



Applying National Community Social Vulnerability Indicators to Fishing Communities in the Pacific Island Region

Danika Kleiber
Dawn Kotowicz
Justin Hospital



U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Pacific Islands Fisheries Science Center

NOAA Technical Memorandum NMFS-PIFSC-65
<https://doi.org/10.7289/V5/TM-PIFSC-65>

January 2018

Applying National Community Social Vulnerability Indicators to Fishing Communities in the Pacific Island Region

Danika Kleiber¹
Dawn Kotowicz²
Justin Hospital³

¹Joint Institute for Marine and Atmospheric Research
University of Hawaii
1000 Pope Road
Honolulu, Hawaii 96822

²Coastal Institute
University of Rhode Island
Kingston, Rhode Island, 02881

³Pacific Islands Fisheries Science Center
National Marine Fisheries Service
1845 Wasp Boulevard
Honolulu, Hawaii 96818

NOAA Technical Memorandum NMFS-PIFSC-65

January 2018



U.S. Department of Commerce
Wilbur L. Ross, Jr., Secretary

National Oceanic and Atmospheric Administration
Benjamin Friedman, Acting NOAA Administrator

National Marine Fisheries Service
Chris Oliver, Assistant Administrator for Fisheries

Recommended citation:

Kleiber, D., D. Kotowicz, and J. Hospital. 2018. Applying national community social vulnerability indicators to fishing communities in the Pacific Island Region. NOAA Tech. Memo. NMFS-PIFSC-65, 63 p.

Copies of this report are available from:

Science Operations Division
Pacific Islands Fisheries Science Center
National Marine Fisheries Service
National Oceanic and Atmospheric Administration
1845 Wasp Boulevard, Building #176
Honolulu, Hawaii 96818

Or online at:

<https://www.pifsc.noaa.gov/library/>

Cover: Photo courtesy of (Clockwise from top left) Grace-McCaskey, Levine, Pan, and Grace-McCaskey

Table of Contents

Table of Contents	iii
List of Tables	iv
List of Figures	v
I. INTRODUCTION	1
Defining Fishing Communities.....	1
Developing Social Indicators.....	2
Social Indicators in Fishing Communities.....	3
Social Vulnerability	4
Gentrification Pressure	4
Fisheries Engagement and Reliance	5
Natural Hazard Risk.....	5
II. METHODS.....	5
Assessing Community Scales	5
Secondary Data Gathering	6
Statistical Analysis.....	7
Metadata and Data Access	9
III. RESULTS	9
Scale of Community	9
Community Outliers	10
Indices	11
Social Vulnerability	14
Commercial Fishing Vulnerability	28
Natural Hazard Vulnerability.....	31
IV. DISCUSSION.....	33
Constraints of the Data	33
Integrating the Data into Socio-ecological Assessments	35
Next Steps.....	37
V. CONCLUSION.....	37
VI. REFERENCES	38
VII. APPENDICES.....	43
Appendix A. Variables.....	43
Appendix B. Secondary Data Collection	48
Appendix C. Index Scores	52

List of Tables

Table 1. Indicators and indices 4

Table 2. Community Scale comparison for island communities in the western Pacific..... 10

Table 3. Vulnerability Indices results 13

Table 4. Housing Characteristics community examples..... 14

Table 5. Labor Force community examples 17

Table 6. Personal Disruption community examples 20

Table 7. Population Composition community examples 22

Table 8. Poverty community examples..... 24

Table 9. Occupational Diversity community examples 26

Table 10. Fishing engagement community examples..... 28

Table 11. Fishing reliance community examples 29

List of Figures

Figure 1. Vulnerability level based on Housing Characteristics	15
Figure 2. Vulnerability level based on Labor Force	18
Figure 3. Subsistence activity	19
Figure 4. Vulnerability level based on Personal Disruption	21
Figure 5. Vulnerability level based on Population Composition.....	24
Figure 6. Vulnerability level based on Poverty	25
Figure 7. Shannon Index of Occupational Diversity	27
Figure 8. Fishing Engagement and Reliance indices	25
Figure 9. Natural Hazards	32
Figure 10. Localized Poverty index scores	36

I. INTRODUCTION

The Magnuson-Stevens Fishery Conservation and Management Act (16 U.S.C. § 1801 - 1891 (d)) requires regional fisheries management councils and the National Marine Fisheries Service (NMFS), in the context of proposed management measures, to consider potential effects of proposed management measures upon fishermen and fishing communities and:

“[T]ake into account the importance of fishery resources to fishing communities by utilizing economic and social data...to provide for the sustained participation of such communities, and...to the extent practicable, minimize adverse economic impacts on such communities” (16 U.S.C. § 1851(a)(8)).

Fishery management plans must also consider fairness and equity in conservation and management measures such that “no particular individual, corporation, or other entity acquires an excessive share of [fishing] privileges” or impacts (16 U.S.C. § 1851(a) (4)).

Social impact assessment is one tool used to compare management measures and inform decisions about fisheries management; however, this type of assessment addresses only the issue being examined and commonly misses “a nuanced representation of fishery systems’ dynamics, including how impacts arise from multiple stresses and pressures” (Tuler et al., 2008). Social indicators derived from secondary data can complement social impact analysis and provide a broader measurement of a community that may be affected by changing conditions in social and ecological systems connected to those communities.

Defining Fishing Communities

The Magnuson-Stevens Fishery Conservation and Management Act (MSA) defines a “fishing community” 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” (16 U.S.C. § 1802 (17)).

Using this definition to identify fishing communities can highlight the “awkward incongruities between the anthropological emphasis on situational meaning and legal demands for exactness” (Clay and Olson, 2007). In anthropological contexts community can include shared geographies, shared culture, experiences, and histories. When applying the MSA definition to the Pacific Islands Region, The Western Pacific Regional Fishery Management Council (WPRFMC) observed that:

“[A] large proportion of the people living in the Western Pacific region observe and interact daily with the ocean for food, income and recreation...fishing also continues to contribute to the cultural integrity and social cohesion of island communities...These individuals are not set apart...from island populations as a whole” (Western Pacific Regional Fishery Management Council, 1998).

The emphasis on the ubiquitous and shared economic, subsistence, and cultural ties to fisheries led to broadly defined fishing communities. Guam, the Northern Mariana Islands, and American Samoa were each recognized as a fishing community without further delineation within those territories. It was also initially proposed that the State of Hawai‘i be defined as a single fishing community, but this was later revised to seven fishing communities representing the main inhabited islands including Kauai, Ni‘ihau, O‘ahu, Maui, Molokai, Lanai and the island of Hawai‘i (Western Pacific Regional Fishery Management Council, 2002).

While the WPRFMC definitions of fishing communities were purposefully broad, this analysis uses geographic distinctions at the Census County Division (CCD) level. Analysis of communities at the CCD level was chosen to provide geographical boundaries that capture census-designated geography. This differs from fishing community Social Vulnerability Index development done in other U.S. regions that used a Census Designated Place scale (Jepson and Colburn, 2013). This will be discussed further in the results.

Developing Social Indicators

The impetus for this research comes from a need to evaluate social impacts of proposed fisheries management measures on fishing communities and to assess potential differential impacts of proposed measures on communities. This analysis could supplement social impact analyses, providing a broader view of community dynamics when assessing the impacts of changes in a fishery or fishing community. There is also a need to predict or evaluate impacts of environmental, economic or social disruptions such as from a natural hazard, on fishing communities. The framework presented here could lay a foundation to predict vulnerabilities.

