Title: A framework for the preliminary assessment of vulnerability of fisheries-dependent communities

Global climate change is projected to have far-ranging effects on the oceans and marine life. In turn, fisheries will likely undergo changes in their distributions and abundance. Coastal Alaskan communities are often highly dependent on commercial fisheries, and as a result will likely be vulnerable to climate change. The purpose of this project is to construct a framework for a preliminary assessment of the vulnerability of the fisheries-dependent communities in Alaska to climate change and variability. Employing an indicator-based framework, vulnerability is assessed according to the level of natural, social, and economic capital found in each community. A graphical instrument is used to communicate these findings. The communities of Cordova, Kodiak, Petersburg, Seward, and Sitka are assessed using this method and found to have differing levels of capital and vulnerabilities.
A Framework for the Preliminary Assessment of Vulnerability of Fisheries-dependent Communities

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1. Introduction

Climate change and its effects are causing a dramatic and systemic transformation of the world’s oceans (Pachauri & Reisinger, 2007). Among the myriad changes, ocean surface temperatures have shown a clear increase in the last 50 years, and salinity has weakened in the subpolar ocean regions while increasing in the subtropics (Bindoff et al., 2007). In addition to these physical and chemical changes, ocean ecosystems are showing pronounced changes, such as a decrease in primary production, and shifts in the spatial distribution of marine species (Fischlin et al., 2007).

Fisheries are an area where these changes intersect with the natural resources on which humans rely. People and communities in a wide range of places are dependent on fisheries for subsistence, recreation, and commercial activities. Worldwide, fish are an important source of protein to billions of people; in 2006, fish accounted for about 110 million metric tons of food (Food and Agriculture Organization, 2008). Alaska alone landed nearly 2.5 million metric tons of fish in 2006 (Van Voorhees & Pritchard, 2008). For the people in the 136 Alaskan communities profiled by Sepez, Tilt, Package, Lazrus and Vaccaro (2005) as “significantly involved in commercial fisheries,” these fisheries represent an income, a livelihood, and a cultural resource.

This research is an attempt to develop a preliminary assessment of the vulnerability of fishing communities to climate change and variability. The assessment is based on the concept of community capacity as a result of the social, economic, and natural capital available to the community. Using indicators built from existing data, the assessment tries to capture the levels of capital found in each community. A graphic evaluation system is used to assess the overall vulnerability of each community, and to
communicate the vulnerability of each community. Furthermore, a risk indicator is developed based on the life history attributes of the species most commonly harvested in Alaska. Communities that are assessed are Cordova, Kodiak, Petersburg, Seward, and Sitka, all situated around the Gulf of Alaska.

As climate change affects the fisheries on which these communities rely, decision makers will need a wider range of tools to evaluate vulnerability, impacts, and mitigation and adaptation options (Rosenzweig & Wilbanks, 2010). This assessment is developed as a quick, cost-effective, ‘first-look’ option for evaluating the vulnerability of fishing communities.

2. Literature Review

Vulnerability, as a framing device, is a way of organizing information to tell a story about an event and its impact on a place and time, the processes that led to the impact, and the conditions of that place – in human and natural terms – that attenuated or amplified that impact. The event could be a fisheries management decision, a natural disaster, or climatic variability.

Vulnerability is often defined as a function of three different conceptual components: exposure, sensitivity, and adaptive capacity (Turner et al., 2003). Preston & Stafford-Smith (2009) define exposure as the extent to which a place or system is affected by hazards that act on that system. Sensitivity refers to the responsiveness of a system to climate hazards. Adaptive capacity refers to the state of resilience and the ability of a system to change in a way that makes it better equipped to manage or mitigate its exposure and/or sensitivity to climatic influences. A fourth subject often found in climate change vulnerability studies is the definition of the climate hazard and the
pathways through which it connects to the human system. Definition of the magnitude or impact of climate-related hazards is exceedingly difficult. There are myriad reasons for this, primarily that projecting scenarios of the conditions of a complex system in the future is extremely difficult and highly uncertain at best. Vulnerability has been recognized as a “dynamic characteristic, a function of the constant evolution of a complex of interactive processes” (Adger, Brooks, Bentham, Agnew & Eriksen, 2004).

Historically, there is a wide and varying literature using the concept of vulnerability. It is frequently a focus in the natural hazards literature, where the exposure of communities to natural hazards such as tsunamis or hurricanes is of concern (Wood, 2009). The concept has now established a strong, although still evolving, presence in the climate change research field, across a variety of disciplines. Research spans from changing climate regimes’ impact on typhoon frequency and intensity on coastal areas (Adger, 1999) to social factors influencing the capacity of communities to sustainably manage coral reef resources (McClanahan et al., 2008).

The Intergovernmental Panel on Climate Change (IPCC) (2007) defines vulnerability to climate change as “the degree to which geophysical, biological and socio-economic systems are susceptible to, and unable to cope with, adverse impacts” resulting from physical changes. Furthermore, differentiation occurs between the vulnerability of a system or state (e.g., a near-shore ecosystem); impacts to the system (such as coral reef bleaching); or the physical process that caused the impacts (such as thermal changes in the surrounding waters) (IPCC, 2007). These broad applications of the concept and different approaches to the examination of vulnerability necessitate varying definitions of vulnerability.
Brooks (2003) conceives of a framework for studies to handle vulnerability to climate variability and change. He asserts there is a distinction between two frequently researched concepts of vulnerability: social vulnerability and biophysical vulnerability. Social vulnerability is the conditions of a system prior to the occurrence of a hazard. This definition of vulnerability comprises variables such as degree of dependence on a resource, demographics, or the level of poverty in the system. On the other hand, biophysical vulnerability is the outcome of the hazard and its impacts on the system. According to these definitions, the variables comprising social vulnerability shape the biophysical vulnerability of an area by influencing the social preparedness and human response of the system. Similarly, Adger (1999) defines social vulnerability as “the exposure of groups or individuals to stress as a result of social and environmental change, where stress refers to unexpected changes and disruption to livelihoods.” This definition further encompasses the social and economic variables that influence vulnerability of a community.

2.1 Vulnerability

There are several scales at which to carry out an investigation of the vulnerability of fisheries to climate change. Different impacts on fisheries occur at the international, national, regional or community levels, each comprising different variables. “At the regional and local scales, impact and vulnerability assessments can begin to uncover the complexity of vulnerability, addressing the questions not only of ‘whether’, but of ‘where, how, and why’.” (Obrien, Sygna & Haugen, 2004)

Allison et al. (2009) provides an investigation into the vulnerability of fisheries to climate change at the national scale, using an indicator-based approach. By comparing
161 countries, their research identifies regions that are highly vulnerable to climate change, based on things like the amount of fish in the populations’ diets, and the relative importance of fisheries to the national economy. Fisheries constitute a relatively minor role in the economy of the United States, thus the nation has a low vulnerability. However, that is not to say fisheries are unimportant when viewed at that level; the geographic distribution of fisheries dependent communities along all coasts of the United States indicates a substantially local importance.

Impacts become even more significant at a finer grain of investigation. At a regional or community level, the economic benefits and costs can be substantially magnified relative to the local economy. Additionally, fisheries are of cultural, subsistence and historical importance to many coastal communities. Reliance on fisheries as the primary source of income and subsistence exposes a community to a higher degree of stress, derived from climate variability and its impacts (Adger, 1999). Human and ecological systems are dynamic, and feedbacks and nested scales of interactions between and among systems occur (Turner, 2003).

2.2 Vulnerability Assessments

The vulnerability of a place or system is important to understand for myriad reasons. It may be used to describe the impact of hazards on human systems. Furthermore, the concept is often used to characterize the state of a social system. Finally, vulnerability is used to identify ways in which the adaptive capacity of a social system can be improved so that it can adapt to and mitigate shocks and changes in a natural system. As such, researchers, analysts, and decision makers conduct vulnerability
analyses or assessments. Assessments come in all different flavors, shapes and sizes, as discussed below.

One form of vulnerability assessment was developed by the IPCC. In order to assist decision makers whom are attempting to build adaptation plans, the IPCC Fourth Assessment Report included a set of criteria to classify certain vulnerabilities as “key.” There are seven criteria sourced from the vulnerability research literature that make a system, state, or process qualify as having key vulnerabilities. These are (Schneider et al., 2007):

- Magnitude of impacts,
  - scale and intensity
- Timing of impacts,
  - immediate v. long-term
- Persistence and reversibility of impacts,
- Likelihood (estimates of uncertainty) of impacts and vulnerabilities and confidence of those estimates,
- Potential for adaptation,
- Distributional aspects of impacts and vulnerabilities,
- Importance of systems at risk.

Vulnerabilities may be assessed at different spatial and temporal scales, with each component bearing substantial scientific uncertainties. Furthermore, vulnerabilities are determined within different value systems. This applies to any judgments on the importance of the system, and the level of risk as perceived within that context. Different systems are recognized as important depending on time and spatial scales. Accordingly, different levels of risk are found within different contexts. Furthermore, the ability to act upon risks falls disparately across scales of social organization. Vulnerability assessments are highly influenced by these differing perceptions, and value judgments necessarily need to occur. Therefore, as part of the assessment, assumptions and judgments about the
risks and importance of systems need to be transparent (Moss & Schneider, 2000 in IPCC, 2007).

