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(Un)frozen Spaces: Exploring the Role of Sea Ice in the Marine Socio-legal Spaces of the Bering and Beaufort Seas

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Abstract

Sea ice is a dynamic physical element of the greater Arctic marine system, one that has myriad connections to human systems on a variety of spatial and temporal scales. Changes to the spatial extent of sea ice simultaneously permits and endangers maritime operations, as well as impacts current debates over maritime boundaries, presenting an interesting challenge for international law. Sea ice is not a stationary object; it moves through time and space in response to the physical forces of wind, ocean currents, and heating. It has a tangible, material and substantive role in contestations over territory, resources and marine boundaries in both the Beaufort and Bering Seas. We suggest here that sea ice's material nature in these marine regions continuously challenges stationary conceptions of law in complex and sometimes contradictory ways. Building on recent work on the human geographies of sea ice, the dynamic field of legal geography and recent contributions in ocean-space geography, we outline how the dynamism of sea ice could influence notions of boundary, resources and climate change in ocean-spaces of the greater Arctic region.

Keywords
Sea ice, geography, law, international borders, legal geography, Arctic climate change, ocean- space

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Introduction

In the Arctic, sea ice has been on a marked decline in both thickness and seasonal extent (Overland and Wang, 2007; Parkinson, 2014; Jeffries et al., 2015). These changes have been particularly evident in September, the time of year when the seasonal minimum is observed after a summer of heating (Parkinson, 2014). In 2012, a new record was reached, where total sea ice extent for the region fell to 1.32 million mi^2 (Stroeve et al., 2012). Future projections demonstrate that this trend will continue, with models projecting further decline of summer sea ice extent by as much as 40% in the Arctic Ocean by 2050 (Wang and Overland, 2009; 2012; 2015). The changes that are occurring to this physical system have radiating consequences to a host of social and political systems and practices, all of which are connected in a variety of temporalities to the material nature of the formation, onset and eventual melt of sea ice.

Sea ice forms when the upper-most layer of the ocean freezes in response to the seasonal onset of cold atmospheric temperatures (Parkinson, 2014). After this initial process, sea ice is continuously altered, modified and moved by a host of physical, chemical and biological processes that vary on spatial and temporal scales (Dieckman and Hellmer, 2003). These processes include surface heating, ocean currents and wind forcing. Contrary to popular conceptions, the surface of sea ice is not a smooth, purely white crystalline surface; rather, it can be jagged, uneven, riddled with both organic and terrestrial sediments as well as surface melt ponds. Sea ice is constantly subjected to motion, and can pile up and form miniature "mountain ranges" in the middle of the ocean called pressure ridges (Thomas and Dieckmann, 2008). The thickness of sea ice can vary significantly depending on a variety of factors including its relative age; multi-year sea ice, which has survived a summer melt, forms the foundation of the Arctic sea ice pack and can range between 6 and 8 m in thickness in some regions (Haas, 2003). Conversely, first-year sea ice, newly formed in a single winter season, can vary from just a few inches to 3 m (Eicken, 2003). These variations illustrate the complex set of physical processes that constitute what sea ice is, how it forms and where it persists.

As one of the most expansive geophysical processes on the planet, seasonal sea ice cycles play a key role in global climate processes. The estimated global extent of sea ice cover in both hemispheres at any one moment in time is between 3 and 6 percent of the total surface area of the earth (Comiso, 2003). Sea ice influences the dynamic transfer of heat to and from the atmosphere and the ocean. Its high albedo plays a critical role in the surface reflection of solar energy, and the melting of sea ice consequently lowers albedo (by allowing darker sea ice surface melt ponds or ocean water to appear in its place), engaging the so-called "ice-albedo feedback" that can melt ice even further (Thomas and Dieckmann, 2008). Additionally, sea ice affects the distribution of salinity in the ocean, which impacts density gradients, a driving force behind global ocean circulation patterns which in turn impact global heat fluxes. Furthermore, because sea ice itself is a substrate for plankton communities to adhere to and proliferate, its loss can directly affect biological communities as well (Comiso, 2003; Gradinger, 2008). Thus, sea ice has a tangible, measurable impact upon associated physical, chemical and biological systems in the marine ecosystem. These changes, all inherently complex and interconnected, both affect and are affected by human activities.

The recent trends in the reduction of sea ice cover in the Arctic (Stroeve et al., 2012; Parkinson, 2014) have generated calls for a new, interdisciplinary approach to understanding the impacts that this change to this complex physical system has on associated socio-environmental systems (Eicken et al., 2009; Lovecraft et al., 2011; Druckenmiller et al., 2013; Lovecraft, 2013; Tejsner, 2013; Tyrrel, 2013). A new perspective is particularly pertinent in light of the increase in economic and political interest in the region (Brigham, 2010; Byers, 2013; Zellen, 2013). Shifts in the spatial scale and timing of the breakup and formation of seasonal sea ice in this sensitive region not only have had a strong impact on marine ecosystems, but have impacted myriad human practices, systems, and activities as well (Lovecraft and Eicken, 2011; Druckenmiller et al., 2013). Sea ice and human systems in the greater Arctic are mutually shaping one another; anthropogenic forcings drive climatic changes that drive an increasingly complex array of dynamic interactions with the marine environment.

The perspectives of what climatically driven changes to the sea ice system means for communities or other related social, economic or political systems are quite varied and diverse (Lovecraft and Eicken, 2011). There has been a great deal of excellent work in recent years examining the human geographies of sea ice. Druckenmiller et al. (2013) explain the vital linkages between indigenous use of sea ice for bowhead whale hunting and scientific observations of changing shore-fast ice conditions, and how the transfer of information between these two groups can assist in the growing knowledge base around climate induced changes to the sea ice system. Other investigations have also recently explored the important linkages that sea ice has to indigenous communities in the Arctic. These include an explanation of the various meanings attached to the concepts of place in an always changing environment (Tyrrel, 2013); creating better pathways of communication between agencies and user groups in sea ice areas (Lovecraft et al., 2013); exploring the narratives of risk management and how they relate to the adaptation practices of coastal Arctic indigenous communities (Tejsner, 2013); exploring how philanthropic investments could help foster resiliency in changing sea ice conditions (Henshaw, 2013); and connecting altering spatial patterns of sea ice near coastal Arctic communities with walrus hunting practices (Robards et al., 2013).

