nearshore fishery

As each nearshore fishery is ecologically independent of the others, we can focus on exploitation of the *i*th nearshore fishery:

$$\pi_{i-m}^{NS_i} = p\alpha K E_{i-m}^{i} \frac{\left(d_{i-m}^{i} - mL/n\right)}{s}\left[1 - \frac{\alpha}{rs}\sum_{m=0}^{M} E_{i-m}^{i}\left(d_{i-m}^{i} - mL/n\right)\right] \\ -\left(c + \gamma d_{i-m}^{i}\right)E_{i-m}^{i}, \quad (16)$$

for all $i = 1, \ldots, n$, where, again, $i - m$ represents the country situated $m$ line segments away from $i$ in a counterclockwise direction; $m \in \{0,1, \ldots, M\}, n-1 \geq M \geq 0$. Since we know it will pay each of the *M* countries to fish throughout the *i*th fishery, we can write the first order conditions for an interior solution as

$$E_{i-m}^{i} = \frac{r}{\alpha}\left[1 - \frac{[c + \gamma(s + mL/n)]}{p\alpha K}\right] - E^{i} \forall m, \quad (17)$$

where $E^{i} = \sum_{m \in M} E_{i-m}^{i}$. Summing eqs. (17) over all $m$, and noting that $\sum_{m} m = M(M+1)/2$, we can solve for $E^{i}$. Substituting into (17) gives

$$E_{i-m}^{i} = \frac{r}{\alpha(M+2)}\left[\varphi - \frac{\gamma L[2m(M+2) - M(M+1)]}{2p\alpha K n}\right], \varphi = \left(1 - \frac{(c + \gamma s)}{p\alpha K}\right). \quad (18)$$

To guarantee that a sole owner (the solution to (18) with $m = M = 0$) will choose positive effort, assume $\varphi > 0$. Eq. (18) shows that countries located closer to the fishery (from a counterclockwise direction) apply more effort than countries located farther away.[18] Setting $m = M$ in (18), we can calculate the largest value of $M$ for which $E_{i-m}^{i} > 0$. Solving the resulting quadratic equation gives:

**Lemma 1**. *In equilibrium, the number of countries exploiting a nearshore fishery is either n or the largest integer less than or equal to* $\widehat{M} + 1$, *whichever value is smaller, where* $\widehat{M} = \sqrt{9 + 8p\alpha K\varphi/(\gamma\, L/n)}/2 - 3/2$.

[18] If near-shore fisheries were situated on spokes emanating from each homeport in the direction of the center of the circle, in equilibrium every state would either exploit "its own" fishery or every fishery.

According to Lemma 1, a nearshore fishery will be exploited by from one to $n$ countries, depending on parameter values. For example, as $L \to \infty$, all else equal, $\widehat{M} \to 0$, and each country will fish only within its adjacent fishery ($M$ = 0).

### 4.4 Tragedy of the Commons

The above solutions imply:

**Proposition 1.** *In an ocean subject to freedom of the seas, the "tragedy of the commons" for both highly migratory and offshore fisheries is due to excessive fishing effort, not excessive distance. For nearshore fisheries, effort and distance are both efficient for* $\widehat{M} < 1$, *and both excessive for* $\widehat{M} \geq 1$.

This result anticipates much of what will follow. For highly migratory and offshore fisheries, the only property rights arrangement capable of sustaining a first best outcome assigns an exclusive right to fish to a single country or supranational organization (a World Fisheries Organization, say). If all coastal states retain the right to fish, efficiency requires limits on effort, not geography; that is, it requires effective cooperative agreements, not a property rights solution. By contrast, for nearshore fisheries, efficiency requires that each fishery be exploited exclusively by the country whose homeport lies adjacent to the fishery.

## 5. The ocean with a given EEZ

Figures 4a-c show how property rights map onto the three linear fisheries (again, for $n$ = 4), assuming a given, symmetric EEZ. The figures are drawn from Country 1's perspective. For all three fisheries, establishment of a uniform EEZ removes line segments that can be fished by Country 1 (and, indeed, every country). This, of course, is the purpose of an EEZ: exclusion.

# Figure 4: Seas Available to Country 1 for a Given, Common EEZ of Length z

Figure 4a: Property Rights in the Highly Migratory Fishery

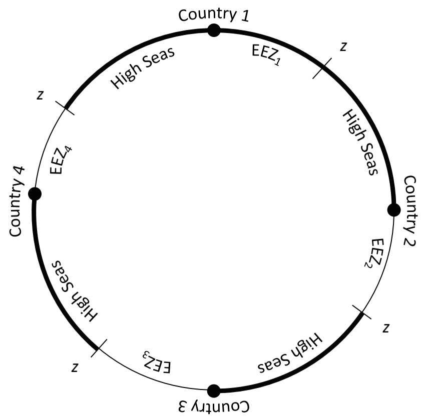



Figure 4b: Property Rights in the Offshore Fishery

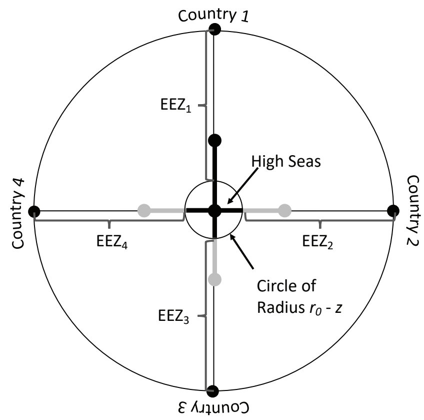
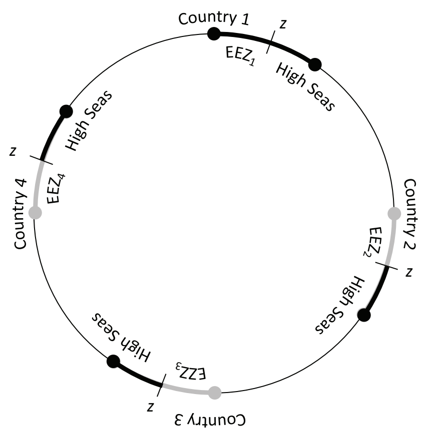



Figure 4c: Property Rights in the Nearshore Fishery



### 5.1 Highly migratory fishery

Anticipating a symmetric equilibrium, let $z$ denote the length of each country's EEZ and $y$ the number of foreign EEZs from which each country $i$'s fleet is excluded because of $i$'s choice to fish to a distance $d_i$. In Figure 4a, for example, if $d_1$ reached the high seas part of country 3's line segment, and no farther, country 1 would be excluded from the EEZs of countries 2 and 3 (but not from the EEZ of country 4). In this example, $y = 2$.