2.3 Community Capacity and Forms of Capital

The concept of community capacity is one method of examining the vulnerability of a community. Beckley, Martz, Nadeau, Wall and Reimer (2008; p. 60) define community capacity as the “collective ability of a group (the community) to combine various forms of capital within institutional and relational contexts to produce desired results or outcomes.” These capitals, or resources and assets, can take a variety of forms, but can include human, social, economic and natural capitals. An evaluation of these capitals, in different combinations, can serve as a starting point in assessing the vulnerability of a community.

For the purposes of this research, the concepts of ‘human’ and ‘social’ capital are collapsed and treated as one, even as they are disparate concepts (Beckley et al., 2008). As Reimer and Tachikawa (2008) state, social capital comprises the “social forms as reflected in organizations, collective activities, networks, and relationships.” Beckley et al. (2008) expands on this point by saying that social capital is the “norms and networks that facilitate collective action (p. 63).” Reimer and Tachikawa’s definition refers to the state of social capital, while Beckley points to the use of these networks that results in a productive and desired consequence. Human capital refers to the level of education and skill of the individuals within the community. Essentially, the concept is about the relationships and networks that people form, and how they are collectively used for positive, constructive purposes. Additionally, Beckley et al. (2008) contends that this concept, understood at many levels ranging from the individual to the national level, is
best situated at the community level of analysis. Grafton (2005) extends this assertion to say that social capital *can only* exist at a group or community level. While this assertion is neither contested nor affirmed by the present research, it is worth noting that, at the very least, the community is an appropriate level from which to approach the subject.

Economic capital encompasses financial and built assets that go through the community. Financial assets refer to the access to financial resources available to the community as a whole. This can refer to municipal budgets or public sector funding, and also private sector income (Beckley et al., 2008). By extension, the term economic capital may also apply to different property rights, like harvest leases on timberland, mineral rights, or fishing permits. Another component of economic capital is physical, or built, assets. This includes infrastructure that supports communities, like roads, water and sewer facilities, power plants, schools, and other public buildings. In addition to publicly financed infrastructure, businesses can invest into physical capacity. These take the form of tangible objects, such as manufacturing plants, commercial property and buildings, machinery, trucks and boats.

The concept of natural capital gained prominence as a key component of the emerging field of environmental economics (Akerman, 2003). Adger (2003) refers to natural capital in a broad sense as “the set of unpriced environmental goods and services on which both economic processes and the basis of human and nonhuman life depend (Ekins 2000; Daily 1997).” But Costanza and Daly (1992;p. 38), early promoters of this concept, define natural capital as a “stock that yields a flow of valuable goods or services into the future.” This definition does not require the goods or services to be unpriced, but emphasizes the valuation of the goods and services derived from the stock. Fisheries are a
strong example of a renewable stock of natural capital from which goods and services can be derived into the future. In the context of the community capitals framework, Beckley et al. (2008) defines natural capital as the abundance and diversity of natural resources, recreational opportunities, and other features of the natural world in a specific location.

2.4 Climate Variability in the North Pacific

Evidence suggests the impacts of climate change will fall disproportionately on polar regions, including Alaska (Anisimov et al., 2007). While it is highly certain that the biophysical conditions of fisheries in Alaska are changing, the end-state of these changes, if there is one, is uncertain. This has important implications for fishermen and their communities, both place- and occupation-based, since they rely on a resource that is so sensitive to climate variability (Badjeck, Allison, Halls, & Dulvy, 2009). According to the IPCC, evidence is mounting that marine ecosystems and managed fisheries are increasingly stressed from the effects of climate change (Rosenzweig et al., 2007).

Coastal Alaskan communities are vulnerable to climate change in a variety of ways, from sea level rise to changes in weather patterns and oceanographic conditions. It is believed that large-scale, step-wise shifts in physical and biological variables, termed regime shifts, historically play a large role in the North Pacific ecosystem, influencing species abundance and composition (Hare & Mantua, 2000). In an analysis of 100 environmental time series, Hare & Mantua (2000) determined evidence for a 1977 climatic regime shift in the North Pacific, and a further shift in 1989 in some components of the North Pacific ecosystem. Both the 1977 and 1989 shifts were relatively clear in biological time records, indicating that the ecosystems of the North Pacific and Bering Sea appear to respond strongly to climate variability.
The biophysical impacts of climate change on fish include a shift in their geographical distribution, in both latitude and depth. Testing for changes in fish distributions, Perry, Low, Ellis and Reynolds (2005) found that 15 of 36 North Sea species shifted latitude and depth with rising sea surface temperatures. Not only was it found that the mean centers of the fish distributions shift, but the boundaries – the northward and southward extent of the fish populations – shifted toward the pole as well. Also tested and confirmed was that faster life histories, significantly smaller body sizes, faster maturation, and smaller sizes at maturity are characteristics of these shifting species. This suggests these stocks are somewhat adaptive to different climates in the short-term. The remaining questions lie in the long-term effects of climate change, including community reorganization, changing species interactions, and impacts on abundance. In turn, commercial fisheries must adapt to these new ecological states by pursuing different species, changing gear types, and modifying regulations (McIlgorm, Hanna, Knapp, Le Floc’h, Miller, & Pan, 2010).

2.5 National Standards and Fishing Communities

This research develops a methodology through which to conduct a preliminary assessment of the vulnerability of communities to changes in commercial fisheries related to climate variability and change. The preliminary assessment that this project developed is based around the social impact of variability in commercial fisheries. This assessment occurs at the level of the fishing community. National Standard Eight of the Magnuson-Stevens Fisheries Conservation and Management Act (MSFCMA, 2007) states that:

Conservation and management measures shall, consistent with the conservation requirements of this Act (including the prevention of
overfishing and rebuilding of overfished stocks), take into account the importance of fishery resources to fishing communities by utilizing economic and social data that meet the requirements of paragraph (2), in order to (A) provide for the sustained participation of such communities, and (B) to the extent practicable, minimize adverse economic impacts on such communities. (MSFCMA, 2007a)

Whereas, a fishing community is defined as:

[A] community which is substantially dependent on or substantially engaged in the harvest or processing of fishery resources to meet social and economic needs, and includes fishing vessel owners, operators, and crew and United States fish processors that are based in such community. (MSFCMA, 2007b)

In order to develop and select adaptation and mitigation measures, decision makers must understand what parts of these communities are most vulnerable. The complexity and expense of a formal, integrated, vulnerability assessment over as vast and varying a region as the Gulf of Alaska may be out of reach for government agencies and other applicable organizations. It is pragmatic to develop a scalable, preliminary assessment tool for identifying ports of potential vulnerability, using existing data to develop proxies for measuring vulnerability. This approach, while limited, could be a cost-effective method that can support decision makers.

3. Methods and Materials

This research explores community vulnerability by way of fishing ports in Alaska. For this, it relies on the concept of ‘community capitals.’ A straightforward way to
capture measures of these capitals is with the use of indicators. Indicators, writes Adger et al. (2004), “should be capable of identifying both the steady-state situation and any trend in that situation (p.15).” Ideally, the indicators selected should capture a part of one of three forms of capital: economic, social, or natural. The primary purpose of this research is to construct indicators in order to measure community vulnerability.

This approach does not use a composite index as its final product. Rather, it is a primarily qualitative approach where vulnerability depends on the combination of indicator values. At a basic level, thresholds are set for each indicator. The variables measured can be situated at one of three ranges: low, medium, or high. The selection of thresholds is purely subjective. The reliance on existing data favors a disaggregate approach, allowing for the transparent rating of vulnerabilities using disparate units of measurement.

At the most basic level, the overall methodology has criteria under which it must be developed. It must be quick, simple, and efficient. It must be transparent, reproducible, and scalable to a larger pool of communities. The proxies developed must take into account the exposure of these fishing ports to impacts on the commercially important resource base. This includes the species mix at each port, and the susceptibility of those species. Additionally, the selected indicators must allow for identification of potential conditions that heighten or attenuate the exposure of the community to the impacts. This may include the economic diversity of the community, the proportion of permit holders in the community versus out of the community, and others.

3.1 Typology of Community Vulnerability
The first step in assessing communities is the creation of a classification system of community vulnerability, built around the concepts of natural, social, and economic capital. It is the combination and use of these types of capital in each community that leads to resilience (the ability to adapt to change) or vulnerability.