Perhaps one of the greatest impacts that shifting sea ice conditions in the Arctic has had on human systems are those that are tied to policy and law. Recent and differing changes in the seasonal and spatial extent of sea ice complicate and intensify a variety of political, legal and marine logistical contestations in the region (Byers, 2013; Steinberg et al., 2015) including a focus on the impacts from an increase in maritime traffic through Bering Strait (Huntington et al., 2015), concern for the impacts to marine mammals (Huntington et al., 2015) and the increased need for cooperative efforts towards maritime safety and environmental protection operations (Brigham, 2010). All of these examples share a common linkage: the complex relationship that persists between dynamic sea ice conditions and the varying layers of rules of law that are connected to this dynamic space.

In this paper, we recognize that sea ice is transformative across a range of dimensions (areal coverage, thickness, timing of breakup/formation, etc.) in state and extent that reflect and reproduce sea ice's geophysical dynamism. In addition to supporting the livelihoods of numerous Arctic and sub-Arctic peoples, these processes illustrate the complexity of this environment and how the material attributes of sea ice are constantly being changed and have influenced (or are influencing) a host of associated systems. Exploring the ways in which human

sociolegal systems are connected with, influenced by and integrated into the shifting seasonal cycles of sea ice in the greater Arctic region is a vital task not just for improving our understanding of the impacts of climate change, but, also, more specifically, for understanding how social activities occur across a variety of ephemeral and ever-shifting borders. These include the borders that purport to divide ice from water and ocean from land, define the territories of individual states, or more generally bound and constrain movements within a region where ice is (semi)present. Building on recent work on the human geographies of sea ice (Laidler, 2006; Aporta, 2009; Bravo, 2009; Laidler et al., 2010; Aporta, 2011; Aporta et al., 2011; Laidler et al., 2011), and by recent contributions in ocean-space geography (e.g. Steinberg and Peters (2015), Anderson and Peters (2013)), here we will outline the characteristics that sea ice has for a more nuanced way of thinking about sea ice geographies and issues of human interaction with the marine environment in the greater Arctic region. Furthermore, we will suggest how the conceptual problem of sea ice is a fruitful project for the field of legal geography by highlighting the two conceptual examples in the Beaufort and Bering Seas. What we hope to contribute to this emerging dialogue is a finer examination of how the complex and ever shifting system of sea ice could influence notions of boundary, resources and climate change in ocean-spaces of the greater Arctic region.

Law, dynamic sea ice and ocean-space

At its core, legal geography explores the relationship between the law and the geographies (spatial and temporal) of political and social life, examining how they each influence, structure, and impact one another (Blomley and Clark, 1990). Here, the general themes of boundary, territory and contested spaces within the environment are well explored and have expanded rapidly within the last decade (e.g., Blomley et al., 2001; Delaney 2014). Legal geography represents a highly interdisciplinary approach to the overall understanding of how law shapes physical conditions, legitimates spatial relations, and contains and/or constrains a physical presence (Holder and Harrison, 2003). Within this framework, law is described and understood more as a dynamic, shifting, and sometimes contradictory process than as an object (Delaney, 2014).

This approach could be a welcomed conceptual tool for the world of sea ice and law. Sea ice has a tangible, material and substantive role in contestations over territory and resources. In their review of the legal status of sea ice in the Arctic Ocean, Baker and Mooney (2012) outline the ways in which current legal structures in the Arctic cannot adequately account for the changing physical contexts of sea ice. They note that the legal histories of sea ice, especially in the U.S. and Canada, have been complex, intertwined with territorial claims of the outer continental shelf under the United Nations Convention on the Law of the Sea (UNCLOS), indigenous rights and rights of maritime passage through the Arctic Ocean via the Northwest Passage (Baker and Mooney, 2012). They outline that in recent decades, legal references to sea ice have progressed to acknowledging it as a resource that is connected to a variety of ecosystem services and users in the region (Baker and Mooney, 2012). Although this is a much more dynamic view of sea ice, it is still problematic as it does not fully encompass the role of sea ice system has on sociolegal systems in this changing space. The unique processes of sea ice that make it a vital element of the

marine ecosystem are the same properties that make sea ice a problem for the laws that govern polar spaces; sea ice is not a stationary object, it moves through time and space in response to a variety of physical forcings. Thus, the physical attributes of sea ice destabilize political contestations over territory in this region. What's more, the actual "disappearance" of sea ice in the Arctic region is much more complex. While there is no dispute that there is a continued decline in sea ice trends across the entire Arctic, smaller regions have demonstrated variability over the past decade, with some regions experiencing vast prolonged periods of retreat, and others experiencing fluctuating years of intense seasonal advance and retreat (Frey et al., 2015). The dynamic materiality (i.e., solidity and fluidity, retreat and advance) of sea ice challenges the more dominant geopolitical narratives of land and sea (Steinberg and Peters, 2015), contributing to the debates over the future of territory, resources and policies of this rapidly changing region in a manner that resonates with the work of "new materialists" who offer the perspective that matter is dynamic, composed of relational connections between biophysical forces and social interactions (Coole and Frost, 2010; see also Bakker and Bridge, 2006; Dolphijn and van der Tuin, 2012; Curti and Moreno, 2014). Sea ice fits into this paradigm with its fluid, yet substantive, physical presence. Like many other fluid processes, sea ice shifts in volume, size, density, consistency and location at various spatial and temporal scales. As a material entity, it already has impacted and shaped the way we conceptualize alterations to human systems in the context of climate change.

