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# Men in Grey Suits: Shark Activity and Congestion of the Surfing Commons

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**Abstract:** This study extends recent research on informal property rights at surf breaks by exploring the process through which nature, by establishing conditions conducive (or not) to the presence of sharks, shapes the baseline level of exploitation by surfers of the common-pool resource represented by surf breaks. Since 1980, there have been nine fatal shark attacks off the coast of California, and in all nine cases the great white shark was the offending species. Given this inherent danger, the presence of large sharks mitigates, at least to some degree, the tendency toward the 'tragedy of the commons' in the case of surf breaks. Using data on surf break congestion, surf break quality, shark activity, and other key variables from 144 surf breaks in California, empirical results from OLS and ordered probit models presented in this study indicate that surf breaks in California that are associated with the highest levels of shark activity tend to be less congested, perhaps by as much as 28%, than their counterparts that are visited less often by sharks.

**Keywords:** tragedy of the commons; natural resource economics; surfing commons; common pool congestion

**JEL Classification:** D60; D62; D70; D71; Q25; Q26; Q57

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"If you are looking to learn to surf, Big Bay, which is where I surfed today, is awesome. It's on the Atlantic [Ocean] side [of South Africa]—less 'sharky,' a little bit more cold [than surf breaks on the Indian Ocean side of South Africa]."

*Avid surfer and* YouTube *content creator*, Nicole Eddy, 2016

## 1. Introduction

United States laws, which allow for open access of the ocean coast up to the high-tide mark [1], have contributed to the popularity of seaside recreational activities in states with long ocean coastlines. Access to high-quality shorelines in California has, for example, created what is often referred to as a 'carefree' West Coast culture built on the ancient Polynesian sport of surfing [2]. Surfing provides both direct and indirect benefits in the form of consumer surplus to surfers, tourism revenue, and even higher prices of residential real estate properties situated in close proximity to surf breaks [3,4]. However, as Kaffine indicates [1], the open-access nature of a surf break creates the unpleasant side-effect of congestion, as surfers crowd the surf break in hopes of "harnessing the energy of a wave and experiencing the exhilaration of sliding down its rushing face" [2]. Such crowding, or over-exploitation of the common-pool resource represented by the surf break, inhibits the enjoyment of each individual user (i.e., surfer) of the surf break. As indicated in research by Kaffine, Mixon, and Mixon and Caudill [1,5–7], the result of over-exploitation of the surfing commons is the formation of surf gangs, which establish informal property rights, backed by force, over high-quality surf breaks.

The presence of large sharks in the water is a primary concern of surfers. In the epigraph above, avid surfer and Cape Town native Nicole Eddy alludes to this concern (as part of a YouTube video) that, although colder, the Atlantic Ocean side of South Africa, a country that is home to some of the world's best surf breaks, is less "sharky" than the country's Indian Ocean side. Eddy's assertion is supported by the data, which, according to the Shark Spotters Organization, indicate that at least 193 of the 248 unprovoked shark attacks in South Africa have occurred along the shores of the Indian Ocean (https://sharkspotters.org.za/safety/shark-safety-advice/shark-bite-stats/). In many of these cases, the great white shark (*Carcharodon carcharias*) represented the offending species. In order to prompt their cohorts to exercise caution against a shark attack while surfing, experienced surfers employ a euphemism for the presence of sharks at a surf break—'men in grey suits'. As surfers arrive at a particular surf break, utterance of the presence of men in grey suits informs newer arrivals of the presence of sharks at the break in a way that conveys the appropriate amount of alarm, but without causing a paralyzing degree of stress or anxiety. As the *Urban Dictionary* points out, sharks cruising underwater often appear to surfers as "sleek moving, thin, grey shadows."

The impact of sharks, or nature's guardians of the surfing commons, on congestion of the surfing commons has not heretofore been studied in the academic literature. This study extends previous research on informal property rights at surf breaks by Kaffine, Mixon, and Mixon and Caudill [1,5–7] by exploring the heretofore unexplored process through which nature, by establishing conditions conducive (or not) to the presence of sharks, shapes the exploitation by surfers of the common-pool resource represented by surf breaks. In doing so, this study employs data on both the presence of sharks and congestion at California's surf breaks. Results from an ordered probit model suggest that a marginal increase in the level of shark activity around a surf break reduces the probability of observing the highest levels of congestion at that surf break by 5.5 percentage points, *ceteris paribus*.

Before delving further into the empirical results mentioned above, a brief review of prior literature on the surfing commons is presented in the next section of the study. This section is followed by Section 3 with a brief discussion of the role of large sharks as nature's guardians of the surfing commons, and subsequently by Section 4 with a review of the first two stages in the establishment of informal property rights over the surfing commons that are developed in Kaffine and Mixon [1,6]. This review provides a transition to our presentation in Section 4 of stage zero in the process, wherein the role played by natural guardians of a surfing commons in determining congestion of the commons is discussed.

## 2. Prior Literature: A Brief Review

Research on the common-pool aspects of surf breaks fits into two separate but related streams of the resource economics literature that discuss the positive relationship between private property rights and resource quality. The first of these is represented primarily in the work of Gordon, Scott, Coase, Hardin, Ostrom, and Cole [8–13]. It posits that ill-defined property rights often leads to the "tragedy of the commons," or overexploitation of a common-property resource. As indicated in this literature, overexploitation of a common-pool resource is a problem that can be addressed through assignment of private property rights. Ostrom, for example, provides [12] several design principles for sustaining the commons. The result, in such cases, is rent preservation and an improvement in the quality of the common-pool resource.