Communities can range along a continuum from high to low vulnerability. At a general level, vulnerable communities are those communities that are unable to cope and operate within a normal range of function after a shock or perturbation. As Ford and Smit (2004; p. 393) state, this vulnerability “is related to the social, economic, and other resources that the community can draw on to prepare for, cope with, and recover from hazardous conditions.” More specifically, the vulnerability of a fishing community depends on its exposure to a sensitive fishery, its degree of reliance on that fishery relative to the other fisheries, and its capacity to adapt, based on the condition of its natural, social, and economic assets. As such, vulnerability really is the result of a mixture of the conditions of the community in economic and social terms; the character of the hazards it faces, in terms of magnitude and probability of occurrence; and the capability of the community to adapt to the change brought about by the hazard. A classification of vulnerable communities would take into account these different components of vulnerability. A combination of the community capacity literature (Beckley, 2002) (which refers to the capacity of communities in terms of the availability of their economic, social and natural assets, and the productive use of those assets) and the vulnerability literature provides a basis for outlining the different types of vulnerability (Table 1).
Table 1. Typology of community vulnerability

<table>
<thead>
<tr>
<th>Class of Vulnerability</th>
<th>Social</th>
<th>Economic</th>
<th>Natural</th>
</tr>
</thead>
<tbody>
<tr>
<td>I. High vulnerability</td>
<td>Permit holders are aging, and young people do not own local fisheries permits. The harvesting workforce is inexperienced. The community has little education capacity.</td>
<td>The economy is highly dependent on fisheries. Fixed assets, like boats, are aging and are mostly engaged in one fishery.</td>
<td>Commercially fished species are highly sensitive to climate variability and climate change. There is a lack of diversity in targeted species.</td>
</tr>
<tr>
<td>II. Moderate vulnerability</td>
<td>The age of permit holders is in the middle range, with some new entrants taking part in fisheries. The harvest workforce has some experience. There are marginally fewer people with degrees than without.</td>
<td>Fishing is an important component of the economy, but not the only one. Vessels engage in a few different fisheries. Vessels are aging, but with a few upgrades.</td>
<td>On the whole, commercial species are moderately sensitive to climate variability and change. There are a few alternatives within the mix of species.</td>
</tr>
<tr>
<td>III. Low vulnerability</td>
<td>There are new entrants into the fisheries, and on average, fishermen are younger. The harvest workforce is experienced. A majority of the community has a college degree.</td>
<td>Fisheries are but one part of a diverse economy. Vessels are engaged in diverse fisheries, and they are newer.</td>
<td>Among commercial species, climate sensitivity is low. There are alternatives to sensitive fisheries.</td>
</tr>
</tbody>
</table>

3.2 Communicating Vulnerability

The final part of this research is to evaluate the effectiveness of a graphical instrument in communicating vulnerability. The graphic used is a triangle with three regions, representing high, moderate, and low scores, modeled after a natural and recreational resource assessment developed by Cocklin, Harte, and Hay (1990). The
graphic acts as a communication tool to differentiate between ports’ vulnerabilities. Each indicator is placed in the appropriate region of the triangle to provide an “explicit and readily accessible” (Cocklin et al., 1990; p. 283) visual method of ascertaining the level of community vulnerability. Comparing the collection of indicators with the typology of community vulnerability (Table 1) allows for a determination of the community’s overall vulnerability. This summary ranking is placed at the top of the triangle. An example of the graphic with explanatory labels is below (Figure 1).

Figure 1. Example vulnerability graphic

3.3 Social Capital Indicators

The mean age of permit holders in a community is a rough indication of generational equity in the fisheries. The permits used for this indicator are state permits, as there is no available data on the ages of federal fishing permit holders. The Commercial Fisheries Entry Commission (CFEC) publishes data on the mean ages of
limited, transferable permits issued for Alaskan fisheries. The ages are published by permit and resident type, not by community. For our purposes, an imperfect estimation of the age used for this indicator was made using the mean age of the resident type for the permit. Residents of Kodiak, Petersburg, and Sitka are reported as urban, and Seward and Cordova are reported as rural. The CFEC decision rule for local and nonlocal designation depends on the Alaska Department of Fish and Game administrative district in which the place is located and the fishery prosecuted (CFEC, 2009). For example, if a person holds a permit in the Southeast Salmon Purse Seine Fishery and lives in Petersburg, then they qualify as a rural local. Conversely, if someone from Kodiak holds that same permit, they are considered an urban nonlocal.

Some permits are represented more than others in each community. The weighted average is used as the overall mean age of permit holders in the community. The thresholds for high, moderate, and low values are set at equal to or less than 40 years of age, 41 to 50 years of age, and above 50 years of age, respectively.

Crewmembers, the labor force of the fishing industry’s harvesting sector, are an integral part of the fishing sector and as such, any attempt to look at the capital stock of a fishing community needs to consider crewmembers. However, there is a paucity of information on these employees, as they are considered self employed, and commercial fishermen are not subject to the same reporting requirements as other employers. The information that is available for crewmembers in a community, like that of the permit holders, is provided by the CFEC (2008). Data that is available are the count of crewmembers by community, the statewide age distribution of license holders by year, and mean and median license longevity of license holders.
The capacity of the local crew workforce is defined as the per capita years of crewmember experience for each community. This is calculated as the mean license longevity for the pool of crewmembers for that community, divided by the community population to arrive at the indicator value. Very roughly, this gives a ratio of years of crew experience in fisheries for that community. Thresholds are set at: below a ratio of .4 contributes to high community vulnerability; between .4 and .8 contributes to moderate community vulnerability; and above .8 contributes to low vulnerability.

One aspect of human capital is the level of education found in the community (Costanza & Daly, 1992; Beckley et al., 2008). The education capacity indicator is the percentage of the population of people 25 years of age and over in the community who have attained a post-secondary degree (Census, 2000). The thresholds are: 25% or below is a low capacity, contributing to higher community vulnerability; 50% or below is moderate capacity, contributing to moderate vulnerability; and above 50% points to a high education capacity, contributing to a low community vulnerability.

3.4 Economic Capital Indicators

Economic capital indicators measure both fixed and liquid assets of the community. The first indicator, economic diversity, is a measure of the uniformity of employment across all sectors of the community’s economy. Diversification is a ubiquitous strategy used to reduce risk of hazards and shocks. It is referenced in the literature as an economic dimension of vulnerability (Parkins and MacKendrick, 2009; J. Sepez, personal communication). The Shannon index is used to measure diversity of employment in the community (Pacific Fishery Management Council, 2010). This is calculated as seen in Equation 1.
Equation 1. Shannon index

\[ H' = -\sum_{i=1}^{S} (p_i \ln p_i) \]

S = the number of sectors

\( p_i \) = the proportion of individuals in a given sector to the total number of individuals in the community

\( H' \) = diversity index

A higher index score indicates a more economically diverse community in two ways. For one, more industry sectors make for a higher index value. But since the data for this index is broken down into the same thirteen sectors, this has no impact on comparing the scores. Secondly, a higher index value indicates that employment in all sectors is relatively even, as opposed to a less even employment situation, where a there is a concentration of activity in only a few sectors. So, communities with values exceeding 3.0 can be considered at a low risk of economic concentration; values between 2 and 3 can be considered at moderate risk of economic concentration; and values lower than 2 are at a high risk of economic concentration.

The unemployment rate is also an important measure of the economic capital in a community. However, comparison between communities does not carry much significance. A comparison of the community’s unemployment rate to the state unemployment rate is more illustrative, as there is a common point for comparison. For this, the three-month average deviation from the monthly state unemployment rate is used. The data is gathered from the Bureau of Labor Statistics (2010), and its resolution
is the borough level. It is not seasonally adjusted. It is rated on a three-point scale. Any average deviation of zero or below (signifying an unemployment rate at or below the state’s rate) is considered least vulnerable. A positive difference between .1 and 1.5 is considered moderately vulnerable. Any community with a difference of 1.6 or greater is considered a position of high vulnerability.

Physical assets play a significant role in conducting fisheries. Assets specific to the harvesting side are vessels and gear. For this study, the vessels registered at that homeport are considered a community’s fleet. Yearly data on vessels by homeport community is available from the Commercial Fisheries Entry Commission. Data comes from self-reported vessel registration applications (CFEC, 2008). There are several aspects of vessels on which to report: physical attributes, such as length, size, and material of the hull; the age of the vessel; the power of the vessel in horsepower and fuel type of its engine; whether or not the vessel has refrigeration; and the diversity of gear types used within the fleet. It is prudent to assess these attributes as a whole, not piece by piece. The indicator for this will be a ranking of low, moderate, or high vessel capacity. A lower capacity contributes to higher community vulnerability, while the inverse is true for higher vessel capacities. The threshold for a low capacity is a value below 2; a moderate capacity is achieved below 3; values of 3 or higher are considered a high capacity.

The variables for this indicator are chosen as representations of both the physical characteristics of the vessel and of the uses to which the vessels are put. The variables for the indicator are:

- Ratio of vessels with refrigeration to those without
- Mean use count for vessels
• Ratio of sum vessel length to sum horsepower of the port

The indicator is the sum of these ratios. Essentially, this indicator is an indirect measure of the inputs directed into the fleet. A higher the ratio of boats with refrigeration to those without may indicate that boat owners are investing into their boats. The mean use count for vessels may indicate that vessels are engaged in diverse fisheries, and therefore are less dependent upon one fishery. The length-to-horsepower ratio describes the relationship between the total vessel length and total vessel horsepower for vessels in that port. The relationship between these two inputs is important, as it can signal the productivity of these assets on a foot-by-foot basis. The higher the value of this ratio, the more engine power per foot is available in the fleet.