While legal geography has been a platform to investigate the contingent nature of law within both social and physical environments, little work to date has investigated how shifting physical properties of the marine environment influence and impact the more stationary conceptions of law. Moreover, explorations into the legal role of sea ice in various contestations in the rapidly changing Arctic have thus far been focused on a singular notions of sea ice retreat (or seasonal disappearance) over an entire region, and not focused on contrasting potential differing sea ice regimes and their associated impacts to sociolegal systems on a finer scale (Rayfuse, 2007; Young, 2009; Brigham, 2010; Baker and Mooney, 2012). Sea ice, as a dynamic object in ocean-space, has a tangible impact not only on law, but upon the politics of this region as well. This sentiment has been echoed in the recent work by Steinberg and Peters (2015) who have drawn attention to how a perspective centered on the ocean, with its exceptionally dynamic materiality, can change the way we understand political contestations in and over space. As they note, their call for using the ocean's fluidity to understand the land reverses the more typical analytical framework, where conceptions of "territory" based on linear, land- based notions of law have been imperfectly applied to the changing, fluid marine environment (Steinberg, 1999; Steinberg and Peters, 2015). They argue that the ocean's fluid materiality through space and time necessitates new ways of mapping, understanding and governing not just the oceans but the world as a whole. Here, we draw on evidence from the Beaufort and Bering Seas, two end members of a larger sea ice system in a state of change, to examine the dynamic, material, and vital linkages between sea ice, resources, and law. We do so with a conceptualization of sea ice as an element as equally substantive and important to the human activities and dynamics in these regions as the legal frameworks that govern them.

Beaufort Sea

Sea ice reduction in the Beaufort Sea, a shallow area of ocean bounded by Alaska to the west, Banks Island of the Canadian Archipelago to the east, and the Canadian Mackenzie River delta to the south, has been particularly rapid (**Figure 1**; Hutchings et al., 2012). Since 2007, a combination of factors, including warming, increase of riverine inputs and an increase of wind velocities, have increased ice-free areas on average by 80% (Wood et al., 2013). Recent measurements of sea ice persistence, or how many days a year sea ice is present in the surface ocean, in the localized areas of the Beaufort Sea show a loss of 12.84 days per year over the 2000–2012 period (Frey et al., 2015). Warming surface ocean temperatures occur not only from warmer atmospheric temperatures, but also from the lack of seasonal sea ice cover, which acts as a "cap" to prevent solar radiation from heating the ocean. This heating is particularly significant when placed in combination with an increase advection, which pushes sea ice further away from the coastline (Wood et al., 2013). In addition, the sea ice that does form in the Beaufort has had an ever-decreasing content of thicker, multi-year ice within the last two decades (Wood et al., 2013). These factors have sparked speculation that this warming trend and change in physical conditions represent a "new normal" for the Beaufort Sea, which could leave this region more vulnerable to rapid warming (compared to other regions in the Arctic) and perhaps even greater losses of sea ice in the coming decades (Wood et al., 2013).

Reduction of sea ice cover in the Beaufort Sea has added a new dimension to a longstanding boundary dispute between the United States and Canada (Nord, 2010; Baker and Mooney, 2012; Byers, 2013). The border dispute has its origins in an 1825 Treaty between Britain and Russia, which places the eastern border of Alaska at "…the meridian line of the 141st degree, in its prolongation as far as the frozen ocean" (Nord, 2010; Baker and Mooney, 2012; Byers, 2013). Canada claims that the reference to "prolongation as far as the frozen ocean" means that the land border extends into the sea (in this instance, continuing along the 141st degree meridian line). The United States, by contrast, claims that the boundary applies to land only. At sea, according to the U.S., the normal principles of equidistance that govern maritime boundaries elsewhere in the world- that is the practice of placing a median line evenly distributed between the coastlines of two adjacent countries- should apply (United Nations, 1982: Article 15). Because of the angle of the coast at the point where the 141st meridian line intersects with the coastline, this would result in a maritime boundary that angles to the northeast, giving the United States a greater portion of the Beaufort Sea, at least out to the 200 nautical mile limit of the two nations' Exclusive Economic Zones (EEZs; Baker and Byers, 2012; Byers, 2013).

While part of this dispute can be traced to different interpretations of "as far as" (i.e., does it mean "up to" or "up to and including"?), the implication of the treaty for the United States-Canada maritime boundary is also muddled by the phrase "frozen ocean." The phrase "frozen ocean" is an explicit reference to sea ice. The phrase "frozen ocean," by implying that the ocean is an extension of land (because of its frozen state), can be seen as justifying continuing the 141st meridian line into the sea, in disregard of normal maritime boundary delimitation conventions. On the other hand, by highlighting the "frozen ocean" as "ocean," the phrase could alternatively be seen as affirming that the usual maritime boundary procedures apply beyond the coastline (Nord 2010; Byers 2013). The dispute parallels one being played out between the United States and Canada in the Canadian archipelago regarding the degree to which seawater has exceptional (and, to an extent, land like)

legal properties when frozen (Pharand, 2007; Byers and Lalonde, 2009; Kraska, 2009; Steinberg, 2014; Steinberg et al. 2015) and speaks more broadly to questions about the role of sea ice as a material entity that underpins and adds new dimensions to territorial conceptions of ocean spaces (Rothwell, 1996; Baker and Mooney, 2012). Yet both arguments, "frozen ocean" as exceptional or "frozen ocean" as ocean, attempt to follow the legal model of assigning fixed categories to space, a model that is perhaps exceptionally ill-suited for sea ice's spatial and temporal dynamism (Steinberg and Kristoffersen, in press; Steinberg, Kristoffersen, and Shake, in press). Indeed, what happens to the treaty, based as it is on the concept of "frozen ocean," if the ocean is no longer frozen?