Indicators are quantitative or qualitative factors or variables that provide simple, valid and reliable means to track changes over time. Similar to ecological indicators that may be used to measure the structure, function, and composition of an ecological system, social indicators can track aspects of a social system, to identify changes over time, response to disruptions, and inform policy decisions.

This work draws on social indicators research investigating the different social aspects of human communities in different geographies and its application to social policy related to vulnerability (Smith, 1981). Social vulnerability measures the relative ability of people, communities or institutions to endure stress. This stress could be social such as political unrest, or natural such as disasters. Hence social vulnerability indices are used to compare the relative vulnerability of different groups. These groups could be at the individual, household, community, country or regional scale depending on the scale of data aggregation.

Smith (1981) notes the difficulty of developing valid and reliable indices to measure aspects of society identified as needing monitoring. Social indices, such as the United Nations Development Program’s Human Development Index have been developed internationally to examine human health and access to knowledge and resources, and include variables such life expectancy, and the number of years children go to school (United Nations, 1990). Other international examples include the World Bank’s World Development Indicators which are based on global development and poverty data (World Bank, 2017). International indicators are

often measured at the country level to allow intergovernmental agencies to make country comparisons, and direct policy and resources where they are most needed.

Social aspects of vulnerability have also been developed for disaster studies where researchers acknowledge that social factors are often as important as physical and biological characteristics of a place (Cutter, Mitchell, and Scott, 2000; Jacob et al., 2010; Fatemi et al., 2017). For example Cutter et al. (2003) developed social indicators at a county level from a number of social indicators including variables related to population composition, infrastructure, and occupation. These factors allowed for county level comparative analysis of social vulnerability to natural hazards throughout the United States. Similarly in a review of social indicators for natural disaster vulnerability, Fatemi et al. (2017) found that variables relating to gender, public health, infrastructure and migration patterns were the most commonly used.

Boyd and Charles (2006) detailed the need for community-level social indicators to monitor fishing community sustainability but recognized the difficulty of finding reliable and available data needed to develop relevant and appropriate indicators. Although there has been excellent work to help identify and collect indicator variables in coastal communities (see Wongbusarakum and Pomeroy, 2000), Boyd and Charles (2006) noted that when indicators were identified, ecological measures were more readily available than those social measures, making them more likely to be considered in management decisions. Jacob and Jepson (2009) proposed a community-level index of fish stock sustainability using local landings data and acknowledge that this index would need to be supplemented by other indicators or with local community knowledge to inform policy and management decisions (Jacob and Jepson, 2009). Jacob et al. (2013, 2010) then created more robust social indicators for fishing communities using secondary census and fisheries data and verified their results with on-site observations.

National Marine Fisheries Service Southeastern Regional Office (SERO) and Northeast Fisheries Science Center (NEFSC) have expanded on this work, having developed their own set of social indicators for fishing communities in their regions respectively, and then collectively, to be used as part of the process to assess social impacts upon fishing communities (Jepson and Colburn, 2013). This has also be more recently updated and made publically available through the NOAA website (NOAA, 2017).

Social Indicators in Fishing Communities

In this study we closely follow the indicator framework developed by Jepson and Colburn (2013), and the more recent updates available on the project website (NOAA, 2017). They identified broad indicator categories to examine fishing communities: 1) Social Vulnerability, 2) Gentrification Pressure, and 3) Fishing Engagement and Reliance (Table 1). These indicators have been developed in the U.S. Gulf region (Gulf & South Atlantic Fisheries Foundation, Inc., 2010; Jacob et al., 2013, 2010), and expanded to include the Northeast region (Colburn and Jepson, 2012; Jepson and Colburn, 2013). To these indicators we will also include: 4) Natural Hazards Risk index. These four aspects of vulnerability can be explored using regularly collected secondary quantitative data (Table 1).

Table 1. Indicators and indices.

Indicator	Index	Coverage
1. Social Vulnerability	Housing	Regional
	Labor Force	Regional
	Personal Disruption	Regional
	Population Composition	Regional
	Poverty	Regional
	Occupational Diversity	Regional
2. Gentrification Pressure	Housing Disruption	Regional
	Retiree Migration	Regional
	Urban Sprawl	Regional
3. Fishing Engagement and Reliance	Commercial Fishing Engagement	Hawai'i
	Commercial Fishing Reliance	Hawai'i
4. Natural Hazards Risk	Natural Hazards	Hawai'i

Social Vulnerability

Work on social vulnerability is based on the premise that there are different capacities to deal with disasters, or adapt to incremental yet relentless change, and that these differences can be influenced by social variables. As Morrow points out: “The effect on any particular household...results from a complex set of interacting conditions, some having to do with geography and location, some with the dwelling, and still others with the social and economic characteristics of the people living there” (1999, p. 2). The most recent work by Jepson and Colburn identified 5 indices that describe different aspects of social vulnerability. These include: 1) Labor Force, 2) Housing Characteristics, 3) Poverty, 4) Population Composition, and 5) Personal disruption (NOAA, 2017). To this we also added the Occupational Diversity Index (Table 1). Variables related to education, age, household composition, race and ethnicity, income, public assistance, housing, and employment all contribute to the development of these indices.

Gentrification Pressure

Gentrification is an external factor that can increase the vulnerability of fisheries communities and threaten the viability of commercial working waterfronts (Colburn and Jepson, 2012). Gentrification can include changing demographics of a coastal population and in particular shifts from a working population to a retired population. Gentrification can also include measures of urbanization. The latest indices identified by Jepson and Colburn include: 1) Housing Disruption, 2) Retiree Migration, and 3) Urban Sprawl (NOAA, 2017). Variables used to develop these indices include metrics of age, employment, income assistance, population density, housing availability, and marine access availability.

Fisheries Engagement and Reliance

Measures of fisheries – total and per capita of commercial and recreational fisheries – can be used to indicate engagement in and reliance on fisheries at a community level (Jepson and Colburn, 2013). Variables could include a count of fishing licenses, fishing pressure, amount of landings, value of landings, and number of dealers. Vulnerability in fisheries has been researched extensively, identifying aspects of individual fishermen and fishing communities associated with increased sensitivity to changes and disruptions in their social and economic conditions as a result of environmental and management changes in fisheries and fish stocks on which they rely (Colburn and Jepson, 2012; Jacob et al., 2013, 2010). Again, diversity has been found to decrease vulnerability from the individual fisherman who is skilled at targeting several types of fish, to a fishing community that relies on many different species of fish harvested from various parts of the marine environment using several gear types (Pollnac et al., 2006; Jacob et al., 2013). Communities with alternative livelihood options may also be more resilient to changes to availability or access to fisheries resources (Boyd and Charles, 2006). Diversity of economic engagement in this case is measured by a Shannon Index (Jepson and Colburn, 2013; NOAA, 2017).