Equations (1) and (5) now become[19]

$$h_i = \alpha E_i(d_i - zy)x/L \tag{19}$$

and

$$x = K\left(1 - \frac{\alpha}{rL}\sum_i E_i(d_i - zy)\right). \tag{20}$$

We know from before that as $z$ approaches 0, $d_i^*$ will equal $L$. We also know that as $z$ nears $L/n$ , $d_i^*$ will equal $L/n$. Hence, there must exist a critical value of $z$ such that, for $z$ greater than this critical value, each country will fish only within its own line segment, and for $z$ less than this critical value, each country will fish throughout the ocean. That is, in equilibrium we will have either $y^* = 0$ *or* $y^* = n - 1$. Let

$$\hat{z}^{HM} = \frac{cL}{cn + \gamma L}. \tag{21}$$

Ignoring indifference, we then get (see Online Appendix):

---

[19] I am assuming that every country $i$ regulates total effort without regard to whether this effort is deployed within its EEZ or on the high seas.

**Lemma 2**: *If $z < \hat{z}^{HM}$, coastal states will exploit a highly migratory fishery within their own line segment and throughout the high seas beyond; if $z > \hat{z}^{HM}$, coastal states will fish only within their own line segment.*

Having to traverse another country's EEZ in order to gain access to the high seas beyond it is like having to pay an entrance fee to fish in these waters. As the EEZ increases, the entrance fee increases and the reward to gaining access to the high seas (the share of fish available to foreign fleets in these waters) decreases. Beyond the critical level, $\hat{z}^{HM}$, it pays coastal states to fish only within their own line segments.

### 5.2 Offshore fishery

For the offshore fishery (Fig. 4b), provided $z \leq r_0 - w$, the EEZ limit will not constrain access. As $z \in [0, r_0]$, and, by assumption, it always pays a coastal state to fish within its own line segment, we have:

**Lemma 3**. *For any $z \in [0, r_0]$ every coastal state will exploit an offshore fishery within its own line segment and in any high seas segments of the fishery that exist beyond that.*

Notice that, for $z > r_0 - w$, the EEZ makes the fishery a "straddling stock."

### 5.3 Nearshore fishery

The calculus for a nearshore fishery (Fig. 4c) is akin to that of the highly migratory fishery. Under my assumptions, a state will always fish the entire length of its adjacent fishery. An increase in $z$ has two effects on neighboring states: (1) it increases their cost of access; and (2) it shrinks the stock available to them, should they choose to enter. For both reasons, an increase in $z$ reduces the returns to fishing beyond a state's own line segment, reducing the number of states fishing within any particular fishery.

We know that every state that participates in any nearshore fishery will fish the entire length of the fishery available to it. In the Appendix, I solve for the Nash equilibrium in effort levels. Using these relations, we can solve for $M$, the number of non-adjacent states fishing in fishery *i*. Let

$$\varepsilon(z) = \frac{(s-z)}{s}\left[1 - \frac{(c+\gamma s)(s+z)}{p\alpha K(s-z)}\right]. \tag{22}$$

We then have:

**Lemma 4**. *In equilibrium, the number of countries exploiting a near-shore fishery is either n or the largest non-negative integer less than or equal to* $\widehat{M}(z)+1$, *whichever value is smaller, where* $\widehat{M}(z) = \sqrt{9 + 8p\alpha K\varepsilon(z)/(\gamma\, L/n)}/2 - 3/2$.

Obviously, $\varepsilon(0) = \varphi$, so that $\widehat{M}(0) = \widehat{M}$ from before. Also, $\varepsilon'(z) < 0$ and $\varepsilon(s) = 0$ implying that, for a $z$ sufficiently close to $s$, every coastal state will be the *de facto* sole owner of its adjacent, near-shore fishery.

We can use Lemma 4 to calculate the number of non-adjacent states that will exploit a fishery in equilibrium, for any given EEZ. Inverting this relation gives the length of the EEZ, $\hat{z}$, needed to make the $\widehat{M}$th non-adjacent state indifferent between staying in and exiting from the fishery:

$$\hat{z} = s\left\{\frac{p\alpha K - (c+\gamma s) - \widehat{M}\left(\widehat{M}+3\right)\gamma L/2n}{p\alpha K + (c+\gamma s)}\right\}. \tag{23}$$

One such value is of special interest. Setting $\widehat{M} = 1$ in (23), yields $\hat{z}(1)$. Let $\hat{z}^{NS} \equiv \hat{z}(1)$. We then get:

**Lemma 5.** *If* $z^{NS} > \hat{z}^{NS}$, *every coastal state will be the sole owner of its nearshore fishery.*

### 5.4 Behavior for given EEZ

Summarizing:

**Proposition 2.** *Starting from a free sea regime, incremental increases in the breadth of the EEZ initially have marginal effects on the spatial exploitation of every type of fishery. For an offshore fishery, these effects remain marginal, with coastal states exploiting the entire range of the fishery on their own line segments and in any high seas segments beyond, until z reaches its maximum extent at* $z = r_0$. *For nearshore fisheries, a point may be reached at which (any) neighboring countries exploiting a nearshore fishery begin to drop out, with more distant states dropping out first, until z exceeds* $\hat{z}^{NS}$, *at which point every coastal state becomes the de facto sole owner of its adjacent nearshore fishery. For a highly migratory fishery, incremental increases in the breadth of the EEZ have marginal effects on spatial exploitation until z exceeds* $\hat{z}^{HS}$, *at which point coastal states exploit the resource only within their own line segments.*

Proposition 2 suggests that property rights are especially important for nearshore and highly migratory stocks.