In the case of the Beaufort Sea border dispute, the physicality of ice is present within the written word of law. The designation of the boundary "at the meridian line of the 141st degree, in its prolongation as far as the frozen ocean" uses the notion of the solidity of the surface ocean from the presence of sea ice to indicate that the border between these two territories as delineated on land should be extended to the coast, specifically (or at least to) the part of the coast that would be "frozen ocean." Of course, it is the precise interpretation of what "frozen ocean" is (or, isn't) that is the central component of the legal arguments for either side in relation to the interpretation of this treaty. And yet this debate that hinges on the meaning of sea ice is also characterized by a desire to see *through* the ice. Much of the debate over the boundary line has been less concerned with the extension of sovereignty (which, in any event, extends only to 12 nautical miles from the coast), than with the potential oil and gas reserves that are locked within the seabed of the Beaufort Sea shelf. Although precise values are difficult to measure, the Beaufort shelf is part of a larger formation that is estimated to have nearly 33% of the estimated total of ~90 billion barrels of undiscovered offshore oil in the Arctic (Bird et al., 2008). Thus, there is a vested interest by both parties to assert sovereign control over as much of this area as possible in order to reap the economic benefits that are associated with this type of development.

From a legal geography perspective, it follows that perhaps a better question is to explore how the dynamic presence of sea ice (including the possibility of its complete disappearance from areas such as the Beaufort) produces, maintains or transforms space in this contested area and shapes social and economic relations, both in terms of international politics and in terms of human livelihoods. For example, seasonal sea ice presence in the disputed area could impact open water access to remote offshore oil and gas extraction operations. Its presence in this area might constrain the physical ability to extract resources from the seabed or at least require an expansion of engineering resources (i.e. more time, more costs) to do so. One might conclude that less sea ice in the area of the disputed boundary might accelerate the territorial claim process, which in turn could lead to an acceleration of an increase in oil and gas extraction operations on and below the surface ocean. In this example, sea ice (as a material force) has linkages to an entire host of operations in the coastal ocean. The mere presence (or absence, as the case may be) of sea ice has the ability to intensify debates, and opens the door to possibly investigating such connections across the entire Arctic region. In some way or form, sea ice has a tangible impact upon contestation through the law in these disputed coastal waters.

Bering Sea

Sea ice also plays an important role in maritime boundaries and resource contestations in the Bering Sea (**Figure 2**). Like the Beaufort Sea, the Bering has exhibited a high degree of seasonal variability of sea ice cover (Frey et al., 2015). Over the past decade, however, sea ice persistence has been increasing during the winter months, pushing the ice edge farther south and adding ~9 days per year (over the 2000 to 2012 period) of sea ice cover during the winter months (Frey et al., 2015). It is thought that (in contrast to the nearly ubiquitous secular decreasing trends in Arctic sea ice) these recent shifts in Bering Sea ice are part of more complex multi-year variability in sea ice persistence where this last decade of sea ice increase was preceded by a decade of sea ice decrease, and so on (Frey et al., 2015).

The seasonal onset, formation and subsequent retreat of sea ice (and its variability) in the Bering is a crucial physical process for an array of culturally and commercially valuable fisheries stocks (Pfieffer and Haynie, 2012; Sheffield Guy et al., 2014) which are federally managed under the Magnuson Fishery Conservation and Management Act of 1976, renamed the Magnuson-Stevens Fishery Conservation Act in partnership with the National Marine Fisheries Service (NMFS). The largest and most lucrative of these federally managed stocks is walleye pollock (*Theragra chalcogramma*), which garners over $1 billion annually (Hiatt et al., 2009; Pfeiffer and Hainye, 2012). The pollock fleet in the Bering harvests around 40% of its total allowable catch when sea ice cover is at its seasonal peak, from January to April (Pfeiffer and Hainye, 2012). Although pollock vessels that fish along the shelf region of the Bering don't generally fish within the sea ice, they follow the region of the ice edge to chase the colder, higher saline bottom waters that result from sea ice formation. This colder water, names the cold pool, is prime habitat for roe bearing pollock, which are a more valuable fish product at this time of the season (Pfeiffer and Hainye, 2012). In addition, recent conflicts over the incidental catch of salmon, which congregate with known viable pollock fishing grounds have fostered a new focus on bycatch management (Stram and Evans, 2009; Stram and Ianelli, 2009). Thus, the seasonal spatial allocation of sea ice plays an integral role in the harvesting of, and constraints around, this valuable resource. Changes to the distribution of sea ice in the Bering could have consequences for the marine food web, as the timing of the sea ice retreat is essential for the onset of primary production (Grebmeier et al., 2006; Cooper et al., 2012; Stabeno et al., 2012). Recent increases in the seasonal spatial extent of sea ice in the southern Bering (Frey et al., 2015) could not only present a hazard to fishing vessels in the region, but could perhaps push the harvesting of fisheries resources by international vessels out of the space of international boundaries and into the sovereign shelf areas of the U.S.

Fears of harm to the pollock stock, or even its outright collapse, are not entirely unfounded. Although the Bering Sea shelf currently supports a commercially viable ecosystem, other areas of the Bering in the past have experienced total collapse. Beyond the EEZ of the southwestern coast of Alaska in the Bering Sea is a semicircular enclosed area of approximately 36,000 mi^2 of international waters (Byers, 2013). This area, commonly referred to as the "Donut Hole," is a contested ocean space for Alaska, which views overfishing by international vessels in this bounded area as a threat to the vitality of U.S. sovereign resources (Wespestad, 1993). A large population of pollock was found in the deep waters of this basin, and an international fishery quickly followed (Bailey, 2011). It has been estimated that the Donut Hole catch was 1.7 million tons at its peak in 1987, but quickly plunged to only 10 thousand tons in 1992 (Bailey, 2011). This crash called for an international agreement to halt excess landings of pollock and to maintain their presence in the

ecosystem (Wespestad, 1993; Pfeiffer et al., 2012). In 1994, the U.S., Russia, China, Korea, Poland and Japan signed the Convention on the Management of Pollock Resources in the Central Bering Sea (Wespestad, 1993; Bailey, 2011). Although this agreement effectively closed the pollock fishery in the central Bering, the stock has never recovered and remains threatened.