Recent research has attempted to evaluate the validity of Ostrom's [12] design principles for sustainable governance of the commons. An influential study by Cox, Arnold, and Tomás analyzes [14] the results of 91 studies and finds empirical support for Ostrom's [12] framework. In subsequent research, Cox, Tomás, and Arnold provide [15] a detailed response to Araral's criticism ([16], p. 21) of the validity of their empirical approach used to test the studies of Ostrom's design principles, and conclude that there is a need for "more nuanced, diagnostic, multi-disciplinary and empirical approaches." Even though there has been significant progress made in the understanding of issues related to the governance of the environmental commons over the past few decades, the need for conceptual and empirical analysis to develop a "theoretically grounded, solid, comprehensive, and

differentiated understanding of how specific causal factors influence different outcomes related to common-pool resource systems" ([17], p. 91) continues to exist.

The second of these two research streams encompasses work by Demsetz, Umbeck, and Libecap which asserts [18–20] that property rights are endogenous to resource quality, as property rights are created by resource users when their benefits, which rise over increasing resource quality, exceed the costs of their creation. As Kaffine indicates [1], the historical case of mineral rights creation across the western U.S. provides a good example of this phenomenon. According to this body of research, property rights tend to develop mainly around high-quality resources. As stated earlier, this conclusion is consistent with that of the separate but related stream of research beginning with Gordon and ending with Cole [8–13].

More recently, Gruby and Basurto attempt to bring together [21] common pool resource institutional theories with critical human geography in order to analyze the governance of a large common pool resource in the form of the protected marine areas of Palau. Using field data from interviews, observations from policy planning meetings, and protected area science documents, they "undertake an ethnographically 'thick' approach to institutional analysis that recognizes embeddedness of actors and institutions within particular social, political, and environmental situations" ([21], p. 51). These authors caution [21] that while some benefits to centralized large-scale marine governance exist, the protection of large ecological areas could threaten the sustainability and resilience of coral reefs due to less distributed decision-making and lost local autonomy.

In another recent study that focuses on many complex challenges regarding the governance of large-scale common pool resources, Fidelman, Evans, Fabinyi, Foale, Cinner, and Rosen discuss [22] the issues involved in managing the Coral Triangle, a large scale marine system located in the seas shared by six different countries in East Asia. Similar to Gruby and Basurto [21], they too caution [22] against overemphasizing the regional scale as a governance solution and instead recommend decentralized policies that "focus on enabling and supporting effective collective choice arrangements at lower levels of decision making" ([22], p. 50). Both of these recent studies emphasize [21,22] the need to find more effective methods towards managing this critical regional common resource. Their call for additional research in the field motivates, in part, our exploration of the role that large sharks play as nature's guardians of the surfing commons. Our approach to this subject directly extends research on the surfing commons that is discussed below.

As Mixon indicates ([6], p. 382), the research stream generated by Kaffine, Mixon, and Mixon and Caudill [1,5,7] "provides a novel examination of the common property resource elements of surf breaks and how surf gangs are formed in an effort to prevent crowding of a local surf break by non-locals." Kaffine's study ([1], p. 728) of California's surf gangs explores the strength of user-enforced informal property rights in an equilibrium setting, wherein local and nonlocal surfers enjoy benefits from a surf break of exogenous quality while also suffering costs either from meting out, in the case of local surf gang members, or receiving, in the case of non-local surfers, exclusionary effort, which is referred to as 'localism.' More specifically, Kaffine assumes [1] that in stage one local surfers solve the collective action problem either formally or informally, while in stage two they decide, based on the quality of the surf break, how much localism to mete out in order to prevent non-local surfers from enjoying the local surf break. Kaffine points out [1] that informal "territorial" systems are found in lobster fisheries of coastal Maine [23] and with surf breaks [24]. In testing the hypothesis that stronger informal property rights (i.e., greater levels of localism) will be produced in defense of higher-quality surf breaks, Kaffine employs [1] cross-sectional data on 86 surf breaks along the southern California coast. He finds a positive and statistically significant relationship between surf break quality and the strength of the informal property rights around the break, specifically noting that a 10 percent increase in surf break quality leads to as much as a 17 percent increase in the strength of surf break property rights [1].

Mixon extends [5] Kaffine's [1] empirical analysis to (1) include surf breaks in southern, central and northern California; (2) explore other aspects of surf break quality not tested in Kaffine [1], such as ocean currents, ocean floor, and other risks faced by those who would attempt to enjoy a given surf

break; and (3) redefine "access" to the surf break by would-be users to include physical features of the area around a given surf break (e.g., cliffs) that make access to it more difficult. The results from tests that are found in Mixon [5] of the relationship between surf break quality and the strength of informal property rights to surf breaks are quite compelling, indicating that a marginal increase in surf break quality leads to an increase in the probability of observing the fiercest informal property rights protections by local surf gangs of 23 percentage points.

Next, recent research by Mixon and Caudill extends [7] previous research by Kaffine and Mixon [1,5] by (1) creating an alternative, objective metric of surf break quality, and (2) applying the alternative surf break quality metric to "big-wave" surf breaks worldwide. The objective metric of surf break quality developed in Mixon and Caudill ([7], p. 1704) is based on a logistic transformation of pairwise comparisons of the results of big-wave surfing competitions, wherein the surf breaks themselves are viewed as quasi-participants in the big-wave surfing contests. The first extension above investigates the efficacy of the survey-based measure of surf break quality employed in prior studies by Kaffine and Mixon [1,5], while the second extension recognizes the differences between the "technologies" associated with the type of traditional surfing analyzed in Kaffine and Mixon [1,5] and big-wave surfing, which is characterized by waves measuring 20 or more feet in height, and, thus, may produce differences in the degree of informal property rights protection by local surfers ([7], p. 1698). Empirical results presented in Mixon and Caudill indicate [7] that the objective measure of surf break quality is both positively and significantly related to the strength of the property rights (i.e., localism) around a surf break, a result they assert that supports those reported in the Kaffine and Mixon [1,5] employing survey-based index scores of surf break quality. Mixon and Caudill also indicate [7] that a marginal increase in surf break quality leads to a 30 percentage-point increase in the probability of observing the fiercest level of localism at big-wave surf breaks, thus supporting the idea that big-wave surfing and traditional surfing represent distinct markets.