## 6. The EEZ as an Equilibrium

Property rights to the ocean are established in customary law. How to model customary law? Shaw (2003: 83) explains the process by which an existing customary rule stands or is replaced with reference to the territorial sea:

> "If a state proclaims a twelve-mile limit to its territorial sea in the belief that although the three-mile limit has been accepted law, the circumstances are so altering that a twelve-mile limit might now be treated as becoming law, it is vindicated if other states follow suit and a new rule of customary law is established. If other states reject the proposition, then the projected rule

withers away and the original rule stands, reinforced by state practice and common acceptance."

Applying Shaw's description to establishment of the EEZ suggests the following game:

> **Stage 1**. Every coastal state $i$ claims an EEZ of length $z_i \in [0, L/n]$.
>
> **Stage 2**. An EEZ of length $z$, identical for each country, is established in customary law, and is thus binding upon all states, if and only if at least $k$ states claim this value, where $k$ represents a strong majority; otherwise, the pre-existing property rights arrangement stands.

Parties to a treaty make decisions based on a precise $k$-rule, such as a two-thirds majority. Customary law, by contrast, "reflects the consensus approach to decision-making with the ability of the majority to create new law binding upon all…." (Shaw 2003: 70). US acceptance of a 200-mile EEZ, for example, "was strongly influenced… by the fact that a consensus had developed, or was developing, on a 200-mile zone as a part of a new Law of the Sea Convention" (Carr 2004: 57). Consensus tolerates minor dissent. "When a new rule which contradicts a prior rule is maintained by a large number of states, the protests of a few states would not overrule it…." (Shaw 2003: 86). In the customary law game, each state reasons backwards, claiming an EEZ in stage 1 knowing that its choice will apply universally if adopted. As my model is symmetric, all players desire the same EEZ, and ambiguity about $k$ is inconsequential. The players' only problem is coordinating choice of a particular value, a focal point that falls within the desired range.

How is custom established among asymmetric countries? Though unanimity isn't required, "for a custom to be accepted and recognised it must have the concurrence of the major powers in that particular field" (Shaw 2003: 76). Later I consider an important instance of asymmetry in which the United States, a major maritime power, stood alone in wanting the EEZ to apply to nearshore but not highly migratory stocks.

To know whether the equilibrium in customary law differs from the equilibrium that would be supported in custom's absence, we need also to derive the Nash equilibrium in property rights. Below I derive both equilibria for all three types of fishery.

### 6.1 Highly migratory fishery

Consider to begin the Nash assumption. For $z \leq \hat{z}^{HM}$, coastal states can do no better than to fish within their own EEZ and in all of the high sea beyond it, whereas for $z > \hat{z}^{HM}$, they will fish only within their own line segment. Knowing how distance and effort levels will be chosen subsequently, *i* will choose $z_i \in [0, \hat{z}^{HM}]$ to maximize

$$\pi_i = \frac{p\alpha K(L - z_{-i})E_i^*}{L}\left\{1 - \frac{\alpha}{rL}\left[(L - z_{-i})E_i^* + \sum_{j \neq i}(L - z_{-j})E_j^*\right]\right\} - (c + \gamma L)E_i^*, \quad (24)$$

where $z_{-i} = \sum_{j \neq i} z_j$ *and* $z_{-j} = \sum_{v \neq j, v \neq i} z_v + z_i$.

Solving for the Nash equilibrium gives (see Appendix) $z_{Nash}^{HM} \in [\hat{z}^{HM}, L/n]$. In words:

**Lemma 6.** *In the Nash equilibrium, coastal states exploiting a highly migratory fishery establish a de facto "closed" sea regime.*

With property rights established in customary law, states choose their preferred *universal* EEZ. Substituting the Nash equilibrium values for $d_i, E_i$, and $m_i$ gives

$$\pi_i(z; z \leq \hat{z}^{HM}) = \frac{rpK}{(n+1)^2}\left[1 - \frac{L(c + \gamma L)}{p\alpha K[L - z(n-1)]}\right]^2, \quad (25)$$

and this expression is maximized for $z^* = 0$.

For the other situation we have

$$\pi_i(z; z > \hat{z}^{HM}) = \frac{rpK\phi^2}{(n+1)^2}. \qquad (26)$$

Setting $z^* = 0$ in (24) gives $\pi_i^{HM}(z; z \leq \hat{z}^{HM}) = rpK\theta^2/(n+1)^2$. Comparing this payoff with (26) and noting that $\theta > \phi$ for $n > 1$, property rights established in customary law will choose $z_{Custom}^{HM} = 0$. In words:

**Lemma 7.** *In the customary law equilibrium, coastal states exploiting a highly migratory fishery establish a free seas regime.*

Custom thus restrains states from making excessive property rights claims.

### 6.2 Offshore fishery

The situation for an offshore fishery is akin to that of a highly migratory fishery; a formal proof isn't needed. In the Nash equilibrium, the offshore fishery is partitioned into national sections, whereas with equilibrium property rights established in customary law, the offshore fishery remains a high seas fishery, open to all.

### 6.3 Nearshore fishery

For nearshore fisheries, assuming Nash conjectures, every coastal state will claim an EEZ that excludes others from its adjacent fishery. Choice of $z$ under customary law is less obvious. Though a state will gain by excluding others from its nearshore fishery, it will lose by being shut out of other countries' nearshore fisheries. Overall, however, the gain from exclusion must exceed the loss. This is because exclusion enhances efficiency, by reducing both distance costs and the tragedy of the commons. Hence:

**Lemma 8**. *The equilibrium EEZ established in customary law is of sufficient breadth* ($z > \hat{z}^{NS}$) *to ensure that every coastal state is the sole owner of its adjacent nearshore fishery, the same outcome as supported in the Nash equilibrium.*

Though the intuition is obvious, a formal proof of Lemma 8 is rather involved, as changes in *z* can change *M,* the number of players exploiting a given nearshore fishery. Hence, we have to evaluate play for every range of $z$ admitting a given number of players. For example, if we constrain choice of $z$ to $z \in [\hat{z}(2), \hat{z}(1)]$, precisely two states will exploit every fishery. The nearshore fishery adjacent to country *i* will be exploited to its full length by $i$ and to a length $s - z$ by country $i - 1$. Meanwhile, the fishery adjacent to country $i + 1$ will be exploited to a length s – z by $i$ and to its full length by $i + 1$. Substituting the Nash equilibrium effort levels into country *i*'s aggregate payoff shows (see the Appendix) that every *i* will choose a universal EEZ, $z = \hat{z}(1) \equiv \hat{z}^{NS}$. Every *i* gains more by excluding others from its fishery than it loses by being excluded from others' fisheries. As the reason is that exclusion enhances efficiency, we can be sure that this result holds for any $\widehat{M} \in \{0,1,\dots,n-1\}$.

