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# Assessing climate change vulnerability in Alaska's fishing communities

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ABSTRACT

Alaska's communities are experiencing impacts from unprecedented climate-related changes in the harvests of natural resources. Residents of rural Alaska are reporting heretofore unseen changes in the geographic distribution and abundance of marine resources, increases in the frequency and ferocity of storm surges in the Bering Sea, changes in the distribution and thickness of sea ice, and increases in river and coastal erosion. When combined with ongoing socio-economic change, climate, weather, and changes in the biophysical system interact in a complex web of feedbacks and interactions that make life in rural Alaska challenging.

We present a framework of indicators to assess three basic constituents of community vulnerability: exposure to the bio-physical effects of climate change, dependence on resources that will be affected by climate change, and a community's adaptive capacity to offset negative impacts of climate change. We conduct three principal components analyses, one for each vulnerability constituent, for 315 Alaska communities to assess each community's overall vulnerability to climate change. This research can be used to inform communities about the ways in which their communities are vulnerable to climate change and help develop adaptation strategies. While this study focuses on Alaska communities, the framework is easily adaptable to other regions with different risk factors and sensitivities to climate change.

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## 1. Introduction

The impacts of climate change on coastal communities around the world include effects on both humans and human uses of the environment. In addition, climate change is interacting with other anthropogenic impacts, such as pollution and habitat destruction that are currently negatively affecting the marine environment. Although not well-documented across all marine regions of the U.S., evidence to date suggests marine resource-dependent communities are likely to experience substantial socio-economic impacts from climate change, negative in some areas and positive in others (Griffis and Howard, 2013). Extensive efforts are underway around the world to better understand the socio-economic effects of climate change and how coastal communities will be impacted as the effects of climate change become more prevalent (Arctic Council, 2013; Cutter et al., 2009; Hovelsrud and Smit, 2010). Joining in this effort, we have developed a framework of indicators to assess three basic constituents of community vulnerability to climate change: exposure to the physical effects of climate change, dependence on resources that will be affected by climate change, and a community's adaptive capacity to offset negative impacts of climate change (Adger, 2006; Allison et al., 2009; Cinner et al., 2012; Hovelsrud and Smit, 2010; Kelly and Adger, 2000; Smit and Wandel, 2006; Turner et al., 2003). By taking this approach, we attempt to take a holistic view of the socio-ecological system in which these communities exist and look at the myriad of factors that impact community vulnerability rather than assessing vulnerability based on a single constituent element.

### 1.1. Exposure to the physical effects of climate change

Given its northern location, Alaska's ecosystems are particularly susceptible to changing climactic conditions, where numerous physical effects of climate change, are being observed (Arctic Climate Impact Assessment, 2005; Arctic Monitoring and Assessment Programme, 2011; Cochran et al., 2013; Ford et al., 2013; Ford and Furgal, 2009; Griffis and Howard, 2013; Shrank, 2007). For some regions of Alaska, the economic effects of climate change may be highly favorable, for other regions the effects may be

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highly unfavorable. In recent years, numerous studies have documented significant changes in the distribution and abundance of fish and wildlife; changes in hydrology, seasonality and phenology; the frequency and magnitude of forest fires, landslides, river and coastal erosion; lake and landscape drying; and permafrost degradation (Bronen and Chapin, 2013; Cochran et al., 2013; Loring et al., 2011; Loring and Gerlach, 2009; McNeeley, 2009; Morelien and Carothers, 2012; Rattenbury et al., 2009; White et al., 2007). These changes are expected to have both positive (e.g., increased economic development as the arctic opens up to oil exploration and shipping (Griffis and Howard, 2013)) and negative effects (e.g., reduced habitat for walrus, less stable ice for hunters (Cochran et al., 2013)). Changes in the distribution of important marine resources have also been reported as species distribution shifts decrease resource availability for some fishermen and increase the availability for others (Griffis and Howard, 2013) and can also change the cost of harvesting commercial species (Haynie and Pfeiffer, 2013).

It is unknown how climate and seasonal conditions will change over time (Griffis and Howard, 2013; Lawler et al., 2008; Loring et al., 2011). For example, studies have also shown that river ice is becoming thinner and more erratic each year, and precipitation levels have been decreasing, resulting in less snow pack, earlier melting, and changes to the timing of freshwater input into marine ecosystems (Euskirchen et al., 2007; Griffis and Howard, 2013; Hunt et al., 2008a,b; Loring et al., 2011; Mundy and Evenson, 2011; Wendler and Shulski, 2009). Storm frequency and intensity has been increasing and causing increased rates of coastal erosion and flooding in coastal communities (GAO, 2009; Knutson et al., 2010; Trenberth, 2011; Ulbrich et al., 2008). Permafrost is melting and beginning to shift, further contributing to the erosion of some communities (Rowland et al., 2010; North Slope Borough, 2005; Osterkamp, 2007). In regions that depend on sea ice for transportation and as habitat for food sources (e.g., reindeer, caribou and walrus), increased loss of arctic ice and early ice break-up can be devastating for communities (Griffis and Howard, 2013; Loring et al., 2011; Rattenbury et al., 2009).