Finally, new research by Mixon addresses [6] the stage one collective action problem mentioned only briefly in Kaffine [1] by presenting a model that examines how congestion at a surf break, localism effort, and surfing camaraderie work to determine the optimal size of a local surf gang. As pointed out in Mixon [6], the benefits of surfing in groups fall under the heading of camaraderie, and their presence means that the optimal surf gang size is bounded away from one. Moreover, the benefits of camaraderie in surfing will likely be exhausted at small numbers owing to crowding of the surf break by surf gang members. Mixon finds [6] that successful surf gangs are typically large, although their sizes exhibit wide variation. Where a surf gang has access to portfolio wealth, as in the case of some surf gangs based in high-income areas, it can make supporting investments in physical capital that increase the productivity of the localism efforts of its members. In these situations, smaller surf gangs can be effective [6]. At the same time, when the anti-localism efforts of law enforcement officials are increased, the cost of localism effort on the part of a surf gang increases. In these cases, a larger surf gang is necessary [6]. Here, Mixon indicates ([6], pp. 393–394) that access to portfolio wealth potentially assists a surf gang in "capturing" judicial and regulatory authorities. In these cases, a smaller surf gang can be successful in the face of anti-localism efforts by law enforcement. Lastly, Mixon demonstrates [6] that the size of a surf gang and the size of its surfing territory are positively related. Thus, a larger surf gang is expected to emerge when acquisition of new surf gang territory occurs ([6], pp. 394–395).

As mentioned earlier, the next section of this study presents a brief discussion of the role of large sharks as nature's guardians of the surfing commons. This discussion is followed by section 4, which provides a primer on the first two stages in the establishment of informal property rights over the surfing commons, which are developed more formally in Kaffine and Mixon [1,6]. This primer provides a transition to our development of stage zero in the process, wherein the role played by large sharks—the natural guardians of a surfing commons—in determining congestion of the commons is discussed.

### 3. Sharks as Nature's Guardians of the Surfing Commons

Since 1980, there have been nine fatal shark attacks off the coast of California. In all nine cases, the great white shark was the offending species, and in three of the cases the victim was either surfing or bodyboarding (see www.sharkattackfile.net). The most recent of these occurred in 2012 near Santa Barbara, when a 39-year-old male surfer was attacked and killed by a 15- to 16-foot white shark (see www.sharkattackfile.net). This and the other fatal attacks brought the total number of fatal attacks off the coast of California since 1900 to 17, with 13 to 15 of these involving the great white shark (see www.sharkattackfile.net). Since the most recent fatal attack in 2012, there have been 18 non-fatal shark attacks off California's shoreline. The most recent of these attacks occurred in September of 2016, and involved a 43-year-old male surfer near Eureka in Humboldt County, while two other surfers—a 54 year old female surfer and a 21 year old male surfer—were attacked during August of 2015 in the same location—near Morro Bay in San Luis Obispo County—by white sharks ranging in size from 10 feet to 12 feet. Being one of the largest of the predator marine species, large white sharks exert a strong top-down effect on marine ecosystems and trophic cascades. Trophic cascades refer to the direct population effects or indirect behavioral effects of predators on their prey, which in turn determine the food web dynamics that help maintain the structure of the ecosystem [25]. Although most shark attacks are unprovoked (i.e., accidental), these and other data clearly indicate that, being at the top of the food chain, large sharks, and the great white shark in particular, serve as nature's guardians of the surfing commons. The presence of great white sharks mitigates, at least to some degree, the tendency toward the "tragedy of the commons" in the case of surf breaks.

In recent years, however, the populations of large sharks have begun to fall [26], which is a problem made especially difficult to address given large sharks' vulnerability to even light fishing pressure, as well as to their relatively low fertility rates and slow growth [26,27]. Moreover, garnering support for shark conservation efforts has been difficult in the past due to public misconceptions about sharks [28], thus more research is needed to inform the public about the importance of conservation management [29]. This relatively recent occurrence (i.e., decrease in large shark populations) has implications for sharks' role as natural guardians of the surfing commons. Where the quality of the break at a surfing commons is relatively high, decreasing shark activity will lead to a larger number of non-local surfers who are attempting to access, and enjoy, the surf break. In response, surf gangs (i.e., local surfers) will tend to become more intense in their attempts to exert informal property rights over the surfing commons [1,5–7]. Aspects of this process are explored in greater depth in the next section of this study.

### 4. Shark Activity and Congestion of the Surfing Commons

Kaffine describes [1] the second stage of what he refers to as a two-stage process wherein the members of a surf gang choose a level of deterrence, generally aimed at non-locals, of unauthorized access to a surfing commons. Stage one of this process, wherein the optimal size of a surf gang is determined at formation, is developed in Mixon [6]. In the sub-sections that follow, we provide a brief review of the development of these two stages of the model and a presentation of what we refer to as stage 0, wherein nature determines the default level of congestion (i.e., over-exploitation) of a surfing commons through conditions around the surf break that make it attractive to large predators, such as great white sharks.