### 6.4 Customary law equilibrium

The above results imply:

**Proposition 3**. *Customary law supports two kinds of property rights regime. For nearshore stocks, custom supports the same regime as the Nash equilibrium: nationalization of the seas adjacent to each coastal state's homeport sufficient to make each such state the sole owner. For highly migratory and offshore stocks, custom urges restraint: the Nash impulse is to nationalize the seas, but custom supports a regime of freedom of the seas.*

The result for nearshore stocks partly explains why the EEZ was established and why selection of an EEZ limit value would have been arbitrary for this purpose, apart from satisfying $z \in [\hat{z}^{NS}, L/n]$. As noted before, the most valuable fisheries lie inside the continental shelf, almost always within 200-miles of shore. However, this explanation cannot be more than partial because Proposition 3 indicates that, in an ocean comprising all three kinds of fishery, efficiency favors different regimes for different stocks. Hence, in addition to deciding the breadth of the EEZ, customary law must also determine the scope of this new property right. Should the coastal state's jurisdiction be zonal in nature, applying to all stocks within 200 miles of shore, or stock-specific?

During the Law of the Sea negotiations, the United States, a major distant water fishing state, insisted that the EEZ be defined as excluding highly migratory stocks. Coastal states with abundant highly migratory stocks off their coasts disagreed. In a symmetric ocean, all states prefer stock-specific rights (Proposition 3). In an asymmetric regional sea, the interests of distant water and coastal states to diverge.

## 7. A Regional Sea

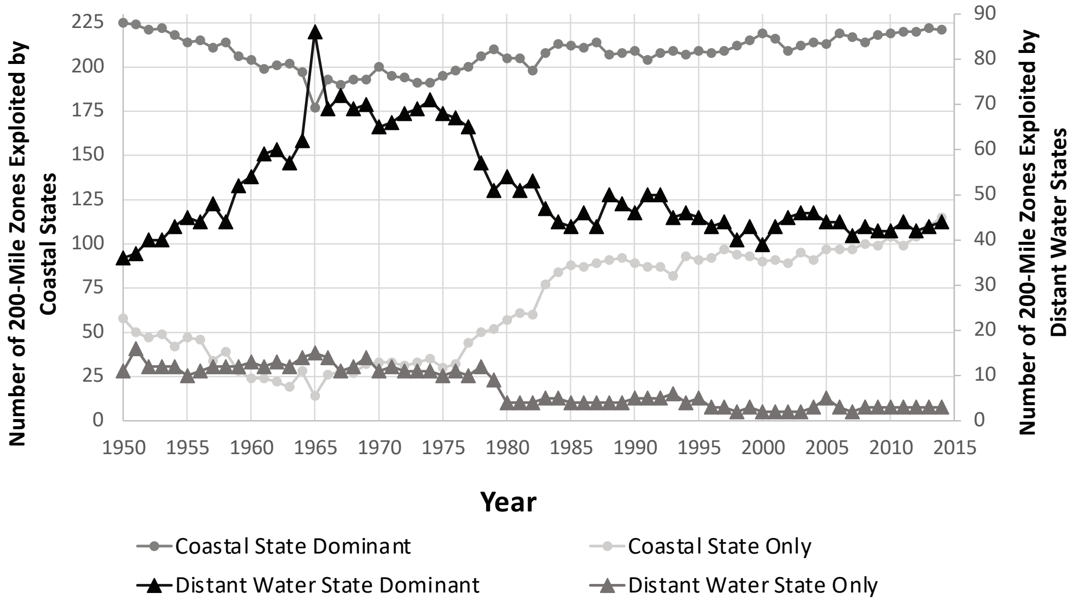
The world has one ocean, and my model can be interpreted as already incorporating all players, including distant water states. However, most states fish close to home, and from a fisheries management perspective the ocean looks more like a patchwork. The UN Food and Agriculture Organization divides the ocean into 19 non-overlapping fishing areas (identified in Figure 1), and defines distant water states as states that fish in areas not containing their own two-hundred-mile zones.[20] In this section, a "regional sea" is best thought of as representing one of these fishing areas.

Figure 5 shows that establishment of the EEZ in the mid-to-late 1970s coincided with changes in the identities of states fishing within 200 miles of shore. Before the EEZ, distant water states came increasingly to dominate these seas; after the EEZ, coastal states regained this "lost ground." Before the EEZ, the number of 200-mile zones

[20] Eighty-six percent of the world's fish harvest is caught by countries within their own EEZ or an adjacent EEZ; the rest is caught by states fishing in more distant EEZs (12 percent) and in the high seas (two percent) (Carlson et al. 2020).

fished exclusively by adjacent coastal states declined; afterwards, it increased, just as the number of 200-mile zones fished exclusively by distant water states decreased. The shift in rents was even greater than suggested by these trends, for once the EEZ became law, coastal states could, and did, demand payment for access.

Figure 5




Source: Carlson et al. (2020), Table S14.

How to model the costs of distant water fishing? Distant water states don't simply export their local fleets. They design fleets for the purpose of fishing a long way from home, sometimes even building port and processing facilities. As well, distant water fishing may have less to do with absolute cost than comparative advantage in fishing (Munro 1989). Finally, distant water fleets are often subsidized, either directly or through weak labor market protection, if not outright forced labor (Sala et al. 2018). To simplify, I assume that distant water and coastal states face the same costs, implying that distant water states gain access the to the fishery via a coastal state's homeport.[21] By assumption, therefore, coastal states have only one advantage over distant water states: their ability to claim an EEZ in the regional sea.

### 7.1 The highly migratory fishery in a regional sea

Focusing on a highly migratory fishery, the above assumptions imply that, in the absence of an EEZ, all of the results obtained previously will go through provided we replace $n$ with $n + N$, where $n$ now represents the number of coastal states in a regional sea and $N$ the number of distant water states. Assuming a positive and exogenously specified EEZ introduces an asymmetry. Coastal states, as before, will fish either within their own EEZ and throughout the high seas or exclusively within their own ocean segment. Distant water states, by contrast, will fish either throughout the high seas or nowhere in the fishing area.