Natural Hazard Risk

Risks from natural hazards are particularly concerning for island communities that must be self-sufficient in the event that a hazard cuts off access for incoming supplies, food or other goods (Mileti, 1999). A given natural hazard affects the population, economy, infrastructure and fisheries in the community where it strikes, so natural hazards vulnerability is heavily intertwined with other types of social vulnerability. Hazards affecting coastal natural and built environments and infrastructure are important to consider for island communities since there is not as much space inland for relocating communities and their associated built environment (Cutter, Boruff, and Shirley, 2003). Natural hazards are also an important concern for fishing communities due to their proximity to the ocean, necessary access to the coast and ocean, and the tendency to locate fisheries-dependent infrastructure (such as ports and processing facilities) close to the ocean for ease of access (Bigford, 1991). Measures of Hazard Risk could include storms, earthquakes, tsunamis, and volcanic activities.

II. METHODS

Assessing Community Scales

For this analysis we chose to use the Census County Division (CCD) scale, however vulnerability indices developed for the Northeast and Southeast regions used Census Designated Place (CDP) scale (Jepson and Colburn, 2013). Census data is also available at the even finer scale of Census Block Group (CBG). To further complicate the choices the WPRFMC defines community at the island or island grouping scale. It is important to consider issues of evenness of representation, ability to perform statistical analyses, scale at which it is meaningful to integrate with ecological vulnerability models, and the scale at which management measures occur. In the results we outline the strengths and limitations of four different scales of community designation.

Secondary Data Gathering

Variables used to examine social vulnerability in fishing communities in Hawai‘i, Guam, Commonwealth of the Northern Mariana Islands (CNMI), and American Samoa are based on those used for Jepson and Colburn’s (2013) and Jacob et al. (2010) analyses, with a few exceptions where comparable data are not available. Additional variables describing risk of natural hazards and more detailed commercial fisheries data were added to the analysis for Hawai‘i fishing communities, but were not available for the territories (Table 1). The census recognizes 44 CCDs in Hawai‘i, 19 in Guam, 8 in CNMI, and 16 in American Samoa. However, because this study focuses only on inhabited communities, a small number of CCDs were removed before the analysis. These include Pu‘unene in Hawai‘i, the Northern Islands in CNMI, and Rose Island in American Samoa. Ni‘ihau is inhabited but lacks social data so it was also removed.

The database used for this analysis includes demographic and fisheries data. All variables are secondary data derived from both government and non-governmental sources. The majority of the demographic data were sourced from the U.S. Census Bureau’s American Community Survey (ACS) using 5-year summary files (ACS 2006-2010) at the CCD level in Hawai‘i, and decadal 2010 data for the territories. Data were obtained using the online American Factfinder tool (U.S. Census Bureau 2017a). These data included variables related to population structure, housing, resident transiency, education, employment, and household income (Appendix A. Variables).

A natural hazard risk score was first attempted using a principle components analysis and weather variables found in Jepson and Colburn (2013). However, these variables – particularly hail, tornados, and wind – were not relevant in Hawai‘i. Therefore the Natural Hazards Risk Index was derived from the overall hazards risks from the *Atlas of Natural Hazards in the Hawaiian Coastal Zone*’s technical hazards maps (Fletcher et al., 2002). The Index is a measure of “overall hazards” which includes tsunami, stream flooding, high waves, storms, erosion, sea level rise, and volcanic/seismic hazard estimates (Fletcher et al., 2002). The Natural Hazards maps of the *Atlas of Natural Hazards in the Hawaiian Coastal Zones* are color coded for each risk variable along the coastline on a 4-level scale from low to high risk. To attain our CCD variable values for overall hazards we joined the CCD (State of Hawaii, 2017) and Natural Hazard shapefiles (“Atlas of Natural Hazards in the Hawaiian Coastal Zone | USGS I Map 2761”, 2017) exporting the database files of joined layers each segment of coastline was checked to see that it was correctly assigned to a CCD (coastline segments did not necessarily align with CCD boundaries and some are much longer than others). Any segments of coastline that fell in two CCD boundaries were treated as a separate segment in each CCD. The average hazard score for all segments of coastline in a CCD was calculated to obtain the final CCD hazard score. The natural hazard variables were limited to Hawai‘i.

Fisheries variables used in this analysis were gathered from three data sources: (1) State of Hawai‘i Division of Aquatic Resources (HDAR) Fisherman’s Reporting System (FRS); (2) HDAR marine dealer data; and (3) Hawai‘i longline federal logbook data. These data includes all commercial fisheries including charter fishers. These data are only available for Hawai‘i (Table 1). The FRS represents monthly catch reports from commercially-licensed fishermen and is the source of all commercial landing data for the State of Hawai‘i except for longline catch data.

Fishermen are required to report all commercial fishing activity on FRS forms provided by HDAR including information about species, gear, location of catch, and landing port. Dealer data consists of daily sales of fish purchased by fish dealers¹ from the Hawai‘i-based commercial fishing fleets and includes information about the sale such as species, number of pieces, pounds sold, price per pound (estimated); and information about the boat such as the vessel name and captain name (Lowe et al., 2016, p. 159). Longline data in Hawai‘i is collected through the mandatory federal longline logbook program supported by NMFS. The logbooks are daily set-and-haul logs submitted at the end of each trip consisting of catch data by number of fish kept and released. These data also include the species, condition at time of haul, and location of catch².

For this analysis, communities are defined as CCDs, a geographical designation used by the U.S. Census Bureau for statistical purposes. Variables used in this analysis were either directly sourced at the CCD level or when not available at this level in Hawai‘i indirectly sourced at the zip code level and then aggregated to their corresponding CCD. Inherent in aggregating zip codes to CCD we find that there are instances of zip codes stretching across multiple CCDs. To avoid double counting the values were recalculated using allocation assumptions based on visual examination of overlap on Google map, as well as CDP population distributions within CCDs. See Appendix 2 for a listing of Hawai‘i zip codes and their corresponding CCDs (Appendix B. Secondary Data Collection).

Statistical Analysis

We used variables and methods in Jepson and Colburn (2013) in an attempt to apply their index structure to the Pacific Island Region. In total, 105 variables were gathered, describing socioeconomic and fisheries aspects of the 83 populated CCDs of Hawai‘i, Guam, Commonwealth of the Northern Mariana Islands, and American Samoa (Appendix A. Variables). Social vulnerability variables were divided into five index categories: 1) Labor Force, 2) Housing Characteristics, 3) Poverty, 4) Population Composition, and 5) Personal disruption (NOAA, 2017). The variables used in these categories were available throughout the region. Variables were also grouped into three Gentrification Pressure index categories: 1) Housing Disruption, 2) Retiree Migration, and 3) Urban Sprawl.

For the Social Vulnerability, Gentrification Pressure and Fishing indicators we used a factor analysis to create indices with single factor solutions. Principle component analyses were used to reduce these variables into single factor solutions using the “prcomp” function in the R stats package (R Core Team, 2017). For the principal component and factor analyses, several tests were used to determine if the sample was suitable for the analysis: (1) Kaiser-Meyer-Olkin (KMO) measure; (2) Bartlett’s test of sphericity; (3) Armor’s reliability theta; and (4) the determinant. The KMO measures the size of the sample to determine if it is large enough and if there is sufficient variation in the data; values greater than 0.5 indicate an adequate sample

¹ Fish dealers in Hawaii are not licensed at the state or federal level. They are required to report to the state, but it is effectively voluntary.

² Longline logbooks have latitude and longitude by set, and these are typically aggregated to 5 or 10 mi² grids for reporting purposes.