This type of relationality between "open" spaces of international waters and commercially viable mobile living resources that move through (indeed around) them is not isolated to this region alone. While what Steinberg et al. (2015) call 'sovereignty holes' can be found throughout the world's oceans, they have generated particular concern in the Arctic. East of the central Bering, in the Sea of Okhostk, there is an elongated area of "open" international waters surrounded by the sovereign waters of Russia's coast called the "Peanut Hole" (Goltz, 1995). In the early 1990s international vessels began to harvest large amount of pollock from the area inside the Peanut Hole, spurring fears of a collapse of the Russian stock. Like in the Bering Sea, international agreements were forged in 1993 to help stop the incidents of illegal fishing and protect the resource (Goltz, 1995). Another example can be found in the Barents Sea Loophole, which is an ongoing political contestation for fishing rights between Norway and Russia in the swath of international waters enclosed within the Barents Sea (Stokke, 2001). Like the Bering, the Barents Sea has sea ice present for a portion of the year, although to a lesser spatial extent. We present the case of the pollock collapse in the central Bering Sea as an example of the dynamic relationality that persists between maritime boundaries and the extraction of living marine resources in sea ice systems. There is (and was) a dynamic flow of resources to and from this area in response to the opening and closing of this marine space as sea ice retreats and forms. Sea ice in the Bering Sea is an active component to these relationships between material resources, economic systems and dynamic ocean-space. Exploration into connections that persist between the spatial allocation of vessels and pollock resources on the Bering shelf has been recently explored by Watson and Haynie (2016). This type of work demonstrates an increased need to (re)conceptualize the spatial connections that persist between the changing marine environment, mobile living resources and vessel flows. In the case of more persistent sea ice conditions in the Bering (Frey et al., 2015), increases of seasonal sea ice in this commercially active region could not only increase the number of interactions of vessel traffic with ice, but also could perhaps shift incidents of illegal fishing out of bounded international areas. This could result in the extraction of commercially viable species of fish by international vessels from within the EEZ of the U.S. Recent work also suggests that these conditions might reverse themselves in the future if the Bering shifts to a warmer period, which would reduce the length of time that sea ice is seasonally present (Frey et al., 2015). In this case, reduced sea ice conditions could invite an increase of fishing in prohibited areas.

With its geographical proximity and likeness to the Arctic Ocean (as a bounded space of international waters surrounded by land), the legal histories of the central Bering Sea have sparked fears that similar contestations over the harvesting of resources could be a harbinger of what is to come for future living marine resources in the Arctic (Byers, 2013), particularly as spatial patterns of sea ice extent continue to change in this dynamic marine environment. We suggest here as above that legal geography in conjunction with ocean-space studies could be a conceptual tool for exploring how sea ice might impact notions of ownership and access to living marine resources and marine logistical operations in this dynamic region, in complex, and potentially contradictory ways.

Conclusions

The changes observed to the seasonal sea ice regimes of the Beaufort and the Bering Seas indicate and speak to the dynamic interactions that are present in these physical oceanographic systems, representing two distinct endmembers of a rapidly changing global sea ice system. In the Beaufort, seasonal sea ice extent has been rapidly declining, reigniting contestations over territory and non-renewable resources. Farther south, the Bering Sea has exhibited recent increases in seasonal sea ice persistence, possibly impacting a vital commercial fishing industry. Even though the sea ice conditions that currently persist in the Beaufort and Bering Seas are likely to change in the coming decades (most likely to less persistent sea ice conditions in both regions; Frey et al., 2015), our discussion serves as a novel thought experiment for exploring how the multi-dimensional, material elements of marine systems impact (and are impacted by) human systems on a variety of spatial and temporal scales. On its surface, our discussion adds to a growing community of cross disciplinary researchers who are working towards elucidating a new way to conceptualize the complex spaces of a rapidly changing Arctic. Our rather limited focus here on changes in sea ice cover is intended to facilitate broader consideration of the interplay between sea ice, as a dynamic substance, and the conditions of sociolegal existence. The delineation of sea ice and the delineation of sovereign spaces (or spaces of sovereign resource rights), as well as the delineation of regional seas, require the drawing of borders in a dynamic seascape. Yet the cases from the Beaufort and Bering Seas developed here demonstrate that these borders create (and challenge) other borders, between species, ecosystems, and fishers' livelihoods. Amidst these processes of de- and re-bordering, it is not enough to think of sea ice as a "disappearing" entity. Rather, sea ice should be understood as a substance that is ever present (for now), continuously moving across ocean-spaces and challenging stationary conceptions of law.

Precisely how regulations and debates over territory and resources (both fixed and mobile) will change in response to alterations to the spatial extent of sea ice in the maritime spaces of the Arctic remains to be seen. However, as this article demonstrates, one approach to assessing its role is through employing the tools of legal geography and ocean-space studies. This approach, by accounting for the dynamic nature of both law and space, provides a means for complementing our understanding of law with insights from environmental science, in borderlands and beyond. Through such explorations, we could perhaps enhance our understanding of how seemingly distinct seas like the Beaufort and Bering are indeed connected. While this approach is particularly well suited for understanding the changing terrain of (un)frozen oceans, it also has the potential to inform a more nuanced approach to effective governance practices across our dynamic planet. These are just two examples, and we hope that through continued collaboration we can explore these types of connections even further. For these reasons, as we enter a new decade of uncertainty, it will be necessary to engage more critically with the role that sea ice has in larger international conversations over policy, law, territory and resources as we begin to formulate progressive responses to climatic change in this complex region.