What value of $z$ makes entry by distant water states unprofitable? Given the assumed symmetry in payoffs, we know that this value will also cause coastal states to fish only within their own line segments.[22] As shown in the Appendix, this value is

$$\tilde{z}^{HS} = \frac{L}{n}\left[\left(\theta - \frac{n\phi}{(n+1)}\right)\Big/\left(1 - \frac{n\phi}{(n+1)}\right)\right]. \quad (27)$$

The term in square brackets is positive and strictly less than one, implying:

**Lemma 9**: *In a regional sea, if $z < \tilde{z}^{HS}$, distant water and coastal states will exploit a highly migratory stock throughout the high seas (coastal states will additionally fish within their EEZs), whereas if $z > \tilde{z}^{HS}$, distant water states will exit the fishing area and coasal states will fish only within their own line segments.*

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[21] Coastal states are not required to provide access to their ports. However, obtaining access to port facilities may be negotiated along with access to the EEZ fishery.

[22] This critical value for $z$ will, in general, differ from $\hat{z}^{HS}$, the value that ensures coastal states, in equilibrium, earn a higher payoff when fishing only within their own line segments than when fishing within their own EEZ and throughout the high seas.

Of course, distant water states may continue to operate within EEZs under license agreements, but with the rents from such exploitation accruing to coastal states.

### 7.2 Property rights in a regional sea

Will coastal states prefer to restrict access by distant water states or to maintain a free regional sea for all? Let $\underline{N}$ denote the minimum number of distant water states needed to make coastal states want to establish an EEZ limit that deters entry by distant water states. It can be shown (see Appendix) that $\underline{N}$ is given by

$$\underline{N} = c(n+1)(n-1)/\phi\,. \tag{28}$$

Establishment of an EEZ in a regional sea benefits coastal states when $N \geq \underline{N}$. Will it increase aggregate payoffs? On the one hand, exclusion reduces competition and, thus, overfishing. On the other hand, exclusion also restricts where coastal states may fish, increasing their costs. It can be shown that exclusion of distant water states is efficient overall if and only if $N > \underline{\underline{N}} > \underline{N}$, where $\underline{\underline{N}}$ is characterized in the Appendix.

Summarizing:

**Proposition 4**. *In a regional sea harboring a highly migratory stock, coastal states will wish to establish an EEZ in customary law of sufficient breadth* $(z \in [\tilde{z}^{HS}, L/n])$ *to deter entry by distant water states if and only if* $N \geq \underline{N}$*; otherwise, coastal states will favor a free seas regime. An EEZ enhances efficiency overall if and only if* $N > \underline{\underline{N}} > \underline{N}$.

Combining this result with Proposition 3 suggests that different states will claim an EEZ for different reasons. Some will do so to protect their nearshore fisheries, others to deny distant water fleets access to highly migratory stocks. Suspension of distant water fishing during the Second World War revealed the benefits of sole access to coastal states. Chile claimed a 200-mile zone after the war, “in the knowledge that factory ships from Europe would soon be returning” (Armanet 1984: 28). Chile sought an EEZ for whales, Ecuador for tuna, and Peru for anchovy.

Distant water states will generally oppose coastal state claims to highly migratory stocks within their EEZs, though if $N > \underline{\underline{N}}$ access agreements could in principle ensure that both types of country gained from creation of an EEZ. The US was the hold-out in contesting coastal state jurisdiction over tuna within their EEZs, arguing that these stocks should instead be regulated by RFMOs (Munro 1990). In the Eastern Tropical Pacific, where the US fleet dominated, disagreement about how custom should be interpreted triggered a “tuna war.” States from Canada to Chile seized US boats fishing for tuna within their EEZs. Meanwhile, the US government reimbursed these operators so as to encourage their defiance (Rasmussen 1981). In this regional sea, states with opposing interests acted to mold custom to their advantage.

Over time, local fleets in the Eastern Tropical Pacific expanded, and US tuna boats began relocating to the Central and Western Pacific. Here, another tuna war ensued. But, here, cohesion among archipelagic states coupled with a willingness by the US’s Cold War adversary, the USSR, to negotiate access agreements, caused the US to abandon its long-held position (Carr 2004). In 1987, the US signed a treaty requiring it to pay Pacific Island states for the right to fish for tuna within their EEZs (Munro 1990). Finally, in 1991, the US removed the tuna exception from its own legal claim to an EEZ, effectively settling the question of the EEZ’s scope in customary law.

## 8. Ban high seas fishing?

Can a ban on high seas fishing limit overfishing of highly migratory stocks? Can it increase rents? Suppose a uniform EEZ of length $z'$ is in place. Taking both $z'$ and the ban on high seas fishing as given, country $i$’s payoff is

$$\pi_i^{ban}(z') = \frac{p\alpha K z' E_i}{L}\left[1 - \frac{\alpha z'}{rL}\left(E_i + \sum_{j\neq i} E_j\right) - \frac{(c+\gamma z')}{p\alpha K z'}\right]. \qquad (29)$$

Solving for the Nash equilibrium in effort and comparing the resulting payoff to those corresponding to complete freedom on the seas (no EEZ) and choice of an EEZ that completely encloses the seas we get (see Appendix):

**Proposition 5**. *In a symmetric ocean, the collective payoff to exploiting a highly migratory fishery is higher when there is freedom throughout the seas (no EEZ) than when the seas are fully enclosed, and higher when the seas are fully enclosed than when there exists an EEZ short of the maximum breadth and fishing on the high seas is banned. A high seas ban is neither efficient nor supportable as an equilibrium in customary law.*

White and Costello (2014) reach a different conclusion. According to their analysis, a ban on high seas fishing yields a higher collective payoff than complete enclosure of the seas, which in turn yields a higher payoff than freedom throughout the seas. It is difficult to know the reasons their results are the reverse of my own; their model differs from mine in numerous ways.[23] It is as well to note, however, that a ban on high seas fishing would need to be established in customary law, and Proposition 5 is at least consistent with the fact that no such customary law exists.