(Kaiser, 1974). Bartlett’s test is used to evaluate the data for homoscedasticity or homogeneity of variances (Bartlett, 1937). In this test the null hypothesis is that the variables are orthogonal. If the test statistic is ≤ 0.05 significance level then the correlation matrix can be said to be significantly different than the identity matrix and there is enough variation to analyze for underlying factors or components. Armor’s reliability theta is a measure that evaluates the internal consistency of the items in the first factor scale derived from a principal component analysis (Armor, 1973). It is a coefficient of the correlation of the resulting scale with the hypothetical scale that measures the actual scale, therefore, the closer theta is to 1, the higher the internal consistency of the factor. Finally, the determinant is assessed to ensure that the matrix for analysis is not an identity matrix and does not demonstrate multicollinearity. The matrix is suitable for analysis as long as the determinant is greater than zero.

To begin developing indices multicollinearity among variables within each index was examined and variables with very low multicollinearity were removed. If variables were perfectly correlated redundancies were removed. We then performed a varimax rotation and following Kaiser’s rule included the number of principle components with an eigenvalue > 1 . We followed the methods of Jepson and Colburn (2013) to examine which variables loaded highest onto the factor, and thereby have a list of likely substitute variables if we were not able to reach a single factor solution. Variables were chosen to represent a diversity of measures that a clear relationship to vulnerability. Whenever possible we selected variables used by Jepson and Colburn (2013).

A Shannon Index to measure Occupational Diversity was calculated following the methods developed by Jepson and Colburn (2013). In each community the percent of people in each of five possible occupation categories (Appendix A. Variables) were inputted into a Shannon Index calculation (Equation 1). The assumption of this index is that as the proportional abundance becomes more equal, the overall diversity of occupations increases (Jepson and Colburn, 2013). Because this is calculated differently from the other indices the scores range will also differ.

Equation 1. Calculation for the Shannon Index of Occupational Diversity³

$$H = \sum_{i=1}^S - (P_i * \ln P_i)$$

H = the Shannon occupational diversity index

P_i = fraction of the entire population made up of occupation i

S = number of occupation categories encountered

Σ = sum from occupation 1 to occupation S

Natural Hazard Risk was initially calculated using a principle components analysis. However a single factor solution could not be reached because only one risk variable (hurricanes) occurred in all communities. Hail and wind were not found in any communities (a score of zero for each

³ Jepson and Colburn, 2013, p 71.

community), and tornados risk scores above zero were only found in five communities. Instead we used the natural hazard risks outlined in the “Atlas of Natural Hazards in the Hawaiian Coastal Zone” (Fletcher et al., 2002). We used the “Overall Risk” measure that is based on the combined risk factors of seven variables (Appendix A. Variables). Both the Shannon Index and Natural Hazard Risk Index were transformed by centering on the mean.

For the purposes of data visualization the vulnerability index scores were categorized as “High” (more than one standard deviation above the mean), “Med high” (between 0.5 and 0.99 standard deviation above the mean), “Med” (between 0 and 0.49 standard deviation above the mean), or “Low” (below the mean). The indices were plotted using ggplot2 package in R (Wickham, 2009).

Metadata and Data Access

Full metadata of this project is available through the NMFS InPort enterprise management system (PIFSC, 2018). The metadata record will provide variable definitions for all data utilized in this analysis and links to access the source data.

III. RESULTS

Scale of Community

Island

This definition of fishing community follows the mandate from the WPRFMC definition which contends that:

“A large portion of the people living in the Western Pacific region observe and interact daily with the ocean for food, income and recreation...fishing also continues to contribute to the cultural integrity and social cohesion of island communities...These individuals are not set apart...from island populations as a whole.” (Western Pacific Regional Fishery Management Council, 1998).

This means that all communities in the islands should be considered fishing communities. Under this definition there are 10 communities under U.S. jurisdiction in the western Pacific: American Samoa, Guam, Commonwealth of the Northern Marinas Islands, and 7 islands of Hawai‘i (Table 2). While this scale acknowledges that all people on the islands are connected to fishing, it may not capture important differences among communities within islands and island groups. The population size of the communities also varies quite a bit, which would lead to uneven representation, while at the same time the number of communities is quite small making statistical analysis difficult. An added difficulty is that census data does not come at this scale and would have to be aggregated.

Census County Division (CCD)

A CCD scale allows for a finer scale analysis for comparisons of communities within islands. The population mean and median of each CCD is smaller than the island level (Table 2). The

scale allows for statistical analysis on most indices and meaningful integration into biological vulnerability models (Oliver, pers. comm. 2017).

Census Designated Place (CDP)

A CDP scale is even finer (Table 2), but geographically it only covers inhabited land areas. There were concerns that it may miss portions of the population, but that appears not to be the case as the total population calculation is very similar to CCD (Table 2). In American Samoa the CDP scale is designated at the village level. While the increase in samples could help with index development, the finer scale may not allow for meaningful integration into biological vulnerability models.

Census Block Group (CBG)

A CBG scale is even finer than the CDP scale and is being considered as a community scale for future vulnerability index development. This scale provides greater flexibility of use because new data can be aggregated to a CCD or CDP level.

Table 2. Community scale comparison for island communities in the western Pacific.

Scale	Number of Communities	Population size		
		Mean	Median	Total
Island*	10	154,892	59,276	1,548,923
Census County Division (CCD)	83	17,805	5,371	1,549,001
Census Designated Place (CDP)	420	3,733	886	1,567,715
Census Block Group**	1,190	1,398	1,235	1,629,061

*Islands include: Kauai, Ni‘ihau, O‘ahu, Molokai, Lanai, Hawai‘i, Guam, CNMI and American Samoa.

**Removed Block Group 0s from the analysis (water cover).

Community Outliers

In the analysis a small number of communities were often listed as having very high or very low vulnerability. In most cases this may be caused by very small population sizes which overinflate proportional data. Of the four communities identified as outliers, only Ni‘ihau was excluded because the ACS did not provide demographic data for this community.

Ni‘ihau, Hawai‘i (population 170)

A small population of 170 was estimated in 2010, but the data from the American FactFinder (2005–2009) give a population size of zero and contain no other demographic information. Hence Ni‘ihau was excluded from this analysis.

Kalawao, Hawai‘i (population 74)

Located on the island of Molokai, this small community was once a forced quarantine area for people with Hansen's disease, and is now encompassed by Kalaupapa National Park. The population consists of residents who have decided to remain in the community. There are no children in this community (median age = 62.5 in 2010).

Sprecklesville, Hawai'i (population 280)

The Maui Country Club is found here and the community is home to many vacation rentals.

Swains Island, American Samoa (population 17)

The community consists of 17 people of Tokelauan descent that harvest coconuts for copra.

Indices

We were able to replicate a single-factor solution for 5 Social Vulnerability indices and 2 Fisheries indices (Table 3 and Appendix A. Variables). A single-factor solution could not be reached for the 3 Gentrification Vulnerability indices. A limited number of variables could be substituted, often because variables that were available for Hawai'i (such as the Cost of Living Index) were not available in the territories. There were also some inconsistencies over time for some variables measured in Hawai'i and the territories. Finally certain variables had inconsistencies suggesting problems with data collection. In the future, developing these indices will require finding other reliable and widely available variables.