Furthermore, the mean age and length of the vessels in each community are reported as additional features on which to measure the fleet. These are calculated as a weighted mean, as some years are more and less represented in the vessel ages (CFEC, 2008). Vessels with no build year data are excluded from the average. The build year is subtracted from 2010 to find the vessel age. The weighting each age receives in the mean calculation is the frequency with which that age appears in the vessel data. For these values, it is assumed that a community with older vessels has less capital to use towards building and retaining community capacity.

On the processing side of fisheries, processing plants are the important physical assets. As we are referring to place-based communities, these are shore-based processing plants. For reasons of confidentiality, available information on processing plants is scarce. However, the number of processing plants that hold a federal processing permit in
a location may be found. Counts are not included as an indicator, but to further describe these communities (National Oceanic and Atmospheric Administration, 2008).

### 3.5 Natural Capital Indicators

Fish species are a significant source – if not the primary source – of natural capital for these communities. Situated as coastal fishing communities, each port relies on fish for a variety of activities. The vast majority of fish available to communities is used in commercial fisheries. It should be noted that besides commercial fishing, each port has recreational and subsistence activities on which some in the community rely. However, for this study we exclusively look at commercial fisheries as the source of natural capital.

Each port lands a unique mix and abundance of commercially fished species. It is this mix that allows us to distinguish between each port’s exposure to climate variability and change. The first task is the identification of commercially important fish species in Alaskan fisheries. Species were selected using the following method. The proportion of revenue and landings by weight for each species was calculated for 2008 (Office of Science and Technology, 2010). To be included, a species must exceed 1% in both percentage of total pounds and total revenue. The following species met or exceeded that threshold: walleye pollock, Pacific cod, yellowfin sole, pink salmon, sockeye salmon, Atka mackerel, chum salmon, rock sole, Pacific herring, Pacific halibut, and snow crab (Table 2). The species list was adjusted in five ways. 1. Crustaceans were excluded in order to keep the sensitivity attributes simple. 2. Atka mackerel was also excluded, as they are not typically caught in large quantities in the regions of the Gulf of Alaska in which these communities are located. 3. Sablefish (also commonly known as black cod) was included for two reasons: it is commonly linked with the halibut longline fishery, and
it represents over 5% of revenue, implying it is significant as a commercial species. 4. Yellowfin sole was excluded because it was not found in significant quantities in any of the ports. 5. The data for the three salmon species (pink, sockeye, and chum) was collapsed into a single set for this analysis.

Table 2. Species, by pounds and revenue, total and as percentage of total landings (OS&T, 2010)

<table>
<thead>
<tr>
<th>Species</th>
<th>Pounds</th>
<th>Revenue</th>
<th>% Pounds (Total)</th>
<th>% Revenue (Total)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Walleye Pollock</td>
<td>2,276,144,004</td>
<td>323,212,449</td>
<td>50.2</td>
<td>19.0</td>
</tr>
<tr>
<td>Pacific Cod</td>
<td>493,813,610</td>
<td>274,066,553</td>
<td>10.9</td>
<td>16.1</td>
</tr>
<tr>
<td>Yellowfin Sole</td>
<td>311,370,613</td>
<td>54,744,630</td>
<td>6.9</td>
<td>3.2</td>
</tr>
<tr>
<td>Pink Salmon</td>
<td>260,522,209</td>
<td>74,430,887</td>
<td>5.7</td>
<td>4.4</td>
</tr>
<tr>
<td>Sockeye Salmon</td>
<td>224,434,665</td>
<td>175,294,147</td>
<td>5.0</td>
<td>10.3</td>
</tr>
<tr>
<td>Chum Salmon</td>
<td>116,965,145</td>
<td>59,841,050</td>
<td>2.6</td>
<td>3.5</td>
</tr>
<tr>
<td>Rock Sole</td>
<td>116,787,103</td>
<td>27,419,902</td>
<td>2.6</td>
<td>1.6</td>
</tr>
<tr>
<td>Pacific Herring</td>
<td>83,787,188</td>
<td>22,911,961</td>
<td>1.8</td>
<td>1.3</td>
</tr>
<tr>
<td>Pacific Halibut</td>
<td>64,638,789</td>
<td>208,982,549</td>
<td>1.4</td>
<td>12.3</td>
</tr>
<tr>
<td>Sablefish</td>
<td>30,306,868</td>
<td>97,311,224</td>
<td>.7</td>
<td>5.7</td>
</tr>
</tbody>
</table>

There is insufficient data and understanding of climate change and fish species responses to perform a quantitative analysis of each fish species’ susceptibility to climate change. However, a semi-quantitative procedure can be used to incorporate present knowledge of these species into a risk assessment. NOAA has adopted one risk assessment approach, the productivity-susceptibility analysis (PSA), in response to National Standard 1, to gauge the vulnerability of fisheries to overfishing (Patrick et al, 2009; Patrick et al, 2010). Through some modification, this approach can also be used to quickly assess climate change risk for these species.

Originally, different forms of productivity-susceptibility analyses were developed to assess the sustainability of bycatch in the Australian prawn fishery (Milton, 2001; Stobutzki, 2001). The iteration of this risk assessment approach adopted by National Marine Fisheries Service, NOAA is designed to evaluate the vulnerability of fish stocks
to overfishing. It defines vulnerability to overfishing as a function of two components: susceptibility and productivity. Productivity refers to the ability of the species to recover from a point of depletion. Susceptibility refers to the potential of the species to be impacted by whichever fishery is evaluated (Patrick et al, 2010).

Using this method, the values for productivity and susceptibility are determined by attributes related to each component. These attributes were selected as a strong representation of each of the components. Productivity parameters were largely modeled after King and Macfarlane (2003). Ranges for attribute values are predetermined, and each range is broken into three points. From here, the attribute values of each species are compared against these ranges; they are scored based on this three-point scale. In order to improve accuracy, attribute scores that fall in intermediate ranges can be scored in half-point increments (Patrick et al, 2009). The attributes can be weighted as seen fit, if an attribute is more or less applicable to a certain species. Then, the scores are added and averaged, arriving at two overall scores for productivity and susceptibility. The final vulnerability score is defined as the Euclidean distance of the productivity and susceptibility scores from the origin coordinates. The approach adopted by NOAA is outlined in full detail in Patrick, et al. (2009).

For the purposes of this research, a modified version of the productivity component of the methodology is adopted. The assumption is that productivity can be an indicator of how climate potentially affects the species in question. Life history attributes are an important consideration with regards to species’ response to climatic change. Ranges for scoring these attributes, from Patrick, et al (2010), are adopted. However, I use a five-point scale to score the attributes, instead of a three-point scale. This is done to
expand the range between the species scores. The following are lists and definitions of these attributes, and the ranges are summarized in Table 4.

The **maximum age** \((t_{\text{max}})\) attribute is the observed age of the oldest individual of that species. Maximum age is inversely related to the natural mortality rate, an indication of the productivity of the species.

**Maximum size** tends to be negatively correlated with productivity. Larger fish tend to have lower levels of productivity, while smaller fish tend to have higher levels of productivity.

The **von Bertalanffy growth coefficient** \((k)\) is a measure of how fast a fish reaches maximum size. Long-lived, low productivity fish tend to have lower values of \(k\). Short-lived species have higher values.

The **estimated natural mortality rate** \((M)\) is a reflection of population productivity. Species with high rates of natural mortality require higher levels of production to maintain population levels.

**Measured fecundity** is the number of eggs produced by a female for a given spawning event or period. For the purposes of consistency, this reflects the fecundity at the age of first maturity, as older individuals will be more fecund.


The **recruitment pattern** of the species, according to Patrick (2010), is “a coarse index to distinguish stocks with high frequency of year-class failures from those with relatively steady recruitment.” (p. 309) This is measured as the coefficient of variation in
recruitment, as reported on Fishbase (Froese & Pauly, 2010) and in Hollowed, Hare & Wooster (2001).

The age at maturity ($t_{\text{mat}}$) attribute is included because this parameter is strongly related to maximum age and natural mortality. Longer-lived species will often have higher ages at which individuals mature than short-lived species. Productivity of late maturing species is often lower than early maturing species.

The mean trophic level refers to where the species is positioned in the greater food web. It is an indication of productivity because species that occupy lower trophic levels are often more productive, while higher trophic level species are less productive.