An additional challenge for Alaska, in particular, is that few states encompass the variety of climatic differences that are found in Alaska. Southeast Alaska and the Aleutian Islands are subject to a maritime climate, with cool summers, mild winters and heavy rainfall, while the central latitudes of the state are subject to a continental climate, with moderate summers, very cold winters and rapid changes between seasons. In addition, the North Slope of Alaska is presented with a harsher, arctic semi-arid climate that brings little rain and low temperatures, and snow is present for most of the year. Communities on the North Slope are also all underlain with continuous permafrost while many communities farther south are subject to changes in discontinuous and isolated permafrost.

### 1.2. Dependence on resources that will be affected by climate change

Residents of communities around Alaska depend on marine resources for both economic and personal well-being through involvement in Alaska's commercial, recreational, and subsistence fisheries and marine mammal hunts, all of which are expected to be substantially impacted by climate change (Griffis and Howard, 2013; Himes-Cornell et al., 2013). Living marine resource distribution and abundance are expected to be affected most significantly by shifts in productivity and prey availability, changes in water temperature, ocean acidification, exposure to toxins and pathogens, increased competition with invasive species, changes in sea ice coverage (Griffis and Howard, 2013; Hannah et al., 2009; Loring et al., 2011). Marine shellfish, such as commercially important crab species in the Bering Sea, are especially vulnerable to the effects of ocean acidification on early life stages (Walther et al., 2010; Walther et al., 2009). In 2010, commercial landings in Alaska were valued at over $1.5 billion dollars, which represented 35% of the total landings made in all U.S. ports (NMFS, 2011c). In 2009, Alaska's seafood industry generated $3.3 billion in sales impacts, $1.4 billion in income impacts, and over 44,000 jobs (NMFS, 2011b). In addition, recreational fisheries generated approximately 5300 jobs and saltwater anglers spent over $406 million in 2009 (NMFS, 2011b).

Shifting distribution of marine resources is also a concern in Alaska, especially for Alaskans that depend on the oceans for subsistence harvesting or economic sustainability (Hare and Mantua, 2000; Ottersen et al., 2010; Overland et al., 2010). The condition, behavior, survival and interactions of Arctic marine mammals, many of which are hunted for subsistence, are expected to be fundamentally altered as sea surface temperatures rise and sea ice retreats farther north (Boveng et al., 2009; Cochran et al., 2013; Heide-Jørgensen et al., 2011; Kelly et al., 2010; Kovacs et al., 2011; Moore and Huntington, 2008; Thomas and Laidre, 2011; Wassmann et al., 2011). The importance of wild fish, whether anadromous species (e.g., salmon) or non-anadromous species (e.g., halibut) is the notable constant from south to north in rural Alaska (Nelson, 1986; Norris, 2002; Wolfe, 2004). In many communities across the state, subsistence fishing and hunting is equally, if not more, important to supplement local cash economies. As such, marine ecosystems are critical to the health of the state's economy and survival of communities across the state.

Given the substantial economic value of fisheries in the state, the effects of climate change are likely to be widely felt among communities throughout Alaska. Fishing-dependent communities in Alaska are more likely to be acutely affected by climate change the more dependent they are on fishing and especially if they depend on one or a few fish stocks (Phillips and Morrow, 2007). In addition, although the Arctic is lightly populated by humans, there is a high likelihood that expected environmental change resulting from climate factors (e.g., reduced sea ice, increased primary productivity) will create significant effects on subsistence activities, commercial and recreational fisheries (e.g., changes to species distribution, increased travel time to fishing grounds, development of new fisheries), ocean transportation (e.g., opening up of shipping lanes in the arctic), offshore energy exploitation (e.g., increase in offshore oil opportunities), human habitability (e.g., increase in storms) and geopolitical conflict in polar areas (e.g., increase in discussions over sovereignty) (Himes-Cornell and Orbach, 2012; Pfeiffer and Haynie, 2012). Understanding how individuals choose to adapt to these changes is also important in determining how these changes will impact communities (Haynie and Pfeiffer, 2012).

### 1.3. Adaptive capacity to offset negative impacts of climate change

The third constituent of community vulnerability to climate change we consider, adaptive capacity, is a community's ability to adapt and recover after a negative event and still retain their desired characteristics of the community (Turner et al., 2003; Adger, 2006). We assume that communities with high incomes, diverse economies, high educational attainment, and with a stable population that does not include a large number of dependents are likely to have a large capacity to adapt to potential hazards. However, communities that lack some or all of these traits are likely to be more heavily impacted and experience that impact for a longer duration than a community with higher adaptive capacity (Adger et al., 2005; Cutter et al., 2000, 2003; Heinz Center for Science, Economics, and the Environment, 2000; Morrow, 1999).

The concepts of resilience and vulnerability are widespread in the literature and are commonly used to understand system dynamics underpinning how and why the social structure of