For most of the indices developed for this region, a single factor solution required at least some alternative variables from Jepson and Colburn (2013). While the Commercial Fishing Engagement index used all the same variables (Table 3, compared to Table 3 in Jepson and Colburn 2013, 19), several other indices shared one to three variables in the index score calculation.

Community index scores are visualized (Figs. 1 and 2, and Figs. 4 – 10) by descending order of vulnerability within island groups in the Commonwealth (Northern Mariana Islands) and Territories (Guam and American Samoa). In Hawai'i the communities are grouped by county, but named by island. Vulnerability index scores were categorized as "High" (more than one standard deviation above the mean), "Med high" (between 0.5 and 0.99 standard deviation above the mean), "Med" (between 0 and 0.49 standard deviation above the mean), or "Low" (below the mean). The indices were plotted using ggplot2 package in R (Wickham, 2009). In each visualization the index score mean (centered at zero) is marked by a dotted line and one standard deviation above and below the mean is marked with grey shading.

For each index the variable value and index score for four communities are displayed in tables 4 to 9 to show the connection between the measures of vulnerability and the variables. One community from each island group was selected to represent the range of vulnerability (Olosega in American Samoa, Hagåtña in Guam, Rota in CNMI, and Lahaina in Hawai'i). The exception is the Occupation Diversity Index where North Hilo was selected as the community from Hawai'i because it was exceptional in its low levels of occupational diversity. For the fishing indices data was only available for the Hawaiian Islands, hence four communities from different

islands were selected as examples (Honolulu on O‘ahu, North Kona on the island of Hawai‘i, Kalawao on the island of Molokai, and Hana on the island of Maui).

Table 3. Vulnerability Indices Results

Index Category	Index	Variable	Factor Loadings	% Variance	KMO	Bartlett	Armor	Determinate
Social Vulnerability	Housing ^a	median rent ^c	0.61	0.66	0.65	< 2e-16	0.75	0.48
		median number of rooms ^c	0.52					
		% households lacking plumbing ^b	-0.60					
	Labor Force ^a	% females employed ^c	0.62	0.69	0.65	0.005	0.77	0.42
		% households with income < \$10,000 ^b	-0.53					
		% in arts, entertainment & recreation ^c	0.59					
	Personal Disruption	% no high school diploma ^b	0.59	0.63	0.67	< 2e-16	0.71	0.57
		% population in poverty ^b	0.59					
		% unemployed ^b	0.55					
	Population Composition	% female single headed households ^b	0.53	0.60	0.60	< 4e-14	0.67	0.61
		% Bachelor's degree ^c	-0.56					
		% population age under 5 ^b	0.64					
	Poverty ^a	% individuals in poverty under 18 ^b	-0.57	0.71	0.63	0.01	0.87	0.04
		% families with children < 5 in poverty ^b	-0.56					
		% female headed families in poverty ^b	-0.41					
		% population in poverty ^b	-0.44					
Commercial Fishing	Engagement	# commercial permits ^b	-0.47	0.83	0.58	< 2e-16	0.93	> 0.00
		# dealers ^b	-0.50					
		pounds of landings ^b	-0.52					
		value of landings (USD) ^b	-0.51					
	Reliance ^a	commercial permits per capita (1000) ^b	0.57	0.51	0.66	< 2e-16	0.68	0.49
		dealers per capita (1000) ^b	0.43					
		% in agriculture, forestry, fishing, & hunting ^b	0.46					
		pounds of landings per capita (1000) ^b	0.53					

^a Index scores reversed so that high factor scores equate to higher levels of vulnerability

^b Increase in variable equates with greater vulnerability

^c Increase in variable equates with lower vulnerability

Social Vulnerability

In the following section we detail the results of the social vulnerability indices. It should be noted that these indices were developed for fishing communities in the East coast of the United States. Differences in urbanization, history, and culture of fishing communities in the Pacific region may make some of these indices inappropriate for modeling vulnerability. We discuss the possible strengths and limitations of each index in turn in the following section, and then explore the issue more generally in the discussion. It should also be noted that while we present the vulnerability of communities by individual indices, vulnerability is a composite of many indices, so no one result should be taken as evidence of high or low vulnerability. Furthermore this assessment is a preliminary analysis and will require a ground truth exercise to verify the findings.

Housing Index

The Housing Characteristics Index indicates greater vulnerability in communities with lower rent, fewer rooms per housing unit, and less plumbing facilities (Table 4). The index was calculated and the communities were listed in order of vulnerability by island grouping (Figure 1). The index scores were reversed so that higher index scores are associated with higher vulnerability.

Lower rent, fewer rooms, and less plumbing are correlated with higher proportions of people in poverty, and households making less than \$10,000 per year, and hence associated with higher vulnerability (Table 4). For example the island community of Rota has a lower median rent and a higher percentage of houses without plumbing facilities. These housing characteristics would be associated with higher vulnerability when compared with the higher rent and plumbing facilities in Lahaina (Table 4).

It is important to note that the housing characteristics index may not be meaningful across all the island groups. While the connection between rent and vulnerability in Hawai'i would be fairly robust, the traditional land tenure system that is found throughout American Samoa would make the measure less meaningful. Under the land tenure system 98% of land in American Samoa is shared at a community level (Levine and Allen, 2009). In practical terms this means that people do not individually own their homes or pay rent, as can be seen Olosega where the median rent is zero (Table 4).

Table 4. Housing Characteristics Community Examples

Variable	Olosega	Rota	Hagåtña	Lahaina
median rent	0	297	752	1231
median number of rooms	4.5	3.7	3.7	3.1
% households lacking plumbing	31.1%	7.4%	7.8%	0.0%
Index score	2.07	1.27	0.66	0.12