#### 4.1. Stage 2 of the Model

Kaffine develops [1] the second half of a two-stage model consisting of the collective action problem of surf gang formation (i.e., stage one) and the determination of user-enforced informal property rights protection (i.e., stage two). Kaffine considers ([1], p. 731) a fixed number of local surfers, $\overline{n}_{\mathrm{L}}$, who maximize their return from a common-pool resource of exogenous quality by collectively

determining a level of exclusionary effort, referred to as localism, to apply to non-local surfers, $n_{\mathrm{NL}}$, such that,

$$\max_{y} U_{\mathrm{L}}(q, n_{\mathrm{NL}}) - c(y) \tag{1}$$

where $U_{\mathrm{L}}$ represents the utility that local surfers receive from a surf break of exogenous quality, $q$, with congestion from an expected number of non-local surfers, $n_{\mathrm{NL}}$. As represented by $c(y)$ in (1), it is costly for local surfers to exclude non-local surfers. Moreover, that cost is increasing in the level of localism (i.e., exclusionary effort), or $y$. Put differently, $c'(y) > 0$ and $c''(y) > 0$. Kaffine also assumes ([1], p. 731) that the benefits derived from a given surf break increase with surf break quality (i.e., $\partial U_{\mathrm{L}}/\partial q > 0$) and decrease with congestion at the surf break (i.e., $\partial U_{\mathrm{L}}/\partial n_{\mathrm{NL}} < 0$), while the marginal benefit from resource quality is decreasing with congestion (i.e., $\partial^2 U_{\mathrm{L}}/\partial q \partial n_{\mathrm{NL}} < 0$).

Next, Kaffine points out ([1], p. 732) that the numerous non-local surfers will access a given surf break if the value to them of surfing there is equal to or greater than the next-best alternative. As such, a given surf break faces infinite congestion pressure from the surrounding geography, and all non-local surfers receive utility, $\overline{V}$, under open access (to the surf break) laws such as those in the U.S. ([1], p. 732). As Kaffine indicates ([1], p. 732), $U_{\mathrm{NL}}(q, n_{\mathrm{NL}}) - p(y) = \overline{V}$, where $U_{\mathrm{NL}}$ represents the benefits garnered by non-local surfers from a surf break of quality $q$ with congestion from other non-local surfers, $n_{\mathrm{NL}}$, and $p(y)$ is the increasing punishment of localism, $y$, at the surf break. Kaffine also adds [1] that the assumptions regarding $U_{\mathrm{NL}}$ mirror those regarding $U_{\mathrm{L}}$, which are explained above. The expected number of non-local surfers at a given surf break is a function of surf break quality, $q$, the degree of localism investment by local surfers, $y$, and reservation utility, $\overline{V}$ ([1], p. 732), as in,

$$n_{\mathrm{NL}} = n\big(q,\ y,\ \overline{V}\big) \tag{2}$$

where $n_{\mathrm{NL}}$ is increasing in $q$, decreasing in $y$, and decreasing in $\overline{V}$ ([1], p. 732).

When local surfers decide $y$, they choose a level of localism with the understanding that they are able to exclude some of the non-local surfers by making it more costly for them to access the surf break ([1], p. 732). As such, substitution of (2) into (1) yields,

$$\max_{y} U_{\mathrm{L}}\big[q,\ n\big(q, y, \overline{V}\big)\big] - c(y) \tag{3}$$

which, as Kaffine explains ([1], p. 732), is solved with an optimal level of localism, $y^* \geq 0$.

### 4.2. Stage 1 of the Model

Mixon extends [6] the literature on the surfing commons by providing the first half of the aforementioned two-stage model, which involves determination of the optimal size of a surf gang. An obvious consideration in this determination is that at the point of surf break congestion, any expansion in the size of the surf gang contributes to negative congestion externalities. Thus, surf break congestion not only results from attempts by non-local surfers to access a surf break, it can also occur when the number of local surfers, $n_{\mathrm{L}}$, or surf gang members, is exceedingly large [6]. The limiting cases where no surf gang forms, and an invasion of non-locals who do not face any localism occurs, and that where all surfers, locals and non-locals, at a given break become surf gang members, provide examples of these situations. On the other hand, Mixon considers [6] the hypothetical case of a Goliath-like surfer who is capable by his or her size to exclude all others from using a surf break. While such a situation may be optimal in the case of a commercial fishery [8], it is not likely to be the case where positive network externalities are present, as in the case of surfing [6]. As Mixon points out ([6], p. 387), surfing is a social activity wherein surfers derive significant enjoyment from shared experiences that are told and retold in various social settings over time.

The benefits of surfing in groups described in Mixon [6] fall under the heading of camaraderie, and their presence means that the optimal surf gang size, referred to in Mixon [6] as $n_{\mathrm{L}}^*$, is bounded, from below, from one (i.e., a one-person surf gang). Still, the benefits of camaraderie in surfing will

likely be exhausted at small numbers owing to crowding, which is evident when surfers crowd the choice spot where the swells are the highest, sometimes even colliding with one another. The exact value of $n_L^*$ is ultimately a function of economic and resource factors, such as the size of the surf break, and perhaps also of the given surfing 'market.' Mixon and Caudill argue [7] that big-wave surfing is a distinct surfing market (from traditional surfing) given that it involves distinct technologies, more specialized techniques and greater inherent danger. For example, surfing large waves may involve tow-in approaches that employ jet skis and specialized surf boards [7].

Mixon's approach [6] to modeling optimal surf gang size is built on recent research on how prison gangs provide governance that works to benefit prisoners (see Skarbek [30–33] and Roth and Skarbek [34]). Following Roth and Skarbek ([34], p. 232), the average or per person cost of operation of a surf gang is modeled as a function of its size, where size is defined as the absolute number of surf gang members (i.e., local surfers). In terms of surf gangs' establishment of informal property rights to the surfing commons, Mixon asserts ([6], p. 388) that as the number of surf gang members increases in size, the fixed costs of localism effort aimed at non-local surfers, referred to as localism costs, or $C^y$, fall on a per-member basis. As with the case of prison gangs [34], there are also other costs associated with the number of surf gang members. These costs relate surf gang size to both camaraderie and congestion of the common pool.