Table 3. Productivity attributes and ranking scheme (adapted from Patrick et al., 2009)

<table>
<thead>
<tr>
<th>Productivity attribute</th>
<th>Ranking attribute</th>
<th>Ranking 5</th>
<th>Ranking 3</th>
<th>Ranking 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum age</td>
<td></td>
<td>&lt;10 years</td>
<td>10-30 years</td>
<td>&gt;30 years</td>
</tr>
<tr>
<td>Maximum size</td>
<td></td>
<td>&lt;60 cm</td>
<td>60-150 cm</td>
<td>&gt;150 cm</td>
</tr>
<tr>
<td>von Bertalanffy growth coefficient (k)</td>
<td></td>
<td>$&gt;0.25$</td>
<td>0.15 – 0.25</td>
<td>$&lt;0.15$</td>
</tr>
<tr>
<td>Estimated natural mortality</td>
<td></td>
<td>$&gt;0.40$</td>
<td>0.20 – 0.40</td>
<td>$&lt;0.20$</td>
</tr>
<tr>
<td>Measured fecundity</td>
<td></td>
<td>$&gt;10,000$</td>
<td>100 – 1,000</td>
<td>$&lt;100$</td>
</tr>
<tr>
<td>Breeding strategy</td>
<td></td>
<td>0</td>
<td>1 – 3</td>
<td>$\geq$4</td>
</tr>
<tr>
<td>Recruitment pattern</td>
<td>Highly frequent recruitment success ($&gt;75%$ of year classes are successful).</td>
<td>Moderately frequent recruitment success (between 10% and 75% of year classes are successful).</td>
<td>Infrequent recruitment success ($&lt;10%$ of year classes are successful).</td>
<td></td>
</tr>
<tr>
<td>Age at maturity</td>
<td></td>
<td>$&lt;2$ year</td>
<td>2 – 4 years</td>
<td>$&gt;4$ years</td>
</tr>
<tr>
<td>Mean trophic level</td>
<td></td>
<td>$&lt;2.5$</td>
<td>2.5 – 3.5</td>
<td>$&gt;3.5$</td>
</tr>
</tbody>
</table>

The risk analysis is conducted independent of the port-specific information, and then applied to the landings by port. There are two data series against which to apply the overall productivity scores: either to the pounds of landings by species, or to the ex-
vessel values by species. The indicator values for either would be the weighted mean productivity score for the species mix of the port (excluding the species landed in that port that are not included in this report). Both are reported. Very generally speaking, those species that are longer lived and perhaps not as productive may not adapt as readily and decrease in abundance in the long run as a reaction to climate changes. But in the near term, those species may decrease or stay at typical abundances. Conversely, species that are highly productive may flourish in the short run. But in the long run, the pattern of distribution of those species may change significantly. Consequently, the interpretation of the scale expresses the effects of climate in the short term. The lower the value the more risky the fishery. A score of 1-2 indicates a species of low productivity and at high risk of adverse climate impacts. A score of 2-4 indicates a species of moderate productivity, and at moderate risk of adverse climate impacts. A score of 4-5 indicates a species of high productivity, and one that is at a lower risk of immediate adverse climate impacts.

The second natural capital indicator is the scale of the fishing resource base of these communities, consisting of the value of the species per 1000 residents (Jacob, Weeks, Blount, & Jepson, 2010). Jacob et al. (2010) use this indicator as one of several in a commercial fisheries dependence index. In this research, a higher resource base value indicates a higher capacity. A value of 10,000 dollars per person and under contributes to a higher vulnerability. A value between 10,000 and 15,000 dollars per person contributes to a moderate vulnerability. A value above 15,000 dollars per person contributes to a low vulnerability.

3.6 Summary

In summary, this research is intended to assess the social, economic, and natural capital of different Alaskan fishing communities as a method of evaluating the
vulnerability of these communities. To assess those three types of capital, indicators are used to evaluate and represent different aspects of the fishing industry, fishing community, and fisheries, summarized in Table 2. The indicator-specific variables are scored based on pre-determined ranges, summarized in Table 3. Furthermore, a typology of community vulnerability is used as a rough guide in determining the overall community vulnerability (Table 1). A comparison of a community’s aggregate indicator values to the typology can elucidate a summary ranking of vulnerability (e.g., I, II, III). Lastly, a graphic instrument is used to communicate the individual indicators scores as well as the overall vulnerability of the community (Figure 1).

Table 2. List of community capital indicators

<table>
<thead>
<tr>
<th>Type of Capital</th>
<th>Indicator</th>
<th>Variable</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Social</td>
<td>Age of permit holders</td>
<td>Mean age of permit holders</td>
<td>CFEC, 2010</td>
</tr>
<tr>
<td></td>
<td>Community education capacity</td>
<td>Education per capita in community</td>
<td>U.S. Census, 2000</td>
</tr>
<tr>
<td></td>
<td>Fisheries workforce capacity</td>
<td>Local crew license longevity</td>
<td>CFEC, 2008</td>
</tr>
<tr>
<td>Natural</td>
<td>Resource base</td>
<td>Value per 1000 residents</td>
<td>CFEC, 2010, The Research Group, 2007</td>
</tr>
<tr>
<td>Risk score</td>
<td></td>
<td>Average risk criteria scores</td>
<td>Patrick et al, 2009</td>
</tr>
<tr>
<td>Economic</td>
<td>Economic diversity</td>
<td>Employment diversity, Shannon index</td>
<td>U.S. Census, 2000</td>
</tr>
<tr>
<td></td>
<td>Fleet capacity</td>
<td>Length-to-horsepower ratio</td>
<td>CFEC, 2008</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Refrigeration ratio</td>
<td>CFEC, 2008</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Mean vessel use count</td>
<td>CFEC, 2008</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Weighted mean age of vessels</td>
<td>CFEC, 2008</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Weighted mean length of vessels</td>
<td>CFEC, 2008</td>
</tr>
<tr>
<td></td>
<td>Unemployment</td>
<td>Mean 3-month deviation from state</td>
<td>Bureau of Labor Statistics, 2010</td>
</tr>
<tr>
<td></td>
<td></td>
<td>unemployment</td>
<td></td>
</tr>
</tbody>
</table>
Table 3. Ranges of community capital indicator values and corresponding levels of vulnerability

<table>
<thead>
<tr>
<th>Indicators</th>
<th>Low vulnerability</th>
<th>Moderate vulnerability</th>
<th>High vulnerability</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Age of permit holders</td>
<td>≤ 40</td>
<td>41-50</td>
<td>&gt;50</td>
</tr>
<tr>
<td>B. Community education capacity</td>
<td>≥50%</td>
<td>25%-50%</td>
<td>≤25%</td>
</tr>
<tr>
<td>C. Fisheries workforce capacity</td>
<td>&gt;.8</td>
<td>.4-.8</td>
<td>&lt;.4</td>
</tr>
<tr>
<td>D. Economic diversity</td>
<td>≥3</td>
<td>2-3</td>
<td>&lt;2</td>
</tr>
<tr>
<td>E. Fleet capacity</td>
<td>≥2</td>
<td>2-3</td>
<td>≥3</td>
</tr>
<tr>
<td>F. Unemployment</td>
<td>≤0</td>
<td>.1-1.5</td>
<td>≥1.6</td>
</tr>
<tr>
<td>G. Resource base</td>
<td>≤$10,000</td>
<td>$10,000-$15,000</td>
<td>≥$15,000</td>
</tr>
<tr>
<td>H. Risk score</td>
<td>5</td>
<td>3</td>
<td>1</td>
</tr>
</tbody>
</table>

4. Results

The contents of this section are structured as a narrative. Each community has an introductory section, followed by a presentation of the indicator results, broken down by the corresponding type of capital. The summary section discusses the overall vulnerability of the community.

4.1 Cordova

Cordova is a community of 2,434 people located on the southeastern end of Prince William Sound and the western edge of the Copper River (Sepez et al., 2005). The Aluutiq people first inhabited the area, but in the late 1880s, copper miners began to arrive. The City of Cordova was formed in 1909 as a port from which to ship copper ore from the Kennecott Mine on the Copper River, which shut down in 1938. Since then, commercial fishing has been the economic base of Cordova (Sepez, et al., 2005). In 1989, the Exxon Valdez oil spill hit Bligh Reef, approximately 45 miles from Cordova, causing widespread ecological damage and shutting down the commercial fisheries in the area.
Salmon fisheries largely recovered, but the herring fishery has only seen six seasons since 1989 (CFEC, 2010).

4.1.1 Social Capital

For the 562 limited entry permits held in Cordova in 2008, the weighted mean age of the permit holders was 52.4 years (CFEC, 2009), considered a high value on the scale. The mean crew license longevity for Cordova in 2006 was 5.8 years, for 300 crew license holders (CFEC, 2008). This translates into .71 years of crew experience for each resident of Cordova, considered a moderate value. As seen in Figure 2, this ratio remained fairly steady in Cordova for the five previous years. The education capacity for Cordova was .30, indicating that nearly one-third of the over-25 years of age population had a post-secondary degree.

Figure 2. Crew license longevity by community, 2001-2006 (CFEC, 2008)

4.1.2 Economic Capital

The economic capital found in Cordova, and all Alaskan fishing communities, takes many different forms, and requires a variety of measures to best describe it. The
Shannon index can be used to measure the diversity of employment in the community (PFMC, 2010). Using data from the 2000 Census Summary File 4, Cordova was found to have an index value of 2.4, considered to be at moderate risk of being economically concentrated. The different values for Cordova and the other communities are shown in Figure 3. The unemployment indicator for the Valdez-Cordova Borough is -0.2, indicating an unemployment rate that is nearly on par with the state unemployment rate (Figure 4).