Housing Characteristics

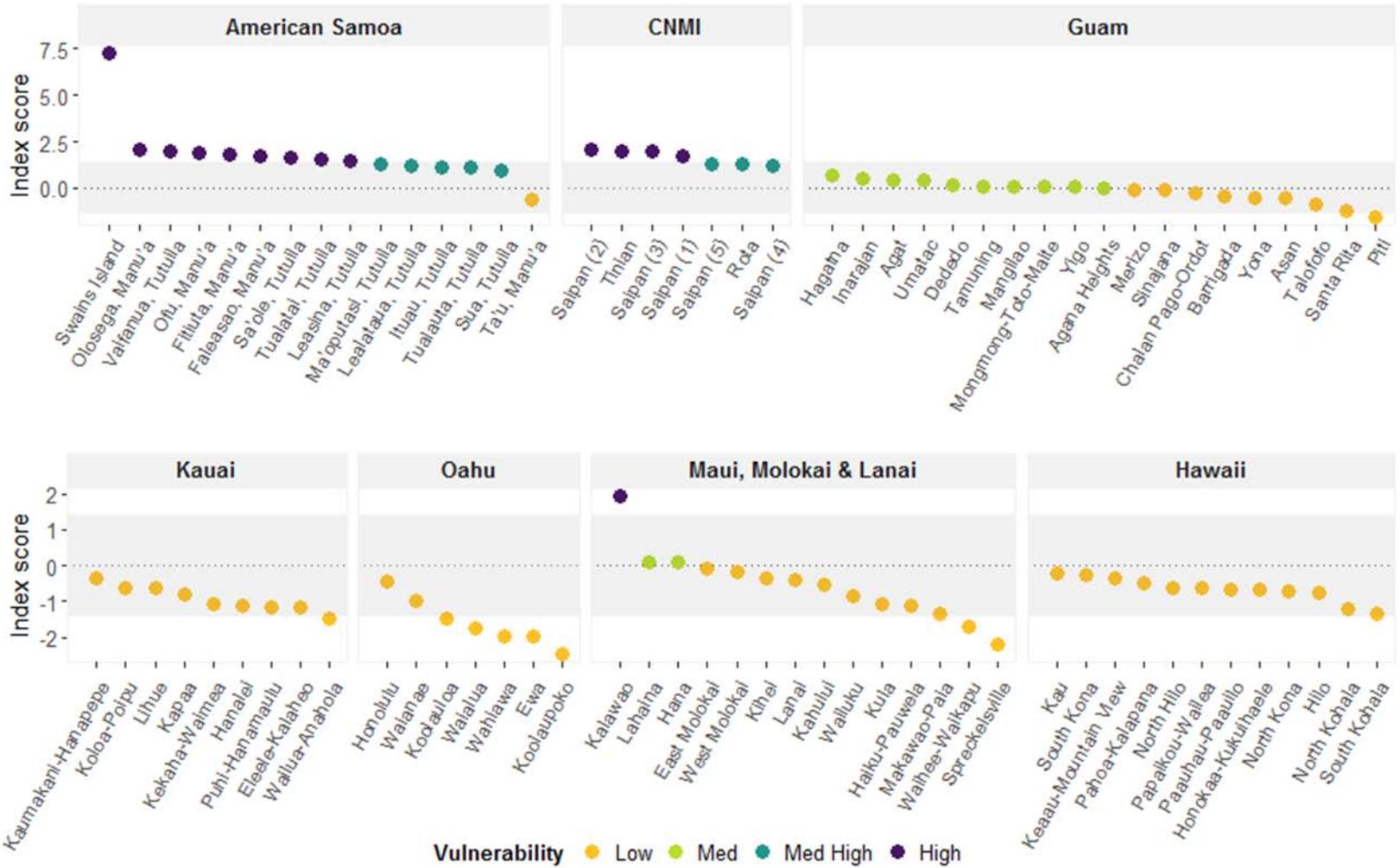


Figure 1. Vulnerability level based on housing characteristics.

Labor Force Index

The Labor Force Index indicates greater vulnerability in communities with fewer women employed, fewer people employed in the arts, entertainment, or recreation industry, and more households with yearly income under \$10,000 (Table 3). The index was calculated and the communities were listed in order of vulnerability by island grouping (Figure 2). The index scores were reversed so that higher index scores are associated with higher vulnerability.

Communities associated with low income, indicated by a higher percentage of households with income under \$10,000 per year, are likely to exhibit low levels of adaptive capacity in times of crisis or change (Cutter, Boruff, and Shirley, 2003). Conversely, higher levels of women's employment have been associated with lower levels of poverty, and greater income distribution (Kasearu, Maestriperi, and Ranci, 2017).

More affluent communities have lower vulnerability index scores while less affluent communities have higher index scores⁴ (Table 5). However measures such as yearly income under \$10,000, may not be universally applicable as a proxy of vulnerability across the region. While this may be a good indication of poverty within communities in Hawai'i, it may not be an indicator of poverty in American Samoa or the other territories. Many of the communities with low vulnerability, such as Lahaina, are centers of tourism, which could explain the higher rates of employment in the arts, entertainment, and recreation industry. These service industry jobs also correlate with women's employment. Because women's employment is also a variable in this index, gender equality as it relates to employment opportunities for women may also be at play when examining the differences between the high vulnerability scores of American Samoa, and the lower vulnerability scores of the other island groups. The high labor force index scores of American Samoa communities should be viewed in the context of a greater prevalence of subsistence livelihoods (Fig. 3)⁵. A greater proportion of people engaged in subsistence livelihoods may mean that people do not rely on jobs or the market economy for their well-being, or community stability and adaptive capacity. In these cases economic measures as a proxy for vulnerability are not as relevant. Census measures of subsistence activities are only available in the territories.

⁴ However this is not a universal finding. In a study of perceived vulnerability to climate change in American Samoa, in some cases below average income households were less likely to report high vulnerability than above average income households (Wongbusarakum, 2009).

⁵ People engaged in subsistence activities "mainly produced goods for his or her own or family's use and needs". This includes farming, fishing, and other activities (United States Census, 2014).

Table 5. Labor Force community examples.

Variable	Olosega	Hagåtña	Rota	Lahaina
% females employed	37	51	65	66
% households with income < \$10,000	28.9	11.9	18.9	2.6
% in arts, entertainment & recreation	0.0	18.1	17.8	35.8
Index score	3.20	0.07	-0.25	-2.58