A possibility not considered by White and Costello is whether a ban on high seas fishing might be supported by custom in a regional sea. The Law of the Sea recognizes that "states of origin" of anadromous species—salmon, which spawn in inland waters—have a "primary interest in and responsibility for such stocks." It further

[23] White and Costello's model is dynamic, and solved numerically, though, like me, they focus on biological steady states, and solve for the Nash equilibrium in effort. They do not model distance, and assume that costs are decreasing in the stock. Their fishery comprises (my notation) $n$ + 1 points, one for each EEZ and one for the high seas. Each point has its "own" stock. Their base case assumes high site fidelity, making each coastal state a quasi-sole-owner of its stock, but they also consider zero site fidelity. In their model, countries choose effort levels separately for the EEZ and high seas, whereas in my model the fishery is a continuum. See also Sanchirico and Wilen (2001), who show in an analytical model how important details can be to the effects of closures on harvests subject to open access.

instructs these states to fish for salmon "only in waters landward of the outer limits of the exclusive economic zones."[24] As this provision is accepted by consensus, and reinforced by state practice, Burke (1991: 118) finds "that the customary international law of freedom of fishing no longer affords any right to harvest [anadromous species] without the agreement of the state of origin," an effective ban on directed fishing for salmon in the high seas. Because salmon move throughout the EEZs of different states of origin in the North Pacific, the ban transforms what would have been a resource available to $n$ coastal plus $N$ distant water states into one owned in common by just $n$ countries.[25] Given the requirement that EEZs be uniform throughout the ocean, the high seas fishing ban may serve as a second best means for excluding distant water states from this fishery.

## 9. Conclusions

I develop a spatial model of the ocean (one dimension, set in a two-dimensional frame) in which property rights are determined in customary international law. According to the model, the exclusive economic zone emerged to exclude foreign fleets from exploiting stocks adjacent to a coastal state's shores. Though this conclusion isn't surprising, my model explains several puzzling features of the property rights regime for the ocean: why freedom on the seas prevailed historically (this arrangement being an equilibrium in customary law and not a Nash equilibrium), why this regime changed in the 1970s (the reason being an increase in fishing activity by foreign vessels), why the EEZ "flipped" from zero to a significant positive value rather than increase gradually (the reason being the threshold effect of entry), and why choice of a particular EEZ value was arbitrary (this value needing only to be "large enough" to cause foreign vessels to exit the fishery).

[24] An exception is allowed in the case of states other than the state of origin for which a ban would cause "economic dislocation." Japan, the principal distant water state in this sea, agreed in 1986, under threat of being denied groundfish allocations in the US fishery conservation zone, to phase out fishing for salmon on the high seas; see Burke (1991). As with the resolution of the scope of the EEZ in a regional sea, the ban on directed fishing for salmon in the high seas was achieved non-cooperatively.
[25] These are the US, Canada, Japan, Russia, and South Korea, all parties to the Convention for the Conservation of Anadromous Stocks, a prime purpose of which is to enforce the high seas ban.

The literature has debated whether customary law determines behavior or whether behaviors that would have occurred in the law's absence have been misinterpreted as evidence of adherence to custom. In a symmetric ocean, I find that the customary law equilibrium coincides with the Nash equilibrium in some situations and diverges from it in others. In all situations, however, I find that customary law supports efficient outcomes in a symmetric ocean. By contrast, in an asymmetric regional sea, the custom adopted depends on the relative power of coastal and distant water states, and cannot be relied upon to promote efficiency. These results offer a more complex view of custom than the interpretations to be found in the previous literature.

My model also offers a different way of looking at proposals to change the current property rights arrangement, from nationalizing the ocean to banning fishing on the high seas. My model suggests that both changes would be harmful to coastal states in a symmetric ocean, and for this reason would not be adopted in customary law.

My model is a simple and highly abstract representation of the ocean, of human exploitation of its bounty, and of the property rights arrangements devised to shape this exploitation for the greater good. The ocean and our exploitation of its resources are vastly more complex than represented here. Issues to explore in further research include: dynamics; alternative assumptions regarding the geography of the ocean and the spatial dimension of each fishery, including how harvesting costs vary in this dimension; alternative representations of distance costs, including distant water fishing costs; ecological features such as the location of spawning grounds and patterns of larval dispersion; compliance with and enforcement of access to EEZs; and the many reasons besides fisheries management for why, in the 1970s, the law of the sea came to be changed fundamentally, and why, even today, the rules governing access to the resources of the sea continue to be challenged. Most importantly, as my model suggests that property rights are a grossly imperfect means for overcoming the tragedy of the ocean commons, more research is needed into strategies to enforce international fisheries agreements.

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## Online Appendix

**Proof of Lemma 2**. Suppose that every country $i$ fishes only within its own line segment (that is, $y = 0$). In a Nash equilibrium, effort will then be

$$E_i^*(d_i = L/n) = \frac{rn\phi}{\alpha(n+1)}, \qquad (A.1)$$

where $\phi(> 0)$ is given by eq. (12), and payoffs will be

$$\pi_i^*(d_i = L/n) = \frac{prK\phi^2}{(n+1)^2}. \qquad (A.2)$$

Suppose instead that every $i$ fishes throughout the ocean, except for the EEZs from which $i$ is excluded (that is, $y = n - 1$). The Nash equilibrium effort level will then be

$$E_i^*(d_i = L) = \frac{rL}{\alpha(n+1)[L - z(n-1)]}\left\{1 - \frac{L(c+\gamma L)}{p\alpha K[L - z(n-1)]}\right\} \qquad (A.3)$$

and the Nash equilibrium payoff will be

$$\pi_i^*(d_i = L) = \frac{prK}{(n+1)^2}\left\{1 - \frac{L(c+\gamma L)}{p\alpha K[L - z(n-1)]}\right\}^2. \qquad (A.4)$$

Eq. (21) is found by setting (A.2) and (A.4) equal to one another, and the lemma is proved by comparing these payoffs.