Figures

Figure 1. Map depicting Beaufort Sea boundary dispute between United States (Alaska) and Canada. The black line indicates the claim of the United States in the Beaufort Sea to the far eastern border of Alaska. The red line indicates the baseline that Canada asserts in their territorial claim, leaving a disputed area of ~7192 mi2 (Burleson, 2012).

Figure 2. Map depicting the enclosed boundary of international waters in the Bering Sea between the United States (Alaska) and Russia (Agreement with the U.S.S.R. on the Maritime Boundary, 1990; Wespestad, 1993).

References

Aporta, C. 2009. "The Trail as Home: Inuit and Their Pan-Arctic Network of Routes." *Human Ecology*. http://link.springer.com/article/10.1007/s10745-009-9213-x.

———. 2011. "Shifting Perspectives on Shifting Ice: Documenting and Representing Inuit Use of the Sea Ice." *The Canadian Geographer/Le Géographe Canadien*. http://onlinelibrary.wiley.com/doi/10.1111/j.1541-0064.2010.00340.x/full.

Aporta, C, DR Taylor, and GJ Laidler. 2011. "Geographies of Inuit Sea Ice Use: Introduction." *The Canadian Geographer/Le …*. http://onlinelibrary.wiley.com/doi/10.1111/j.1541-0064.2010.00339.x/full.

Bailey, KM. 2011. "An Empty Donut Hole: The Great Collapse of a North American Fishery." *Ecology and Society*. http://kevinmbailey.com/uploads/3/0/5/8/3058136/donut_hole.pdf.

Baker, B, and Mooney, S. 2012. "The Legal Status of Arctic Sea Ice in the United States and Canada." *Polar Geography* 35 (1): 1–19.

Baker, J. S., and Byers, M. (2012). Crossed Lines: The Curious Case of the Beaufort Sea Maritime Boundary Dispute. *Ocean Development & International Law*, *43*(1), 70–95. http://doi.org/10.1080/00908320.2012.647509

Bakker, K, and Bridge, G. 2006. "Material Worlds? Resource Geographies and the 'Matter of Nature.'" *Progress in Human Geography* 30 (1): 5–27. doi:10.1191/0309132506ph588oa.

Berry, KA. 2014. "Actor-Network Theory and Traditional Cultural Properties: Exploring Irrigation as a Hybrid Network in 19th Century Hawai`i." *Human Geography* 7 (2): 73–87.

Bird, K.J. et al. 2008. Circum-Arctic resource appraisal; estimates of undiscovered oil and gas north of the Arctic Circle: U.S. Geological Survey Fact Sheet 2008-3049, 4 p. [http://pubs.usgs.gov/fs/2008/3049/].

Bravo, MT. 2009. "Voices from the Sea Ice: The Reception of Climate Impact Narratives." *Journal of Historical Geography* 35 (2): 256–78. doi:10.1016/j.jhg.2008.09.007.

Brigham, LW. 2010. "The Fast-Changing Maritime Arctic." *Proceedings of the US Naval Institute*. https://lisd.princeton.edu/sites/lisd/files/brigham_may2010.pdf.

Burleson, E. 2012. "Polar Law and Good Governance." *Handbook of International Environmental Law*, no. January.

Byers, M. 2013. *International Law and the Arctic*. Cambridge University Press.

Byers, M., and Lalonde, S. 2009. Who controls the Northwest passage. *Vand. J.*

Transnat'l L. 42(1133).
Comiso, JC. 2003. "Large-Scale Characteristics and Variability of the Global Sea Ice Cover." In *Sea Ice: An Introduction to Its Physics, Chemistry, Biology and Geology*, edited by David N.Thomas and Gerhard S. Dieckmann. Blackwell Science Ltd.
Coole, D, and Frost, S. eds. 2010. *New Materialisms*. doi:10.1215/9780822392996.
Cooper, LW, Janout, MA, Frey, KE, Pirtle-Levy, R, Guarinello, ML, Grebmeier, JM, and Lovvorn, JR. 2012. "The Relationship between Sea Ice Break-Up, Water Mass Variation, Chlorophyll Biomass, and Sedimentation in the Northern Bering Sea." *Deep-Sea Research Part II: Topical Studies in Oceanography* 65-70. Elsevier: 141–62. doi:10.1016/j.dsr2.2012.02.002.
Curti, GH, and Moreno, CM. 2010. "Institutional Borders, Revolutionary Imaginings and the Becoming-Adult of the Child." *Children's Geographies* 8 (4). Routledge: 413–27. doi:10.1080/14733285.2010.511006.
Dallman, S, Thien, D, Laris, P, and Ngo, M. 2014. "Reinterpreting Traditional Cultural Properties: A Political Ecology of Emotion Perspective." *Human Geography* 7 (2): 29–45.
Delaney, D. 2014. "Legal Geography I: Constitutivities, Complexities, and Contingencies." *Progress in Human Geography*, 1–7. doi:10.1177/0309132514527035.
Dickson, D. 2014. *Developing a Conceptual Model of the Arctic Marine Ecosystem*. *Workshop Report*. Washington, D.C. http://www.iarpccollaborations.org/uploads/cms/documents/arcticconceptualmodelingreport_final_lowres_citation.pdf#page=46.
Druckenmiller, ML, Eicken, H, George, JC, and Brower, L. 2013. "Trails to the Whale: Reflections of Change and Choice on an Iñupiat Icescape at Barrow, Alaska." *Polar Geography* 36 (1-2): 5–29. doi:10.1080/1088937X.2012.724459.
Eicken, H. 2003. "Growth, Microstructure and Properties of Sea Ice." In *Sea Ice: An Introduction to Its Physics, Chemistry, Biology and Geology*, edited by David N.Thomas and Gerhard S. Dieckmann. Blackwell Science Ltd.
Eicken, H, Lovecraft, AL and Druckenmiller, ML. 2009. "Sea-Ice System Services: A Framework to Help Identify and Meet Information Needs Relevant for Arctic Observing Networks." *Arctic* 62 (2): 119–36. doi:10.14430/arctic126.
Frey, KE, Moore, GWK, Cooper, LW, and Grebmeier, JM. 2015. "Divergent Patterns of Recent Sea Ice Cover across the Bering, Chukchi, and Beaufort Seas of the Pacific Arctic Region." *Progress in Oceanography* 136: 32-49.
Gradinger, R. 2009. "Sea-Ice Algae: Major Contributors to Primary Production and Algal Biomass in the Chukchi and Beaufort Seas during May/June 2002." *Deep Sea Research Part II: Topical Studies in …*. http://www.sciencedirect.com/science/article/pii/S0967064508003469.
Goltz, J. (1995). The Sea of Okhotsk Peanut Hole: How the United Nations Draft Agreement on Straddling Stocks Might Preserve the Pollack Fishery.
Grebmeier, JM, Overland, JE, Moore, SE, Farley, EV, Carmack, EC, Cooper, LW, Frey, KE, Helle, JH, McLaughlin, FA, and McNutt, SL. 2006. "A Major Ecosystem Shift in the Northern Bering Sea." *Science (New York, N.Y.)* 311 (5766): 1461–64. doi:10.1126/science.1121365.
Haas, C. 2003. "Dynamics versus Thermodynamics: The Sea Ice Thickness Distribution." In *Sea Ice: An Introduction to Its Physics, Chemistry, Biology and Geology*, edited by David N. Thomas and Gerhard S. Dieckmann.