Figure 3. Diversity of employment by community (Census Summary File 4, 2000)
Figure 4. Three-month average deviation from Alaska unemployment rate (Bureau of Labor Statistics, 2010)

Cordova has 639 vessels operating from its port. The mean age of these vessels, as of 2010, is 23.7 years, with a standard deviation of 10 years. Figure 5 illustrates the vessel age distribution of Cordova vessels. The mean length of Cordova vessels is 30.29 feet, with a standard deviation of 10.4 feet (Figure 6). The fleet capacity index for Cordova is 1.79, indicating a fleet with a low capacity (Table 6). This is the lowest value for the five communities, and can be largely attributed to a lack of boats with a refrigeration system, and a small length to horsepower ratio. Cordova is unique in this sense, because a majority of its vessels fall in the 26-32 feet range of length, and are only involved in the Prince William Sound salmon drift gillnet fishery. Cordova has seven federal processing permits.
Figure 3. Cordova vessel ages

Figure 4. Cordova vessel lengths

Table 4. Fleet capacity variables and indicator values by community

<table>
<thead>
<tr>
<th>Port</th>
<th>Refrig/Non-refrig Ratio</th>
<th>Vessel Use Diversity Ratio</th>
<th>Length to Horsepower Ratio</th>
<th>Indicator Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cordova</td>
<td>0.19</td>
<td>1.51</td>
<td>0.09</td>
<td>1.79</td>
</tr>
<tr>
<td>Kodiak</td>
<td>0.62</td>
<td>2.26</td>
<td>0.12</td>
<td>3.00</td>
</tr>
<tr>
<td>Petersburg</td>
<td>0.28</td>
<td>1.99</td>
<td>0.15</td>
<td>2.42</td>
</tr>
<tr>
<td>Seward</td>
<td>0.48</td>
<td>1.54</td>
<td>0.12</td>
<td>2.14</td>
</tr>
<tr>
<td>Sitka</td>
<td>0.24</td>
<td>1.75</td>
<td>0.17</td>
<td>2.15</td>
</tr>
<tr>
<td>Alaska</td>
<td>0.21</td>
<td>1.80</td>
<td>0.13</td>
<td>2.13</td>
</tr>
</tbody>
</table>
4.1.3 Natural Capital

Cordova is also unique as a port that is significantly reliant on salmon landings, averaging 66 million pounds between 2005 and 2009 (Figure 7 & 8) (The Research Group, 2007). Cordova is geographically situated to take advantage as the primary processing port of Copper River salmon and the frequently massive Prince William Sound hatchery runs of pink salmon. Furthermore, there are a moderate amount of deliveries of halibut and sablefish to Cordova, averaging 1.4 million and 1.3 million pounds, respectively. Approximately 3.8 million pounds of other species landed in Cordova were not included in this report. Appendix One contains the overall attribute scores by species. The risk indicator value for pounds landed is 3.22, while the risk indicator value for ex-vessel value is 3.08 (Table 5).

Figure 5. Five-year average landings in Cordova, in pounds
4.1.4 Summary

Under this typology, Cordova should be considered a moderately vulnerable community. The vulnerabilities Cordova faces derive from the heavy reliance on a single species (salmon), little diversity in the Cordova fleet, and older permit holders. Cordova
is buoyed by a lower unemployment rate than the state rate, and a relatively diverse economy.

4.2 Kodiak

Kodiak is a community of 6,334 people located on the northeastern tip of Kodiak Island, the largest island of the Kodiak Archipelago. According to Sepez et al. (2005), the Aluutiq people have inhabited Kodiak Island for approximately 8,000 years. In 1882 a cannery was established at the mouth of the Karluk River, beginning a long history of Kodiak’s involvement in commercial fishing. Contemporary Kodiak’s economy is steeped in commercial fishing, including a large processing industry, a diverse fleet, and many commercial fisheries.

4.2.1 Social Capital

For the 1,265 limited entry permits issued in 2008, the weighted mean age of the permit holders was 49.2 years. The mean crew license longevity for Kodiak in 2006 was 6.7 years, for 796 license holders. This translates into .86 years of crew experience for each resident of Kodiak, considered a high value on the crew capacity scale. As seen in Figure 2, this ratio is the highest between the five communities, but has declined since 2001. The education capacity for Kodiak was .22, indicating that less than one-quarter of the over-25 years of age population had a post secondary degree in 2000.

4.2.2 Economic Capital

The Shannon index value for employment diversity in Kodiak was 2.23 (Figure 3), considered to be at moderate risk of being economically concentrated. The
unemployment indicator for the Kodiak Borough is -1.1 (BLS, 2010), indicating an unemployment rate below the state unemployment rate, and not a source of vulnerability.

Kodiak has 553 vessels operating from its port. The mean age of these vessels in 2010 is 26.7 years, with a standard deviation of 10.8 years. Figure 10 illustrates the vessel age distribution of Kodiak vessels. The mean length of Kodiak vessels is 40.6 feet, with a standard deviation of 27.1 feet. The fleet capacity index for Kodiak is 3.00, indicating a fleet with a high capacity. This is the highest value for the five communities, and can be largely attributed to a high number of boats with refrigeration, and the highest average vessel use count. As seen in Figure 11, vessels in Kodiak are of various lengths, with 202 vessels 26 feet or shorter, and 84 vessels that are 60 feet or longer. Kodiak has twelve federal processing permits.

Figure 8. Kodiak vessel ages (CFEC, 2010)
4.2.3 Natural Capital

It could be claimed that the diversity of Kodiak vessels is a reflection of the richness and abundance of fisheries in the Gulf of Alaska, most accessible from the port of Kodiak. In terms of landings, a yearly average 325 million pounds of fish were landed between 2005 and 2009, for an average yearly value of $120,924,148 (The Research Group, 2007). One-quarter of these landings in weight were walleye pollock, nearly one-third of the landings were salmon, and sixteen percent were Pacific cod. The risk indicator value for pounds landed is 3.16, while the risk indicator value for ex-vessel value is 2.89 (Table 5).
4.2.4 Summary

Figure 10. Five-year average landings in Kodiak, in pounds

Figure 11. Five-year average landings in Kodiak, in dollars
Kodiak is the only community that achieved a rating of low vulnerability using this typology. Kodiak’s unemployment rate is lower than the state rate, the resource base is diverse and abundant, and the fleet is diverse and capitalized. There are many crewmembers with plentiful experience. It does suffer from drawbacks in some key areas: it is not a diverse economy relative to the other communities, and the education level of the community is low. This could hurt its chances to diversify in the face of changes in the fisheries.

4.3 Petersburg

Petersburg is a community of 3,224 people located in Southeast Alaska on Mitkof Island, at the confluence of the Wrangell narrows and Frederick Sound (Sepez et al., 2005). Once used as a summer fish camp by Tlingit Indians, this area became a homestead for Peter Buschmann, a Norwegian immigrant and pioneer (Sepez et al., 2005). In 1910, the city of Petersburg was formed, and since then, commercial fishing has
been an important, if not dominant, part of the Petersburg economy. Petersburg, according to Sepez et al., is “one of Alaska’s major fishing communities” (p. 127).

4.3.1 Social Capital

For the 1144 limited entry permits held in Petersburg in 2008, the weighted mean age of the permit holders was 49.1 years (CFEC, 2009), barely considered a moderate value on the scale. The mean crew license longevity for Petersburg in 2006 was 5.9 years, for 460 crew license holders (CFEC, 2008). This translates into .84 years of crew experience for each resident of Petersburg. As seen in Figure 2, this ratio has risen since 2001, achieving parity with Kodiak. The education capacity for Petersburg was .22, indicating that less than one-quarter of over-25 residents had a post-secondary degree.

4.3.2 Economic Capital

The Shannon index value for diversity of employment found in Petersburg was 2.31, the second highest diversity among the five communities, and a value considered to be at moderate risk of being economically concentrated. The unemployment indicator for the Wrangell-Petersburg Borough is 1.6, indicating an unemployment rate higher than the state unemployment rate. However, as Sepez et al. (2005) notes, “the economy of Petersburg is based on commercial fishing and timber harvest and is therefore highly seasonal.”

Petersburg has 596 vessels operating from its port. The mean age of these vessels in 2010 is 28.4 years, with a standard deviation of 15.1 years. Figure 15 illustrates the vessel age distribution of Petersburg vessels. The mean length of Petersburg vessels is 31.8 feet, with a standard deviation of 20.2 feet. The fleet capacity index for Petersburg is 2.42, indicating a fleet with a moderate capacity. This value is the second highest of these
communities. A high average use count and a higher horsepower to length ratio bolster Petersburg’s fleet capacity. Petersburg has nine federal processing permits.

Figure 13. Petersburg vessel ages

![Vessel Ages](image1)

Figure 14. Petersburg vessel lengths

![Vessel Lengths](image2)

4.3.3 Natural Capital

The natural capital available to Petersburg in the form of its commercial fisheries averaged 40 million pounds per year between 2005 and 2009 (Figure 17), exceeding 31
million dollars in value (Figure 18) (The Research Group, 2007). This is another community in which salmon landings make up a significant portion of the total landings, at 74 percent of the average total landings. Halibut and sablefish account for a combined ten percent of the landings by weight. However, salmon accounts for only 26 percent of the value of landings. Halibut accounts for twenty-nine percent, and sablefish accounts for fifteen percent of the total value, combining for nearly half the value of the total landings. By weight, other species not accounted for in this report accounted for approximately twelve percent of the catch, and twenty-five percent of the value. Species of high value that are not included in this report include Dungeness crab and king salmon, both of which are caught out of Petersburg. The risk indicator value for pounds landed is 3.20, while the risk indicator value for ex-vessel value is 2.82.