**Proof of Lemma 4**. Let:

$$\pi_i^i = p\alpha K E_i^i\left\{1 - \frac{\alpha}{rs}\left[E_i^i s + \sum_{m=1}^{M} E_{i-m}^i (s - z)\right]\right\} - (c + \gamma s)E_i^i \qquad (A.5a)$$

$$\pi_{i-m}^{i} = p\alpha K E_{i-m}^{i} \frac{(s-z)}{s}\left\{1 - \frac{\alpha}{rs}\left[E_i^i s + \sum_{m=1}^{M} E_{i-m}^{i}(s-z)\right]\right\}$$
$$-[c + \gamma(m\,L/n + s)]E_{i-m}^{i} \qquad (A.5b)$$

Note that these relations only apply to $z \in [0, s]$. In a Nash equilibrium, we have

$$E_i^i = \frac{r}{\alpha(M+2)}\left\{1 - (M+1)\frac{(c+\gamma s)}{p\alpha K} + M\frac{\left[c + \gamma\left((M+1)\,L/(2n) + s\right)\right]}{p\alpha K\,(s-z)/s}\right\}. \quad (A.6a)$$

$$\sum_{m=1}^{M} E_{i-m}^{i} = \frac{Mrs}{(M+2)\alpha(s-z)}\left\{1 + \frac{(c+\gamma s)}{p\alpha K} - \frac{2\left[c + \gamma\left((M+1)\,L/(2n) + s\right)\right]}{p\alpha K\,(s-z)/s}\right\}. (A.6b)$$

For country *i* – *m*, $m \in \{1,2,\ldots,M\}$, we have

$$E_{i-m}^{i} = \frac{rs}{\alpha(M+2)(s-z)} \times$$
$$\left[1 + \frac{(c+\gamma s)}{p\alpha K} - \frac{2\left[c + \gamma\left(s + \left(2m(M+2) - M(M+1)\right)\right)(L/4n)\right]}{p\alpha K\,(s-z)/s}\right]. \qquad (A.6c)$$

It remains to solve for *M*, the number of non-adjacent states fishing in fishery *i*. Setting *m* = *M* in (29c), and assuming *z* < *s*, we can solve for the maximum value of *M* that sustains a positive effort level. Setting $E_{i-m}^{i} = 0$ and solving the resulting quadratic in *M* gives Lemma 4.

**Proof of Lemma 6**. Maximization of (24) for *i* and of the corresponding payoff functions for every *j*, $j \neq i$, for given property rights arrangements, gives

$$E_i^* = \frac{rL}{\alpha(n+1)[L - z(n-1)]}\left\{1 - \frac{(c+\gamma L)L(L - z_i n + z)}{p\alpha K[L - z(n-1)][L - z(n-2) - z_i]}\right\} \quad (A.7)$$

$$E_j^* = \frac{rL}{\alpha(n+1)[L - z(n-2) - z_i]}\left\{1 - \frac{(c+\gamma L)L(L - zn + z_i)}{p\alpha K[L - z(n-1)][L - z(n-2) - z_i]}\right\}, (A.8)$$

where $z$ represents the (symmetric) EEZ established by every country other than *i*. Both of these solutions are identical to (22) for $z_i = z$.

Substituting these solutions back into (24) gives

$$\pi_i = \frac{prK}{(n+1)^2}\left\{1 - \frac{L(c+\gamma L)(L - z_i n + z)}{p\alpha K[L - z(n-1)][L - z(n-2) - z_i]}\right\}^2, \qquad (A.9)$$

which corresponds to (A.4) when $z$ is symmetric. Maximizing (A.9) by choice of $z_i$ subject to $z \in [0, \hat{z}]$ requires

$$\frac{2r(n-1)L(c+\gamma L)}{\alpha(n+1)^2}\left\{1 - \frac{L(c+\gamma L)(L - z_i n + z)}{p\alpha K[L - z(n-1)][L - z(n-2) - z_i]}\right\} + \mu - \lambda, \quad (A.10)$$

where $\lambda$ is the Lagrange multiplier on the constraint $z \leq \hat{z}$ and $\mu$ is the multiplier on the constraint $z \geq 0$. In a symmetric Nash equilibrium, $z_i = z$, and the term in brackets in (A.10) will be positive. This means that $\lambda$ must be positive, which implies that the Nash equilibrium is $z^* = \hat{z}$. Finally, since effort and payoffs will be identical for any $z$ larger than this, the Nash equilibrium EEZ is $z^* \in [\hat{z}, 2\pi r_0/n]$. The Nash equilibrium effort level is thus given by (A.1) and the payoff by (A.2).

**Proof of Lemma 8**. For $z \in [\hat{z}(2), \hat{z}(1)]$, every nearshore fishery will be exploited by two countries. Substituting the Nash equilibrium effort levels for countries *i* and *i* -1, the country closest to *i* in the counter-clockwise direction, country *i*'s payoff in its adjacent fishery is:

$$\pi_i^i = \frac{prK}{9}\left[1 - \frac{2(c+\gamma s)}{p\alpha K} + \frac{[c + \gamma(s + L/n)]}{p\alpha K\,(s-z)/s}\right]^2. \qquad (A.11a)$$

Moving clockwise, in the next fishery over, *i* competes with country *i* +1 and gets

$$\pi_i^{i+1} = \frac{prK}{9}\left[1 + \frac{(c+\gamma s)}{p\alpha K} - \frac{2[c+\gamma(s+L/n)]}{p\alpha K\,(s-z)/s}\right]^2. \qquad (A.11b)$$

Clearly, to maximize its payoff, *i* wants *z* to be a large value in its adjacent waters and a small value in other countries' adjacent waters. This is the trade-off inherent in choosing an EEZ. Combining these payoffs and differentiating gives

$$\frac{d\pi_i}{dz} > 0 \Leftrightarrow \frac{z}{s} >= \frac{p\alpha K - [c+\gamma(s+5\,L/n)]}{p\alpha K + 4(c+\gamma s)}. \qquad (A.12)$$

By assumption, $z \geq \hat{z}(2)$. Also, $\hat{z}(2) = \big[p\alpha K - [c+\gamma(s+5L/n)]\big]/[p\alpha K + (c+\gamma s)]$. Hence, condition (A.12) must hold. Under customary law, coastal states will extend their EEZs until the more distant state exits the fishery.