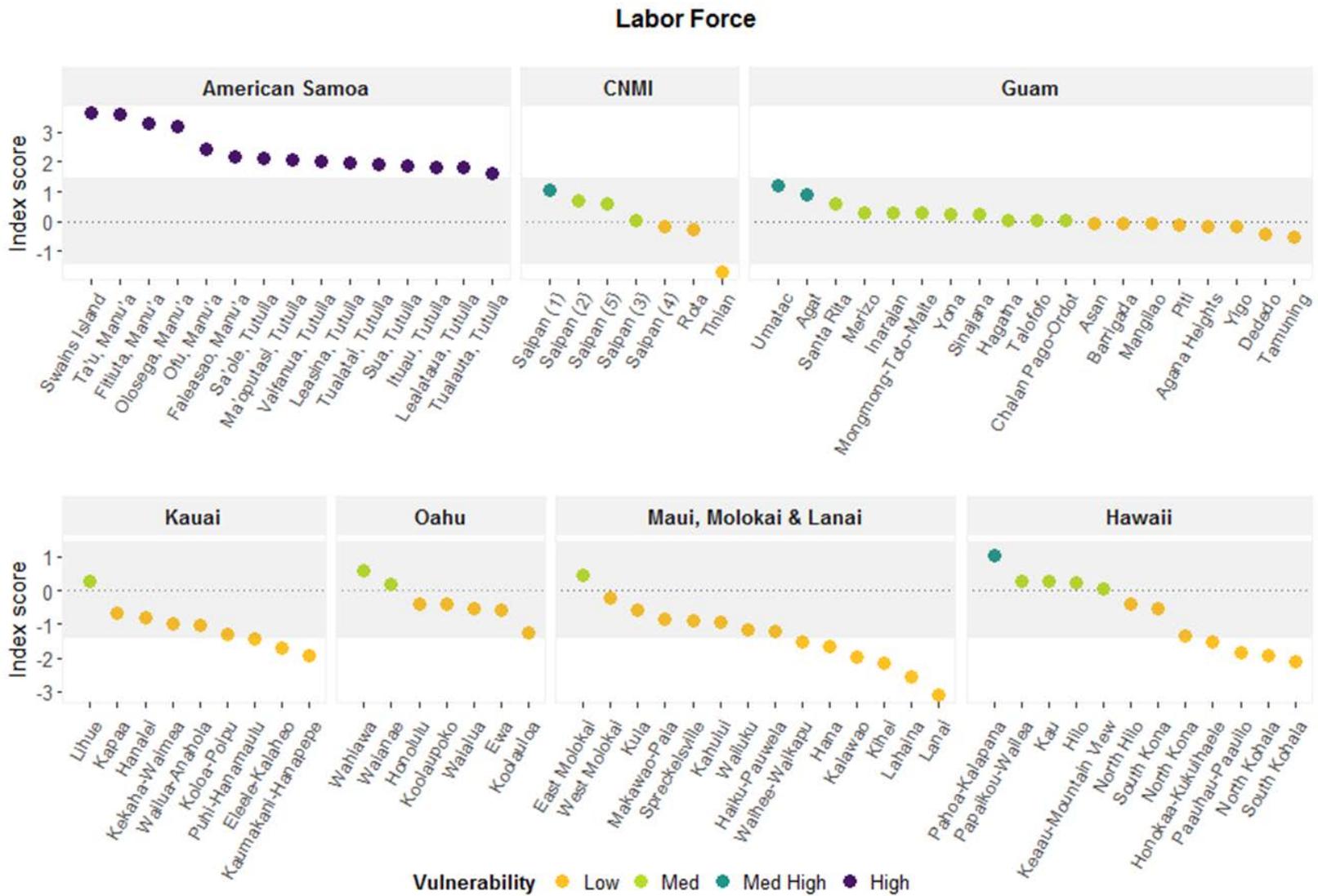


Figure 2. Vulnerability level based on Labor Force.

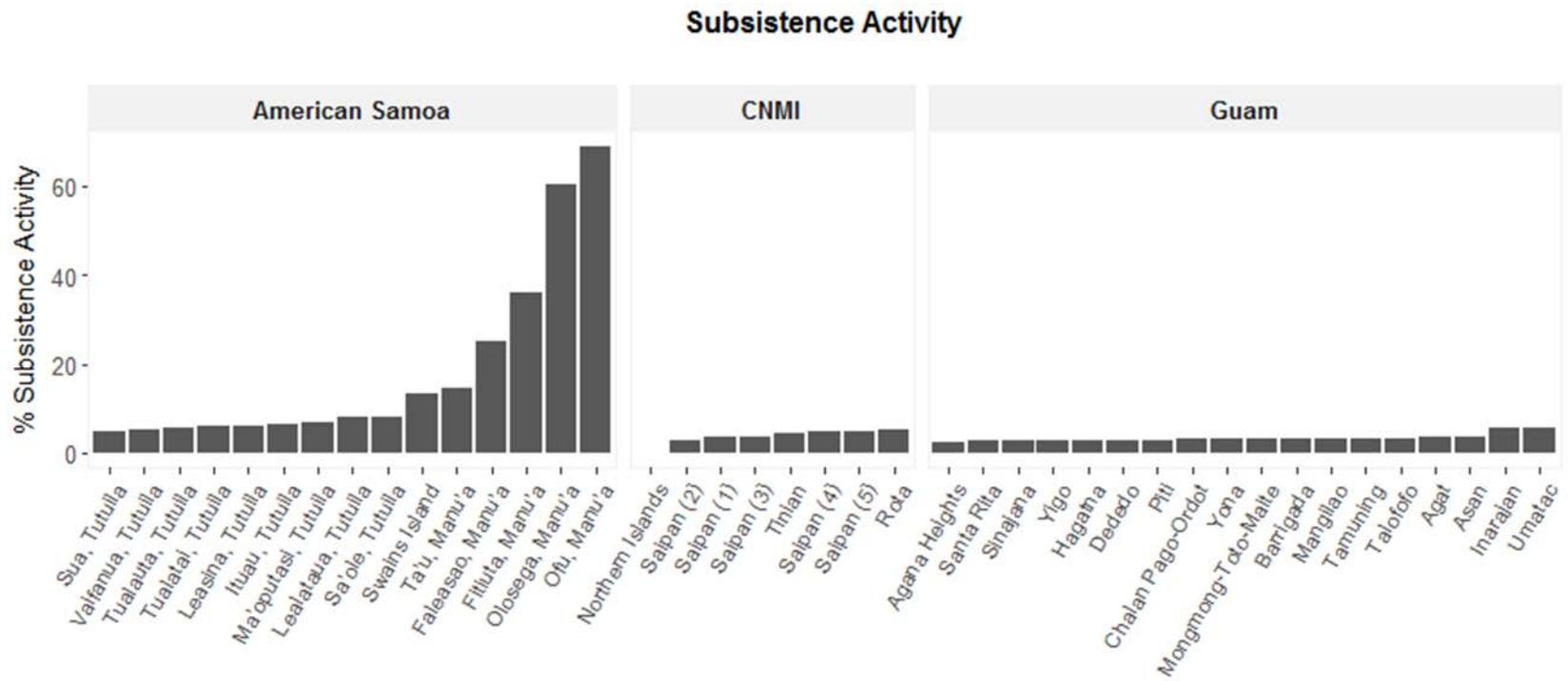


Figure 3. Subsistence activity.

Personal Disruption Index

The Personal Disruption Index indicates greater vulnerability in communities with more people without a high school diploma, more people in poverty, and more unemployed people (Fig. 4). Higher index scores are associated with higher vulnerability.

The variables used in this index overlap with other indices (Labor Force, Population Composition, Poverty), but allow for a singular focus on factors that add to community disruption. The index developed by Jepson and Colburn (2013) included a crime index which are based on FBI data of personal crime rates. This index has yet to be developed for the territories at a CCD level.

There were higher scores for Personal Disruption in the territories than Hawai‘i. For example Lahaina had lower rates of poverty, unemployment, and people without a high school diploma than Olosega, Hagåtña, and Rota (Table 6). As with other indices, measures of poverty and unemployment that indicate high levels of vulnerability in American Samoa, should be viewed within the context of high levels of subsistence activities (Fig. 3), and strong cultural support networks (Levine and Allen, 2009). Measures of poverty may be particularly problematic, and this will be discussed more fully in the Poverty Index section.

Table 6. Personal Disruption community examples.

Variable	Olosega	Hagåtña	Rota	Lahaina
% no high school diploma	7.3%	14.6%	7.0%	6.7%
% population in poverty	55.9%	27.2%	44.2%	6.4%
% unemployed	11.3%	5.2%	5.8%	4.5%
Index score	2.39	1.00	0.53	-0.98