Figure 15. Five-year average landings in Petersburg, in pounds
4.3.4 Summary

Petersburg is a moderately vulnerable community. Most indicators register as contributing to moderate or high vulnerability. While the unemployment is high relative to the state rate, and the resource base is low per person, the Petersburg economy and
fleet are moderately diverse. However, the education capacity is low, and the age of the permit holders is nearly fifty.

4.4 Seward

Seward is a community of 2,830 people located on the fjord-like Resurrection Bay, on the southeast coast of the Kenai Peninsula (Sepez et al., 2005). Unlike the other four communities, there is little evidence that the area occupied by Seward had an historical Native Alaskan population (Sepez et al., 2005). Russian fur traders and explorers discovered Resurrection Bay in 1792, but the town was not settled until the 1890s, after Alaska was bought by the United States. Because of its ice-free port and access by highways to Anchorage and other Kenai Peninsula communities, Seward is considered a major transportation hub (Sepez et al., 2005). As such, it is highly involved in the tourism industry, hosting an annual 320,000 cruise ship visitors.

4.4.1 Social Capital

For the 111 limited entry permits held in Seward in 2008, the weighted mean age of the permit holders was 46.7 years (CFEC, 2009), considered a moderate value on the scale. The mean crew license longevity for Seward in 2006 was 5.8, for 129 crew license holders (CFEC, 2008). This translates into .27 years of crew experience for each resident of Seward, considered having weak crew capacity. As seen in Figure 2, this ratio remained depressed from 2001 to 2005, with a slight uptick in 2006. The education capacity for Seward was .22, indicating that less than one-quarter of the over-25 years of age population in 2000 had a post secondary degree, the same as Kodiak and Petersburg.

4.4.2 Economic Capital
The Shannon index value for employment diversity in Seward was 2.30 (Figure 4), comparable to that of Petersburg. This level is considered to be at moderate risk of being economically concentrated. The unemployment indicator for the Kenai Peninsula Borough, of which Seward is a part, is 1.7, indicating an unemployment rate above the state unemployment rate. This could be considered a point of vulnerability, and on the scale is considered to be highly vulnerable.

Seward has 84 vessels operating from its port. The mean age of these vessels in 2010 is 28.9 years, with a standard deviation of 11.5 years. Figure 20 illustrates the vessel age distribution of Seward vessels. The mean length of Seward vessels is 36.1 feet, with a standard deviation of 19.5 feet (Figure 21). The fleet capacity index for Seward is 2.14, the second lowest value out of the five communities. Seward’s small fleet of vessels has the highest length to horsepower ratio, but is otherwise middling with regards to refrigeration and the average use count of each vessel. While this port is tied to the Prince William Sound both the salmon and the halibut and sablefish fisheries in substantial amounts, it does not seem that permit holders or vessel owners prefer Seward for living in or mooring their vessels. Seward has four federal processing permits.
4.4.3 Natural Capital

As both an ocean port and a gateway to Alaska’s population centers via roadways (and by extension the contiguous United States), illustrates Seward’s advantage as a commercial fishing port. According to Google Earth, it is located approximately 74 miles from the Armin F. Koernig hatchery (AFK), an Alaska Department of Fish & Game
hatchery operated by the Prince William Sound Aquaculture Corporation (PWSAC, 2010). According to Google Earth, Cordova is approximately 95 miles from AFK. In 2010, over 13 million pink salmon were harvested from this hatchery alone (PWSAC, 2010).

For the 36.5 million pounds of fish delivered in Seward, sixty-six percent of it was salmon, while sixteen and fourteen of the landings by weight were halibut and sablefish, respectively (The Research Group, 2007). In Seward, as in Petersburg, halibut and sablefish account for fifty-one and thirty-three percent of the value of landings. Salmon accounts for only fifteen percent of the ex-vessel value. The risk indicator value for pounds landed is 3.02, while the risk indicator value for ex-vessel value is 2.57. Obviously, the second indicator score is depressed by the disproportionate role that halibut and sablefish play in the value of Seward’s landings. Also important to note is the distinct lack of diversity in the species landed in Seward. While salmon, halibut and sablefish are landed in high numbers in Seward, they represent over 95% of the landings by weight. This lack of diversity in fisheries could indicate a source of vulnerability that is not captured in the other indicators.
4.4.4 Summary
Seward is considered a highly vulnerable fishing community. It entirely lacks any indicators that fall into the low category, and is weighed down by a high unemployment rate. Its economy is moderately diverse, but it barely has a fleet, and holds the least permits out of the five communities. In terms of value, it relies on two species with low productivity scores, indicating a higher risk from climate variability. The crew capacity is lacking, as is the education capacity for the community.

4.5 Sitka

Sitka is a community of 8,835 people located in Southeast Alaska, on the west coast of Baranof Island (Sepez et al., 2005). It is most immediately on the shores of Sitka Sound, which opens into the North Pacific. The original inhabitants of the area were Tlingit Indians, until the Russian Bering expedition found it and established a trading post and fort (Sepez et al., 2005). By 1808, Sitka was the capital of Russian Alaska, and subsequently became the capital of the Alaska Territory until 1906. Contemporary Sitka
has a relatively diverse economy, with only retail trade and educational, health, and social services breaking ten percent of the workforce (Census Summary File 4, 2000).

4.5.1 Social Capital

For the 1068 limited entry permits held in Sitka in 2008, the weighted mean age of the permit holders was 50.9 years (CFEC, 2009), considered a high value on the scale. The mean crew license longevity for Sitka was 5.8 years, for 566 crew license holders (CFEC, 2008). This translates into .37 years of crew experience for each resident of Sitka, considered a low crew capacity. As seen in Figure 2, this ratio remained fairly low, but steadily rising between 2001 and 2006. The education capacity for Sitka was .39, easily the highest among the five communities. This means that nearly 40 percent of the over-25 population has a post-secondary degree.

4.5.2 Economic Capital

The Shannon index value for employment diversity in Sitka was 2.22, considered to be at a moderate risk of being economically concentrated (Figure 3). Over thirty percent of the workforce is found in the educational, health, and social services, and it is likely that this concentration is the cause of the moderate score. The unemployment indicator for Sitka Borough and City is -1.8, indicating an unemployment rate well below the state unemployment rate, and not a source of vulnerability (Figure 4).

Sitka has 604 vessels operating from its port. The mean age of these vessels in 2010 is 32 years, with a standard deviation of 19.7 years. Figure 25 illustrates the vessel age distribution of Sitka vessels. The mean length of Sitka vessels is 33.2 feet, with a standard deviation of 13 feet (Figure 26). The fleet capacity index for Sitka is 2.15, indicating a fleet with moderate capacity. As a generally older fleet, this is not surprising.
Twenty percent of the vessels are wooden hulled, 293 of the vessels are used to longline, and 249 vessels are used to power troll, presumably for high quality troll-caught salmon. Of the 123 wood-hulled vessels, 105 of them power troll and 60 use longlines. Generally, woodhulled boats are older vessels; in this case, the average age of these vessels is 61.4 years (CFEC, 2010). Sitka has four federal processing permits.

Figure 23. Sitka vessel ages

![Vessel Ages](image1)

Figure 24. Sitka vessel length

![Vessel Length](image2)
4.5.3 Natural Capital

Sitka Sound is home to the Sitka Sound herring fishery, accounting for thirty-four percent of the average 77.5 million pounds of fish landed in the port between the years 2005 and 2009 (The Research Group, 2007). Caught for its roe, the nearly 26 million pounds of herring is not as valuable as the 3.3 million pounds of halibut or the nearly five million pounds of sablefish landed in Sitka. Like Petersburg, the exclusion of crustaceans and king salmon in this report is evident in Sitka’s landings picture; eleven percent of the average annual landings, accounting for twenty-six percent of the value, are marked as other species. The value of Sitka’s landings is fairly evenly distributed among four known species: salmon, herring, halibut, and sablefish, plus the other species. The risk indicator value for pounds landed is 3.66, while the risk indicator value for ex-vessel value is 3.14. As in the other communities, the risk indicator for the ex-vessel value is lower because of the dominance of halibut and sablefish, both lower risk species.

Figure 25. Five-year average landings in Sitka, in pounds
4.5.4 Summary

Figure 27. Summary graphic, Sitka

Overall, Sitka is a moderately vulnerable fishing community. However, it has some advantages that other communities do not. For one, it has a high education capacity, with nearly forty percent of its population having received a post-secondary degree.
Secondly, it boasts a species mix that is less vulnerable overall, as thirty-four percent of the mix is herring, a highly productive species.