**Proof of Lemma 9**. Every distant water (superscript *DW*) state *i* will choose its effort level to maximize

$$\pi_i^{DW} = \frac{p\alpha K E_i^{DW}(L-zn)}{L} \times$$
$$\left\{1 - \frac{\alpha}{rL}\left[\left(E_i^{DW} + \sum_{j\neq i}^{N} E_j^{DW}\right)(L-zn) + nE^{CS}[L-z(n-1)]\right]\right\} - (c+\gamma L)E_i^{DW}. (A.13)$$

Suppose that *z* is of a size that impels coastal states to fish only within their own line segments. Then $E^{CS}$, every coastal state's chosen effort, will be given by (A.1). Substituting this value into (A.13), and maximizing, yields effort $E_i^{DW}$ that depends on *z*. Solving for the value of *z* at which this optimal $E_i^{DW}$ equals zero gives (27). Distant water states will exit the fishing area for any z greater than or equal to this value.

**Proof of Proposition 4**. Compare the payoffs that coastal states get if they (i) allow entry by distant water states, by setting $z < \tilde{z}^{HS}$, or (ii) deter entry by setting $z > \tilde{z}^{HS}$.

If they allow entry, every coastal state *i* will choose its effort level to maximize

$$\pi_i^{CS} = \frac{p\alpha K E_i^{CS}[L - z(n-1)]}{L} \times$$
$$\left\{1 - \frac{\alpha}{rL}\left[\left(E_i^{CS} + \sum_{j \neq i}^{n} E_j^{CS}\right)[L - z(n-1)] + NE^{DW}(L - zn)\right]\right\} - (c + \gamma L)E_i^{CS}. \quad (A.14)$$

Similarly, every distant water state *i* will choose its effort level to maximize

$$\pi_i^{DW} = \frac{p\alpha K E_i^{DW}(L - zn)}{L} \times$$
$$\left\{1 - \frac{\alpha}{rL}\left[\left(E_i^{DW} + \sum_{j \neq i}^{N} E_j^{DW}\right)(L - zn) + nE^{CS}[L - z(n-1)]\right]\right\} - (c + \gamma L)E_i^{DW}. (A.15)$$

Maximization of (A.14) and (A.15) yields the Nash equilibrium in effort levels:

$$E = \frac{rL}{\alpha(n + N + 1)[L - z(n-1)]}\left\{1 - \frac{L(c + \gamma L)[L - z(n+N)]}{p\alpha K(L - zn)[L - z(n-1)]}\right\} \qquad (A.16)$$

$$E^{DW} = \frac{rL}{\alpha(n + N + 1)(L - zn)}\left\{1 - \frac{L(c + \gamma L)(L + z)}{p\alpha K(L - zn)[L - z(n-1)]}\right\}. \qquad (A.17)$$

Upon substituting (A.16) and (A.17) into (A.14) we find that, if coastal states choose *z* to accommodate entry by distant water states, coastal state *i* will earn

$$\pi_i = \frac{prK}{(n + N + 1)^2}\left[1 - \frac{L(c + \gamma L)[L - z(n+N)]}{p\alpha K(L - zn)[L - z(n-1)]}\right]^2. \qquad (A.18)$$

(Eq. (A.18) reduces to (A.4) for $N$ = 0.) Eq (A.18) is maximized at $z$ = 0. By accommodating entry, coastal state $i$ will earn the payoff

$$\pi_i(z = 0) = \frac{prK}{(n + N + 1)^2}\left[1 - \frac{(c + \gamma L)}{p\alpha K}\right]^2. \qquad (A.19)$$

By choosing $z$ so as to deter entry by distant water states, each coastal state $i$ will earn

$$\pi_i(z \in [\tilde{z}, L/n]) = \frac{prK}{(n + 1)^2}\left[1 - \frac{(nc + \gamma L)}{p\alpha K}\right]^2. \qquad (A.20)$$

It will thus pay coastal states to choose $z \in [\tilde{z}^{HS}, N]$ provided

$$\frac{\phi^2}{(n + 1)^2} > \frac{\theta^2}{(n + N + 1)^2}. \qquad (A.21)$$

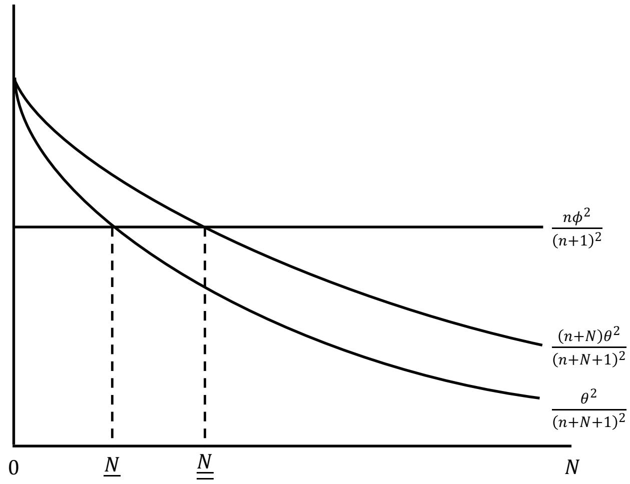
Rearranging, and letting $\underline{N}$ denote the minimum number of distant water states needed to make coastal states want to establish an EEZ limit that deters entry by distant water states, gives (28).

Similar calculations show that exclusion is efficient overall if

$$\frac{n\phi^2}{(n + 1)^2} > \frac{(n + N)\theta^2}{(n + N + 1)^2}. \qquad (A.22)$$

Multiplying both sides of (A.21) by $n$ shows that the RHS of (A.22) exceeds the RHS of (A.21) for $N$ > 0. Figure A.1 shows these relations.

Figure A.1




**Proof of Proposition 5**. Maximization of (29) yields

$$E_i^{Ban}(\check{z}) = \frac{rL}{\alpha \check{z}(n+1)}\left[1 - \frac{(c+\gamma \check{z})L}{p\alpha K \check{z}}\right]. \qquad (A.23)$$

Substituting back into (29) gives

$$\pi_i^{Ban}(\check{z}) = \frac{prK}{(n+1)^2}\left[1 - \frac{(c+\gamma \check{z})L}{p\alpha K \check{z}}\right]^2. \qquad (A.24)$$

Obviously, this payoff is increasing in $\check{z}$. The proposition follows by comparing (A.20) to (A.2), and (A.4), for $z = 0$, to (A.2).