Blackwell Science Ltd.
Henshaw, AS. 2012. “Fostering Resilience in a Changing Sea Ice Context: A Grant Maker’s Perspective.” *Polar Geography*, no. May 2014: 1–16. doi:10.1080/1088937X.2012.724460.
Huntington, HP et al. 2015. “Vessels, Risks, and Rules: Planning for Safe Shipping in Bering Strait.” *Marine Policy* 51 (January): 119–27. doi:10.1016/j.marpol.2014.07.027.
Hutchings, J.K, and Rigor, IG. 2012. “Role of Ice Dynamics in Anomalous Ice Conditions in the Beaufort Sea during 2006 and 2007.” *Journal of Geophysical Research* 117 (May): C00E04. doi:10.1029/2011JC007182.
Jeffries, MO, Overland, JE, Brown, R, Mudryk, L, andLuojus, K. 2015. *Arctic Report Card*. http://www.arctic.noaa.gov/reportcard.
Kao, S-M, Pearre, NS and Firestone, J. 2012. “Adoption of the Arctic Search and Rescue Agreement: A Shift of the Arctic Regime toward a Hard Law Basis?” *Marine Policy* 36: 832–38.
Kraska, J. 2009. International security and international law in the Northwest Passage. *Vand. J. Transnat’l L* 42(1109).
Kwok, R, Spreen, G, and Pang, S. 2013. “Arctic Sea Ice Circulation and Drift Speed: Decadal Trends and Ocean Currents.” *Journal of Geophysical Research: Oceans* 118 (5): 2408–25. doi:10.1002/jgrc.20191.
Laidler, G J, Elee, P, Ikummaq, T, Joamie, E, and Aporta, C. 2010. “Mapping Inuit Sea Ice Knowledge, Use, and Change in Nunavut, Canada (Cape Dorset, Igloolik, Pangnirtung).” In *SIKU: Knowing Our Ice*, 45–80.
Laidler, GJ, Hirose, T, Kapfer, M, Ikummaq, T, Joamie, E and Elee, P. 2011. “Evaluating the Floe Edge Service: How Well Can SAR Imagery Address Inuit Community Concerns around Sea Ice Change and Travel Safety?” *The Canadian Geographer/Le Géographe Canadien* 55 (1): 91–107.
Laidler, GJ. 2006. “Inuit and Scientific Perspectives on the Relationship between Sea Ice and Climate Change: The Ideal Complement?” *Climatic Change*.
Lovecraft, AL. 2013. “The Human Geography of Arctic Sea Ice:Introduction.” *Polar Geography* 36 (1-2): 1–4.
Lovecraft, AL, and Eicken, H. 2011. “Transdisciplinary Collaboration in the Fourth International Polar Year: Connecting Studies of the Arctic Change across the Science and the Arts.” In *North by 2020: Perspectives on Alaska’s Changing Social-Ecological Systems*, edited by Lovecraft, AL and Eicken, H.
Lovecraft, AL, Meek, C, and Eicken, H. 2013. “Connecting Scientific Observations to Stakeholder Needs in Sea Ice Social–environmental Systems: The Institutional Geography of Northern Alaska.” *Polar Geography* 36 (1-2): 105–25.
McClelland, JW, Holmes, RM, Dunton, KH, and Macdonald, RW. 2012. “The Arctic Ocean Estuary.” *Estuaries and Coasts* 35 (2): 353–68. doi:10.1007/s12237-010-9357-3.
Napp, JM. 2000. “A Synthesis of Biological and Physical Processes Affecting the Feeding Environment of Larval Walleye Pollock (Theragra Chalcogramma) in the Eastern Bering Sea.” *Fisheries Oceanography* 9(2): 147-162.
Nord, DC. 2010. “The North in Canadian-American Relations: Searching for Collaborations in Melting Seas.” In *Borders and Bridges: Canada’s Policy Relations in North America*, edited by Gattinger, M. and Hale, G. Oxford University Press.
Overland, JE, and Wang, M. 2007. “Future Regional Arctic Sea Ice Declines.”