Borrowing from elements of club goods theory [35–37], Mixon expresses ([6], p. 388) the utility of the $i$th member of the surf gang as

$$U^i = U^i\left(z^i, \ldots, n_L\right) \tag{4}$$

where $z^i$ is a private numeraire good, and, following Kaffine [1], $n_L$ is the number of local surfers at a given surf break. Based on Buchanan's approach [35], local surfers, $n_L$, enjoy camaraderie up to point $\overline{n}_L$, beyond which negative congestion externalities dominate ([37], p. 268). In other words, $\partial U^i / \partial n_L > 0$ for $n_L \leq \overline{n}_L$. The camaraderie and subsequent congestion costs described in Mixon [6] are referred therein as $C^r$. Up to $\overline{n}_L$ surf gang members, $C^r$ reflects the negative 'psychic costs' associated with camaraderie enjoyed by local surfers from surfing the break, while beyond $\overline{n}_L$ surf gang members, surf gang membership congestion, $r$, dominates, leading to a positive and increasing $C^r$ (over $n_L$). Lastly, the summation of $C^y$ and $C^r$ yields the aggregate surf gang cost function, $C^A$, which the surf gang seeks to minimize in deciding on optimal size, $n_L^*$ [6].

*4.3. Stage 0 of the Model*

An unexplored element in the work of Kaffine and Mixon [1,6] is the role played by natural forces in providing the characteristics of a surf break—sandbars, reefs, rocky shore breaks, vegetation, varying depths and water clarity and temperature—that make it attractive to marine life, such sea lions, seals and sea otters, also make it attractive to large predators, such as great white sharks. The likelihood that large sharks—such as great white sharks, bull sharks, and tiger sharks—will patrol a surf break at any given time exerts some influence on the attractiveness of the surf break to surfers, particularly in the case of non-local surfers, $n_{NL}$. This likelihood, therefore, will play a role in determining the baseline level of congestion at a given surf break, *ceteris paribus*.

An element of game theory provides an avenue for the integration of the role played by large predators in determining the baseline level of congestion at a surf break. External uncertainty is handled in game theory by introducing an outside player referred to as "Nature," to whom control over random events is ceded ([38], p. 49). In developing what is referred to in this story as stage zero of the two-stage model of the surfing commons begun in Kaffine [1] and extended in Mixon [6], Nature sets each surf break's 'type' with regard to the likelihood of encountering large sharks, wherein the probability that a surfer will encounter large sharks at a given surf break, $b$, at time $t$, is denoted as $p$, and $1 - p$ represents the probability that large sharks will not be encountered. Thus, in addition to being a function of reservation utility, $\overline{V}$, the expected number of non-local surfers at a given surf break is, at stage zero, a function of surf break quality, $q$, and, using Eddy's terminology in the epigraph,

the "sharkyness," $s$, of the surf break. Here, $n_{NL}$ is decreasing in $s$ (i.e., $\partial n_{NL}/\partial s < 0$). As such, large sharks serve essentially as natural guardians of the surfing commons (i.e., they are natural 'owners' of the surf break), and their presence shapes, at stage zero, surf break congestion, the resulting value of which is dealt with by surf gangs at stages one and two of the surfing commons model.

Using data similar to that employed in Kaffine and Mixon [1,5], we test hypotheses emerging from our conceptual model of stage zero of the three-stage process wherein surf gangs establish informal property rights over the surfing commons. The empirical methodology and data used to conduct these tests are described in the next section of the study. In the final sub-section below, we discuss the empirical results.

## 5. Econometric Model and Data

The hypothesis that the level of shark activity at a given surf break impacts congestion at that break is testable in a way similar to that in Kaffine and Mixon [1,5] concerning the relationship between surf break quality and the degree of localism. In the sub-section that follows, an econometric model for testing this hypothesis is presented. Additionally, a discussion of the data used to test the hypothesis is included in the second sub-section.

### 5.1. Econometric Model

In order to test the hypothesis that shark activity around a surf break is negatively related to congestion at that particular surf break, the specification in (5) is estimated,

$$
\begin{aligned}
Congest_i = \quad & \alpha_0 + \beta_1 WaveQuality_i + \beta_2 DiffAccess_i + \beta_3 Dirty_i \\
& + \beta_4 Sand_i + \beta_5 Sharks_i + \beta_6 CentCali_i + \beta_7 NorCali_i \\
& + \varepsilon_1
\end{aligned}
\tag{5}
$$

where, following Mixon [5], the dependent variable, $Congest_i$, is an index of congestion at surf break $i$ ranging from 0 (least congested) to 4 (most congested). Mixon employs [5] a five-point scale (i.e., 1 through 5) for congestion that is constructed from information on surf break congestion from SurfLine.com. We subtract 1 from each surf break's congestion score in Mixon [5] to produce a revised five-point scale that begins with zero (i.e., 0 through 4). Among the regressors in (5) is $WaveQuality_i$, which is an index of surf break quality that ranges from 1 (lowest quality) to 10 (highest quality). As pointed out in Kaffine, Mixon, and Mixon and Caudill [1,5,7], California is home to some of the world's top surf breaks. This list includes Mavericks and Rincon, which score highest in $WaveQuality_i$, and smaller surf breaks, such as Pigeon Point and Stinson Beach, which score among the lowest in $WaveQuality_i$. It is expected that higher-quality surf breaks will attract larger numbers of surfers, particularly non-local surfers, *ceteris paribus*. Thus, it is expected that $b_1$, the estimate of $\beta_1$ in (5) above, will be positively signed.

Among other regressors is $DiffAccess_i$, which is a dummy variable equal to 1 if surf break $i$ rates among the most difficult surf breaks to access, and 0 otherwise. Construction of this variable, following Mixon [5], is based on the availability of parking near the surf break and the difficulty that surfers face in getting to the shore. Mixon illuminates ([5], p. 385) discussion of this variable by indicating that it addresses accessibility issues related to the requirement to descend a cliff or to use watercraft in order to access the surf break. This variable (i.e., $DiffAccess_i$) is expected to be negatively related to $Congest_i$ [5]. The third regressor in (5) above, $Dirty_i$, is an index of the dirtiness of surf break $i$ that ranges from a low of 1 for least dirty to a high of 10 for most dirty. As Mixon indicates ([5], p.384), surf breaks located near river mouths are typically dirtier (in terms of bacteria, etc.) than other surf breaks. In describing this variable, Mixon provides ([5], p. 384) a unique example of surf break dirtiness by way of a south Los Angeles area surf break known as "Shitpipe", which is located across from the Hyperion Sewage Treatment Plant. In this case it is expected that $b_3$, the estimate of $\beta_3$ in (5) above, will be negatively signed. Next, $Sand_i$ is a dummy variable equal to 1 if the ocean floor at surf break $i$ consists of sand,

and 0 otherwise (e.g., rocks, reef). In this case, surf breaks exhibiting a less (more) punishing ocean floor, such as sand (rocks, reef), are expected to be more (less) congested than those with a punishing ocean floor [5]. As such, it is expected that $Sand_i$ will be positively related to $Congest_i$.