5. Discussion

This methodology was not intended to project what increased climate variability will do to these fish species and the humans that rely on them. The community capacity framework was designed to indicate whether those humans and the environment in which they exist have the capacity to cope with and adapt to changes in baseline conditions (Beckley et al., 2008). As Eriksen and Kelly state, the “measurement of vulnerability must focus on the condition, shaped by existing circumstances, that determines the ability to respond to some future threat” (p. 506). The indicators and framework I present in this research are an attempt to capture an initial assessment of the condition of these fishing communities, their associated fishing industries, and to a lesser extent, the fisheries themselves.

The result of this assessment demonstrate that each fishing community has varying amounts of capital – in social, economic, and natural forms – in reserve from which to draw in order to adapt and cope. Table 5 summarizes the values for each indicator by community. The distribution of capacity matters greatly when evaluating a community’s vulnerability (Eriksen & Kelly, 2007).
Table 5. Summary of indicator results by community

<table>
<thead>
<tr>
<th>Indicator score by community</th>
<th>Cordova</th>
<th>Kodiak</th>
<th>Petersburg</th>
<th>Seward</th>
<th>Sitka</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Mean age of permit holders</td>
<td>52.4</td>
<td>49.2</td>
<td>49.1</td>
<td>46.7</td>
<td>50.9</td>
</tr>
<tr>
<td>B. Community education capacity</td>
<td>.30</td>
<td>.22</td>
<td>.22</td>
<td>.22</td>
<td>.39</td>
</tr>
<tr>
<td>C. Fishing industry workforce capacity</td>
<td>.66-.72</td>
<td>.83-.91</td>
<td>.70-.85</td>
<td>.23-.30</td>
<td>.30-.38</td>
</tr>
<tr>
<td>D. Economic diversity index</td>
<td>2.4</td>
<td>2.23</td>
<td>2.31</td>
<td>2.30</td>
<td>2.22</td>
</tr>
<tr>
<td>E. Fleet capacity indicator</td>
<td>1.79</td>
<td>3.00</td>
<td>2.42</td>
<td>2.14</td>
<td>2.15</td>
</tr>
<tr>
<td>F. Unemployment indicator</td>
<td>-0.2</td>
<td>-1.1</td>
<td>1.6</td>
<td>1.7</td>
<td>-1.8</td>
</tr>
<tr>
<td>G. Resource base ($/1000 residents)</td>
<td>18368.13</td>
<td>19091.28</td>
<td>9708.13</td>
<td>14229.29</td>
<td>7054.46</td>
</tr>
<tr>
<td>H. Species risk indicator (lbs. &amp; $)</td>
<td>lbs.: 3.22</td>
<td>lbs.:3.16</td>
<td>lbs.: 3.20</td>
<td>Lbs.: 3.02</td>
<td>Lbs.: 3.66</td>
</tr>
<tr>
<td></td>
<td>$: 3.08</td>
<td>$: 2.89</td>
<td>$: 2.82</td>
<td>$: 2.57</td>
<td>$: 3.14</td>
</tr>
</tbody>
</table>

In addition to use as a community evaluation tool, the assessment framework could be utilized on a regional basis to compare communities. As Jacobs et al. (2007) remark, indicator-based studies allow for “a reliable process of measurement and comparability” (p. 1313) between communities. The processes that create or destroy community capacity in one community could be examined for application in another community. However, the indicators developed and selected for this research are not without deficiencies, both minor and major.

Specifically, As Yohe and Tol (2002) state, “For most systems, though, change and variability over short periods of time fall within a “coping range” – a range of circumstances within which, by virtue of the underlying resilience of the system, significant consequences are not observed” (p. 26).

For the physical asset indicator, the variables used can provide a rough indication of whether a community’s fleet is diverse or specialized, aging or young, or somewhere
in the middle. The composition of the fleet of boats may signal if and how resources are invested within the fishing industry. However, it is difficult to compare the composition of fleets across communities. For one, each fleet develops around specific fisheries in different geographies. For open water fishing, one tendency is to develop larger, more powerful boats. Conversely, in sheltered waters, or for fisheries prosecuted exclusively during the calmer summer months, smaller boats will suffice. These indicators are not entirely sufficient tools to describe the level of this type of capital in each community.

There are several shortfalls inherent in the natural capital indicators. First, it is abundantly clear that environmental forcing is not the only factor driving these large marine ecosystems (Stram & Evans, 2009). Fishing has a large effect on the resources, its habitat, and environment. The effect of management, the reduction of apex predators, the role of market forces, or even fuel costs all have an effect on the distribution and abundance of fish stocks and fisheries effort (Knapp, Livingston, & Tyler, 1998).

These factors and others make it extremely difficult to interpret the results of the natural capital risk indicator. I base my interpretation on the assertion that life history attributes of different species indicate the potential for different adaptations and reactions to climate variability and change. Each species will be uniquely impacted by climate in the long and short run. It seems that the fast-growing species – i.e. pollock, herring – are likely to experience shifts in abundance in a shorter time frame. That is to say, the inter-annual variability of abundance of these species is high.

On the whole, one of the largest drawbacks in the realm of indicator-based studies is that there is not sufficient sensitivity to the dynamism, texture, and multifaceted nature of communities. For example, consequences arising from the combination of income
from natural capital and the other forms of capital are not taken into account in this framework. A positive increase in the abundance of the fisheries may induce further, unsustainable, capital investments into the community’s fleet, infrastructure, or other forms of economic capital. Furthermore, the labor force may become dependent on the fishing industry, while other areas of the community economy may under-develop or even atrophy. Hence, these community indicators are likely not useful in identifying the processes that lead to vulnerability (Eriksen & Kelly, 2007), just merely the condition of the community.

One possible resolution to this lack of sensitivity would be following or supplementing this assessment with a more in-depth approach. Should the assessment point to a community of high vulnerability, ethnographic methods could play a larger role in defining the nature of the vulnerability facing the community. As Jacobs et al. (2010) write:

“Though social indicators analysis can greatly enhance and streamline community profiling and social impact assessment in fisheries management, ethnography remains an important component in assuring the external validity of the social indicators. In addition, in-depth ethnography should be conducted when specific communities will be extraordinarily impacted by changes in fisheries regulations because the social indicators based on secondary data may be too insensitive to analyze rapidly changing or soon to be changing situations.” (p. 1313)

The proxies developed in this assessment are precisely that: too insensitive to capture a rapidly changing situation. However, this framework is adequate for the task at-hand: act
as a preliminary assessment of vulnerability of a community, and do it in a fast, cost-effective, and transparent manner.

6. Conclusion

The effects of climate change are innumerable, and will have wide ranging consequences on the human and natural environments. This is especially true with regards to communities dependent on natural resource extraction, such as fishing communities. Part of the vulnerability of fishing communities to climate change results from the changing availability of the natural capital, and part of it results from the human community’s capacity to absorb change and adapt to different circumstances.

The preliminary assessment presented in this research is an attempt to evaluate the vulnerability of fishing communities in Alaska. It uses an indicator-based framework developed on the notion of social, economic, and natural capital to assess Cordova, Kodiak, Petersburg, Seward, and Sitka. Based on the abundance of these various capitals in these communities, it found that Cordova, Petersburg and Sitka are moderately vulnerable, while Seward was highly vulnerable, and Kodiak has a low vulnerability. These are preliminary assessments, based on secondary quantitative data from varying sources, methodologies, and of differing levels of quality. Still, the methodology developed in this research, in a refined form, could be used as a fast and cost-effective preliminary assessment of fishing communities.

Alaska and the North Pacific are rich in natural resources and the projected disproportionate impact of climate change on the polar and subpolar regions justify an increased attention on this area. This is an area of high human interaction and incorporation within the natural landscape, and as such, “it is increasingly important to
learn more about human and natural system sensitivities to changes in climatic conditions and thresholds for continued viability, including possible costs of and limits to adaptation” (Rosenzweig & Wilbanks, 2010, p. 104). This research is only a small contribution to the vulnerability assessment project currently underway worldwide. The worldwide project is focused on the people and natural systems of lesser-developed countries, as they are likely at a more vulnerable disposition from a lack of access to resources (Adger, 1999). But further research can and should be done in Alaska “that consider the ecological, economic, and sociopolitical ramifications of climate change effects,” (Alaska Department of Fish and Game, 2010, p. 15), not only for improved knowledge of the effects, but because lessons in coping, adaptation, and capacity building may be transferable to other places around the world.
References


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Appendix A. Productivity attribute scores and overall scores by species
### Appendix B. Real attribute values by species

<table>
<thead>
<tr>
<th>Productivity Attributes</th>
<th>Walleye Pollock</th>
<th>Source</th>
<th>Pacific Cod</th>
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<tbody>
<tr>
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<td>31</td>
<td>Age and Growth Program, 2006</td>
<td>14</td>
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<td>Maximum Size (cm)</td>
<td>105</td>
<td>Dorn et al., 2009</td>
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<td>Age and Growth Program, 2006</td>
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<td>0</td>
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<td>Sockeye Salmon</td>
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<td>6</td>
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<td>76</td>
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<td>26</td>
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<td>Salo, 2003</td>
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<td>9</td>
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<td>Pacific Halibut</td>
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<td>King &amp; McFarlane, 2003</td>
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<td>Maximum Age (years)</td>
<td>94</td>
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