Geophysical Research Letters 34 (17).
Parkinson, CL. 2014. “Changes in Arctic and Antarctic Sea Ice as a Microcosm of Global Climate Change.” In *Washington Academy of Sciences’ Capital Science 2014 Conference*. Arlington, Virgina.
Peters, K. 2014. “Tracking (Im)mobilities at Sea: Ships, Boats and Surveillance Strategies.” *Mobilities* 9 (3): 414–31. doi:10.1080/17450101.2014.946775.
Pfeiffer, L, and Haynie, AC. 2012. “The Effect of Decreasing Seasonal Sea-Ice Cover on the Winter Bering Sea Pollock Fishery.” *ICES Journal of Marine Science: …*. http://icesjms.oxfordjournals.org/content/69/7/1148.short.
Pharand, D. (2007). The Arctic Waters and the Northwest Passage: A Final Revisit. *Ocean Development & International Law*, *38*(1–2), 3–69.
Rayfuse, R. (2007). Melting moments: The future of polar oceans governance in a warming world. *Review of European Community & International Environmental Law*, *16*(2), 2.
Robards, MD, Kitaysky, AS and Burns, JJ. 2013. “Physical and Sociocultural Factors Affecting Walrus Subsistence at Three Villages in the Northern Bering Sea: 1952–2004.” *Polar Geography* 36 (1-2): 65–85. doi:10.1080/1088937X.2013.765519.
Rothwell, D. 1996. The polar regions and the development of international law (Vol. 3). Cambridge University Press.
Sheffield, LG, and Duffy-Anderson, J. 2014. “Understanding Climate Control of Fisheries Recruitment in the Eastern Bering Sea.” *Oceanography* 27(4): 90-103.
Steinberg, PE. 1999. Navigating to Multiple Horizons: Toward a Geography of Ocean-Space.” *Professional Geographer* 51 (3): 366–75.
Steinberg, PE. 2014. Steering Between Scylla and Charybdis: The Northwest Passage as Territorial Sea. *Ocean Development & International Law*, *45*(1), 84–106. http://doi.org/10.1080/00908320.2014.867193
Steinberg, PE and Kristoffersen, B. in press. “The ice edge is lost…Nature moved it” Mapping Ice as State Practice in the Canadian and Norwegian North. *Transactions of the Institute of British Geographers.*
Steinberg, P, and Peters, K. 2015. “Wet Ontologies, Fluid Spaces: Giving Depth to Volume through Oceanic Thinking.” *Environment and Planning D: Society and Space* 33
Steinberg, PE, Kristoffersen, B, Shake, KL.in press. “Edges and flows: Exploring legal materialities and biophysical politics at the sea ice edge.” In: Ocean Legalities: The Life and Law of the Sea. Braverman, I, Johnson, E. (eds). Durham, North Carolina: Duke University Press
Steinberg, PE., Tasch, J and Gerhardt, H. 2015. *Contesting the Arctic*. London: I.B. Tauris.
Stewart, EJ, Dawson, J, Howell, SEL, Johnston, ME, Pearce, T and Lemelin, H. 2012. “Local-Level Responses to Sea Ice Change and Cruise Tourism in Arctic Canada’s Northwest Passage.” *Polar Geography*, no. May 2014: 1–21. doi:10.1080/1088937X.2012.705352.
Stokke, OS. 2001. Managing Fisheries in the Barents Sea Loophole: Interplay with the UN Fish Stocks Agreement. *Ocean Development & International Law*, *32*(3), 241–262.
Stroeve, JC, Serreze, MC and Holland, MM. 2012. “The Arctic’s Rapidly Shrinking Sea Ice Cover: A Research Synthesis.” *Climatic Change*. http://link.springer.com/article/10.1007/s10584-011-0101-1.

Tejsner, P. 2013. “Living with Uncertainties: Qeqertarsuarmiut Perceptions of Changing Sea Ice.” *Polar Geography* 36 (1-2): 47–64. doi:10.1080/1088937x.2013.769282.

Thomas, DN, and Dieckmann, GS. 2008. *Sea Ice: An Introduction to Its Physics, Chemistry, Biology and Geology*. John Wiley & Sons.

Tyrrell, M. 2013. “Enacting and Renewing Identity, Kinship, and Humanity on the Sea Ice.” *Polar Geography*, no. May 2014: 37–41. doi:10.1080/1088937X.2013.765520.

United Nations. 1982. United Nations Convention on the Law of the Sea (Doc A/Conf.162/122). New York: United Nations. Available at <www.un.org/depts/los/convention_agreements/convention_overview_convention.htm>

Van der Tuin, I, and Dolphijn, R. 2012. *New Materialism: Interviews & Cartographies*. http://dspace.library.uu.nl/handle/1874/256718.

Wang, M, and Overland, JE. 2009. “A Sea Ice Free Summer Arctic within 30 Years?” *Geophysical Research Letters* 36 (L07502).

———. 2012. “A Sea Ice Free Summer Arctic within 30 Years: An Update from CMIP5 Models.” *Geophysical Research Letters* 39 (L18501) http://onlinelibrary.wiley.com/doi/10.1029/2012GL052868/full.

———. 2015. “Projected Future Duration of the Sea-Ice-Free Season in the Alaskan Arctic.” *Progress in Oceanography*. http://www.sciencedirect.com/science/article/pii/S0079661115000038.

Watson, J., and Haynie, A. (2016). Using Vessel Monitoring System Data to Identify and Characterize Trips Made by Fishing Vessels in the United States North Pacific. *PLoS One* 11(10): e0165173.

Wespestad, VG. 1993. “The Status of Bering Sea Pollock and the Effect of the ‘Donut Hole’ Fishery.” *Fisheries* 18 (3). Taylor & Francis Group: 18–24. doi:10.1577/1548-8446(1993)018<0018:TSOBSP>2.0.CO;2.

Wood, KR, Overland, JE, Salo, SA, Bond, NA, Williams, WJ, and Dong, X. 2013. “Is There a ‘new Normal’ Climate in the Beaufort Sea?” *Polar Research* 32 (October). doi:10.3402/polar.v32i0.19552.

Zellen, BS. 2013. *The Fast-Changing Arctic: Rethinking Arctic Security for a Warmer World*. Calgary: University of Calgary Press