The key variable in our study, $Sharks_i$, appears next in (5) above. This variable is an index of shark activity at surf break $i$ that ranges from a low of 1 for the least shark activity to a high of 10 for most shark activity. As discussed in the previous section of this study, large sharks serve as nature's guardians of the surfing commons, and their presence shapes surf break congestion. As indicated earlier, congestion at surf break $i$, $Congest_i$, is expected to be decreasing in shark activity around the surf break. Thus, it is expected that $b_5$, the estimate of $\beta_5$ in (5) above, will be negatively signed.

The final two regressors in (5), $CentCali_i$ and $NorCali_i$, are, following Mixon [5], included to capture any structural differences in congestion of the surf break commons located in different portions of California's Pacific Ocean coastline. These are binary variables equal to 1 for surf breaks located in central California and northern California, respectively, and 0 otherwise. Mixon finds ([5], p. 393) that localism at the surf breaks of central California is fiercer than that at southern California's surf breaks, a result he asserts is not surprising given that the surf breaks around San Francisco/San Mateo County, Santa Cruz, and Monterey are infamous for fiercely protective local surfers. This result reflects that 'culture' (loosely defined) may play a role in determining property rights strength at a given group of surf breaks. Although no *a priori* is offered with regard to $CentCali_i$ and $NorCali_i$ in this study, they are included given that 'culture' may also relate to congestion of surfing commons in a particular area or region vis-à-vis those in other areas or regions.

*5.2. Data*

Data used in this study cover 144 individual surf breaks along the coastlines of California's three regions (southern California, central California, and northern California). Each variable is constructed by scientists at Surfline.com, arguably the premier website for information on surfing conditions at surf breaks around the globe. The ratings provided by Surfline.com are based on travel reports produced by experienced surfers who have visited each surf break. These describe conditions at each surf break, including congestion, wave quality, accessibility, water quality (dirtiness), ocean floor conditions, and shark activity, among others. Prior studies by Kaffine and Mixon [1,5] make use of these data. For example, Kaffine uses data [1] on surf breaks across all of southern California and the southernmost portions of central California. Mixon employs a larger data set [5], including surf breaks from all three regions in California.

Table 1 includes descriptions of all of the variables included in (5) above, along with sample statistics (i.e., means and standard deviations). As indicated there, the mean of $Congest_i$ is about 2.3, which is greater than the mid-point of the range for this particular index. Next, the mean wave quality (i.e., $WaveQuality_i$) in our sample is about 5.5, which is at the mid-point of this particular index. As is also indicated in Table 1, those surf breaks that are among the most difficult for surfers to access constitute 19.4 percent of our sample of California surf breaks. In terms of water quality, the mean value of $Dirty_i$ is about 3.6, or about two points below (cleaner than) the mid-point of the scale for this particular index.

Moving to the bottom of Table 1, 29.9 and 13.2 percent of the surf breaks in our sample reside in central and northern California, respectively. Thus, 56.9 of the surf breaks in our sample are located on the coastlines of southern California. Next, about 39 percent of the surf breaks in our sample present surfers with a sandy (relatively safe) ocean floor. As such, the remaining 61 percent of surf breaks present more dangerous floor conditions, such as reefs and rocks. Lastly, the mean value for $Sharks_i$ in our sample is about 3.9, which is about 1.5 places below the mid-point for this particular index.

**Table 1.** Variable Descriptions and Summary Statistics

| Variable | Description | Mean | Std Dev |
|---|---|---|---|
| $Congest_i$ | An index of congestion at surf break $i$, that ranges from a low of 0 for least congested surf breaks to a high of 4 for most congested surf breaks. | 2.264 | 1.183 |
| $WaveQuality_i$ | An index of wave quality at surf break $i$ that ranges from a low of 1 for lowest wave quality to a high of 10 for highest wave quality. | 5.507 | 1.961 |
| $DiffAccess_i$ | A dummy variable equal to 1 if surf break $i$ rates among the most difficult surf breaks to access, and 0 otherwise. | 0.194 | 0.397 |
| $Dirty_i$ | An index of the dirtiness surf break $i$ that ranges from a low of 1 for least dirty to a high of 10 for most dirty. | 3.552 | 2.312 |
| $Sand_i$ | A dummy variable equal to 1 if surf break $i$ has a sandy floor, and 0 otherwise. | 0.389 | 0.489 |
| $Sharks_i$ | An index of shark activity at surf break $i$ that ranges from a low of 1 for the least shark activity to a high of 10 for most shark activity. | 3.889 | 3.061 |
| $CentCali_i$ | A dummy variable equal to 1 if surf break $i$ is located in central California, and 0 otherwise. | 0.299 | 0.459 |
| $NorCali_i$ | A dummy variable equal to 1 if surf break $i$ is located in northern California, and 0 otherwise. | 0.132 | 0.340 |

## 6. Empirical Results and Discussion

Results from ordinary least squares (OLS) estimation of two versions of (5) are reported in Table 2. As indicated in the second column of Table 2, the specification in (5) is jointly significant and produces an $R^2$ of 0.292. Of the seven coefficient estimates in this specification, five retain their expected signs. The coefficient estimates attached to two variables, *Dirty* and *Sand*, retain signs that counter their respective hypotheses, however neither is statistically significant at conventional levels. On the other hand, as expected *WaveQuality* retains a positively-signed coefficient estimate that is also significant at the 0.01 level. In this case, a one-unit increase in the quality of the surf break increases congestion there by about 0.27 units, which is about 7% of the full range of the congestion index, and about 12% of the mean level of congestion. Next, the difficulty in accessing a surf break is, as expected, negatively and significantly related to congestion at that particular surf break. In this case, a decrease in congestion of 0.368 units represents about 9% of the full range of the congestion index, and about 16% of the mean level of congestion.

Results reported in Mixon [5] suggest that California's surf breaks comprise separate "markets" by region, at least in terms of the exclusionary behavior of the surf gangs that dominate them. A similar result is found in Table 2, with respect to congestion at surf breaks. As indicated in the second column of Table 2, surf breaks located in both central California and northern California are significantly more congested, *ceteris paribus*, than their southern California counterparts. A portion of this effect could be due to the larger number of surf breaks in southern California. This effect may also capture differences in surfing culture in the southern California region.

Lastly, the coefficient estimate attached to the variable of interest, *Sharks*, is both negatively-signed and statistically significant, suggesting that movement up the shark index is associated with a reduction in congestion at a given surf break. More specifically, a one-unit increase in shark activity around a particular surf break leads to a decrease in congestion of about 0.16 units, which represents about 4% of the full range of the congestion index, and about 7% of the mean level of congestion. This result, when combined with the relatively recent decrease in large shark populations [26,27], has implications regarding sharks' role as natural guardians of the surfing commons. Where the quality of the break at a surfing commons is relatively high, decreasing shark activity will lead to a larger number of non-locals who are attempting to access the surf break. Surf gangs will, in response, tend to become more intense in their attempts to exert informal property rights over the surfing commons [1,5–7]. This

conclusion supports the call [14,15] for more multi-disciplinary empirical approaches to common-pool resource issues.

**Table 2.** OLS and Ordered Probit Results

| Variables | OLS Results | | Ordered Probit Results | |
|---|---|---|---|---|
| | (1) | (2) | (3) | (4) |
| *constant* | 1.244 * (3.02) | 0.817 * (1.75) | 0.613 (1.61) | 0.152 (0.38) |
| *WaveQuality* | 0.266 * (4.80) | 0.265 * (4.49) | 0.279 * (5.27) | 0.285 * (5.30) |
| *DiffAccess* | −0.368 * (−1.77) | −0.313 (−1.47) | −0.423 * (−1.85) | −0.367 (−1.59) |
| *Dirty* | 0.016 (0.33) | 0.025 (0.52) | 0.020 (0.43) | 0.032 (0.66) |
| *Sand* | −0.287 (−1.31) | −0.268 (−1.14) | −0.296 (−1.49) | −0.290 (−1.38) |
| *Sharks* | −0.161 * (−3.50) | | −0.170 * (−3.19) | |
| *Shark10* | | −1.376 * (−3.40) | | −1.454 * (−2.52) |
| *Shark9* | | −1.166 * (−2.78) | | −1.298 * (−2.39) |
| *Shark8* | | −0.964 * (−1.93) | | −1.080 * (−1.88) |
| *Shark7* | | −0.476 (−1.37) | | −0.539 (−1.17) |
| *Shark6* | | −0.685 (−1.41) | | −0.702 (−1.31) |
| *Shark5* | | −0.552 (−1.39) | | −0.640 (−1.14) |
| *Shark4* | | −0.544 (−0.19) | | −0.623 (−0.55) |
| *Shark3* | | 0.299 (0.95) | | 0.329 (0.84) |
| *Shark2* | | 0.270 (0.97) | | 0.311 (1.23) |
| *CentCali* | 0.611 * (2.28) | 0.509 (1.57) | 0.623 * (2.03) | 0.557 (1.53) |
| *NorCali* | 0.953 * (1.99) | 1.007 * (2.69) | 0.987 * (2.08) | 1.101 * (2.24) |
| nobs | 144 | 144 | 144 | 144 |
| *F*-statistic | 8.02 * | 4.11 * | | |
| Model $\chi^2$ | | | 50.1 * | 57.0 * |
| $R^2$ | 0.292 | 0.325 | | |
| Estrella $R^2$ | | | 0.309 | 0.346 |

Notes: The numbers in parentheses above are robust *t*-ratios based, which in the case of the OLS results are based on Newey-West standard errors [39]. * denotes significance at the 0.10 level or better.

The relationship between shark activity and surf break congestion is explored in greater depth using the version of (5) tested in the third column of Table 2. There, a series of dummy variables

including *Shark10*, *Shark9*, *Shark8*, *Shark7*, *Shark6*, *Shark5*, *Shark4*, *Shark3*, and *Shark2*, replaces *Sharks* in (5). The first of these variables, *Shark10*, is equal to 1 if a given surf break is scored as a 10 on SurfLine.com's shark activity index, and 0 otherwise. The other variables in this series are defined similarly, using the numerals in their respective names. Each of these variables is expected to be negatively signed, indicating less congestion around surf breaks with shark activity exceeding the lowest level than around their counterparts with the lowest level of shark activity. Moreover, the coefficient estimates in this series should exhibit a cascading effect moving from the first to the last variable in the series.

As indicated in column three of Table 2, this revised specification is jointly significant and produces an $R^2$ of 0.325. The results for *WaveQuality* and *NorCali* generally mirror their counterparts in column two of Table 2. However, in this specification *DiffAccess* and *CentCali* are marginally insignificant at the usual levels. Here, all but two of the variables in the shark activity series are negatively signed, as expected. Estimates for *Shark10*, *Shark9*, and *Shark8* are each statistically significant. The expected cascading effect is exhibited through *Shark7*, as the estimated coefficients are −1.376, −1.166, −0.964, and −0.476, respectively. The cascading effect continues further down the series. Using both the full range and the mean of congestion index as before, surf breaks exhibiting the highest level of shark activity exhibit about 27.5% to about 60% less congestion than their less "sharky" counterparts (i.e., those surf breaks scoring 1 on the shark activity index). The results for the second- and third-most shark activity levels indicate 19–23% less congestion using the full range of the congestion index, and about 43–52% less congestion using the mean level of congestion, than their less "sharky" counterparts.

The discrete and ordered nature of *Congest* points toward a violation of some of the conditions for estimation of (5) by OLS. As such, results from ordered probit estimation of the specification in (5) are reported in the fourth column of Table 2. As before, the specification in (5) is jointly significant and produces a pseudo $R^2$ [40] of 0.309, while the parameter estimates for *WaveQuality* and *DiffAccess* retain their expected signs and are statistically significant. Here, both *CentCali* and *NorCali* are positively signed and statistically significant, while the key variable under study, *Sharks*, retains the expected negatively-signed coefficient and is also statistically significant. This particular result is explored in greater depth in Table 3, which provides marginal probability estimates. As indicated there, a marginal increase in shark activity around a surf break reduces the probability of observing the highest and second-highest levels of congestion at the break by 5.5 percentage points. Again, this result, when combined with the relatively recent decrease in large shark populations [26,27], has implications regarding for sharks' role as natural guardians of the surfing commons. Decreasing shark activity around high-quality surf breaks means that surf gangs will tend to become more intense in their attempts to exert informal property rights over these commons [1,5–7].

**Table 3.** Marginal Probability Estimates.

|  | $\partial P$ (*Congest* = 0)/$\partial X$ | $\partial P$ (*Congest* = 1)/$\partial X$ | $\partial P$ (*Congest* = 2)/$\partial X$ | $\partial P$ (*Congest* = 3)/$\partial X$ | $\partial P$ (*Congest* = 4)/$\partial X$ |
|---|---|---|---|---|---|
| *WaveQuality* | −0.035 | −0.041 | −0.016 | +0.034 | +0.058 |
| *DiffAccess* | +0.053 | +0.063 | +0.022 | −0.051 | −0.087 |
| *Dirty* | −0.002 | −0.003 | −0.001 | +0.001 | +0.005 |
| *Sand* | +0.037 | +0.044 | +0.016 | −0.036 | −0.061 |
| *Sharks* | +0.021 | +0.025 | +0.009 | −0.020 | −0.035 |
| *CentCali* | −0.079 | −0.092 | −0.033 | +0.075 | +0.129 |
| *NorCali* | −0.125 | −0.146 | −0.052 | +0.119 | +0.204 |

In terms of the other variables, the marginal probability estimates provided in Table 3 indicate that a marginal improvement in surf break quality increases the probability of observing the highest and second-highest levels of congestion at the break by 9.2 percentage points. Additionally, a marginal reduction in surf break accessibility decreases the probability of observing the highest and second-highest levels of congestion at the break by 13.8 percentage points. Lastly, a movement from the surf breaks of southern California to those along the coasts of northern (central) California

accompanies an increase the probability of observing the highest and second-highest levels of surfing commons congestion by 32.3 (20.4) percentage points.

Finally, the relationship between shark activity and surfing commons congestion is explored in greater depth using the version of (5) tested in the last column of Table 2. There again, a series of dummy variables including *Shark10*, *Shark9*, *Shark8*, *Shark7*, *Shark6*, *Shark5*, *Shark4*, *Shark3*, and *Shark2*, replaces *Sharks*. As indicated in the last column of Table 2, ordered probit estimation of this revised specification is jointly significant and produces a pseudo $R^2$ of 0.346. Once again, all but two of the variables in the shark activity series are negatively signed, while each of the first three is statistically significant at the 0.10 level or better, thus supporting our main hypothesis. Lastly, the results for *WaveQuality* and *NorCali* in this case generally mirror their counterparts in column four of Table 2. However, both *DiffAccess* and *CentCali* are marginally insignificant in this specification.

## 7. Concluding Remarks

Prior research indicates that surfing provides both direct and indirect benefits in the form of consumer surplus to surfers, tourism revenue, and even higher prices of residential real estate properties situated in close proximity to surf breaks. However, other studies have also shown that the open-access nature of a surf break creates the unpleasant side-effect of congestion, as surfers crowd or over-exploit the common-pool resource represented by the surf break. Such crowding inhibits the enjoyment of each individual user (i.e., surfer) of the surfing commons, and, thus, leads to the formation of surf gangs, which establish informal property rights, backed by force, over surf breaks, particularly those of the highest quality.

While previous studies in ecology have provided support for the importance of sharks in regulating the marine ecosystem, our study shows that sharks also serve as nature's guardians of surf breaks by regulating access to them. Using both ordinary least squares and ordered probit models, we find that surf breaks in California that are associated with the highest level of shark activity tend to be less congested, perhaps by as much as 28% (or more). We arrive at this result while controlling for the quality, difficulty of access, and location of the 144 California surf breaks that are examined.

The results presented in this study have implications for the relatively recent decline in the populations of large sharks at surf breaks worldwide. That is, such declines make previously 'guarded' surf breaks more accessible by humans, which in turn has implications for overexploitation of these common pool resources. As utilization of high-quality surf breaks rises in response to lower levels of shark activity around them, surf gangs are expected to become more tenacious and intense, *ceteris paribus*, in their efforts to exert informal property rights over the surfing commons. This type of activity entails costs to both groups of surfers, locals and non-locals, as well as to taxpayers through greater use of criminal justice and other publicly-financed resources. Thus, the results in this study also support the call by some researchers for more multi-disciplinary empirical approaches, perhaps involving the fields of biology, criminal justice, economics, and law, to address common-pool resource issues such as those concerning the surfing commons.

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