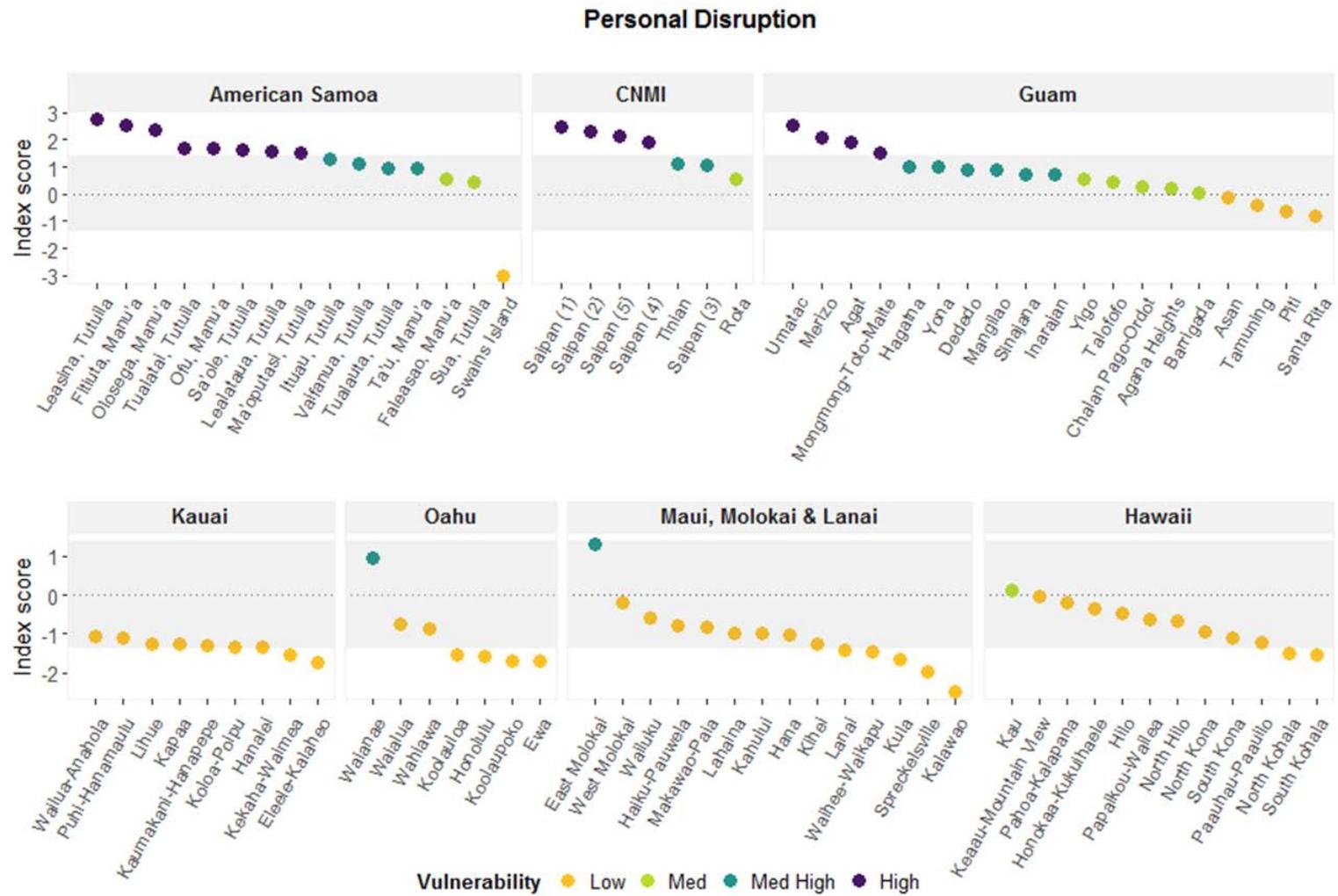


Figure 4. Vulnerability level based on Personal Disruption.

Population Composition Index

The Population Composition Index indicates greater vulnerability in communities with more families headed by a single woman, more people under the age of 5, and fewer people with a Bachelor's degree (Table 3). The index was calculated and the communities were listed in order of vulnerability by island grouping (Fig. 5). Higher index scores are associated with higher vulnerability.

The number of children can influence the vulnerability of families. Small children can be a significant financial burden, and may need additional assistance in times of crises or adapting to changes over time. Likewise single-parent households, and particularly single female-headed households in contexts where women are less likely to find stable or well-paid employment, are often less able to adapt to changing circumstances (Morrow 1999; Cutter, Boruff, and Shirley, 2003). Education on the other hand can offer higher earning potential, and more employment choices. Lower levels of education have also been associated with increased vulnerability to many different types of change and disruption. Less formal education often means these individuals are less aware of how to handle disruptions and have fewer resources to rely upon in times of need (Cutter, Boruff, and Shirley, 2003). However, in a study of two communities in American Samoa, higher education corresponded with lower perception of household vulnerability to specific natural hazards, but also were more likely to perceive lower household resilience (Wongbusarakum, 2009).

As with other indices, communities in Hawai'i exhibit less vulnerability than communities in the territories. All but two communities in American Samoa are listed as having high vulnerability. Lack of access to secondary education may be one factor (but see Wongbusarakum, 2009). For example in Olosega only 1.2% of the population has a bachelor's degree, while the number is much higher in Hagåtña, Rota, and Lahaina (Table 7). American Samoa also had a higher proportion of children under 5 years old. On the other hand Guam had the highest prevalence of single female-headed households.

Table 7. Population Composition community examples.

Variable	Olosega	Hagåtña	Rota	Lahaina
% female single headed households	16.7	26.6	18.1	9.4
% Bachelor's degree	1.2	8.8	13.9	18.2
% population age under 5	10.7	7.6	8.0	6.5
Index score	1.74	1.16	0.07	-1.43



Figure 5. Vulnerability level based on Population Composition.

Poverty Index

The Poverty Index indicates greater vulnerability in communities with more people in poverty⁶, more people under 18 in poverty, more families with children under 5 in poverty, and more families headed by a single woman in poverty (Table 3). The index was calculated and the communities were listed in order of vulnerability by island grouping (Fig. 6). The index scores were reversed so that higher index scores are associated with higher vulnerability.

Overall, economic affluence is associated with greater access to resources which can be used to adapt to changing conditions in social, economic, or ecological systems associated with a community (Cutter, Boruff, and Shirley, 2003; Tuler et al., 2008). Furthermore, at the family level, single-parent households have been found to be more vulnerable than those with two adults (Oliver-Smith, 1996).

Overall rates of poverty were lower in Hawai‘i than in the territories as exemplified by Lahaina when compared to Hagåtña, Olosega, and Rota (Table 8). However the measure of poverty by the ACS relies on a national average (U.S. Census Bureau, 2017b), which does not take into account regional differences. This is problematic when comparing areas with different levels of reliance on a market based economy. In the case of American Samoa subsistence activities and reliance on support from social network could alleviate many of the vulnerabilities associated with poverty such as food insecurity. Furthermore the land tenure system in American Samoa could also alleviate poverty related housing issues such as a lack of affordable housing (Levine and Allen, 2009).

Table 8. Poverty community examples.

Variable	Hagåtña	Olosega	Rota	Lahaina
% individuals in poverty under 18	53.7	45.5	32.7	3.4
% families with children < 5 in poverty	55.3	38.1	37.0	1.4
% female headed families in poverty	42.9	19.0	29.6	8.8
% population in poverty	17.8	55.9	44.2	6.4
Index score	1.36	1.32	0.91	-2.40

⁶ The U.S. Census defines poverty in the following way: "the Census Bureau uses a set of money income thresholds that vary by family size and composition to determine who is in poverty. If a family's total income is less than the family's threshold, then that family and every individual in it is considered in poverty. The official poverty thresholds do not vary geographically, but they are updated for inflation using the Consumer Price Index (CPI-U). The official poverty definition uses money income before taxes and does not include capital gains or noncash benefits (such as public housing, Medicaid, and food stamps)" (U.S. Census Bureau, 2017b) . In 2010 the annual income threshold for a family of 2 with no children was \$14,602. Because they are using a threshold related to a national average, the measure may not be relevant to many areas of the Pacific.

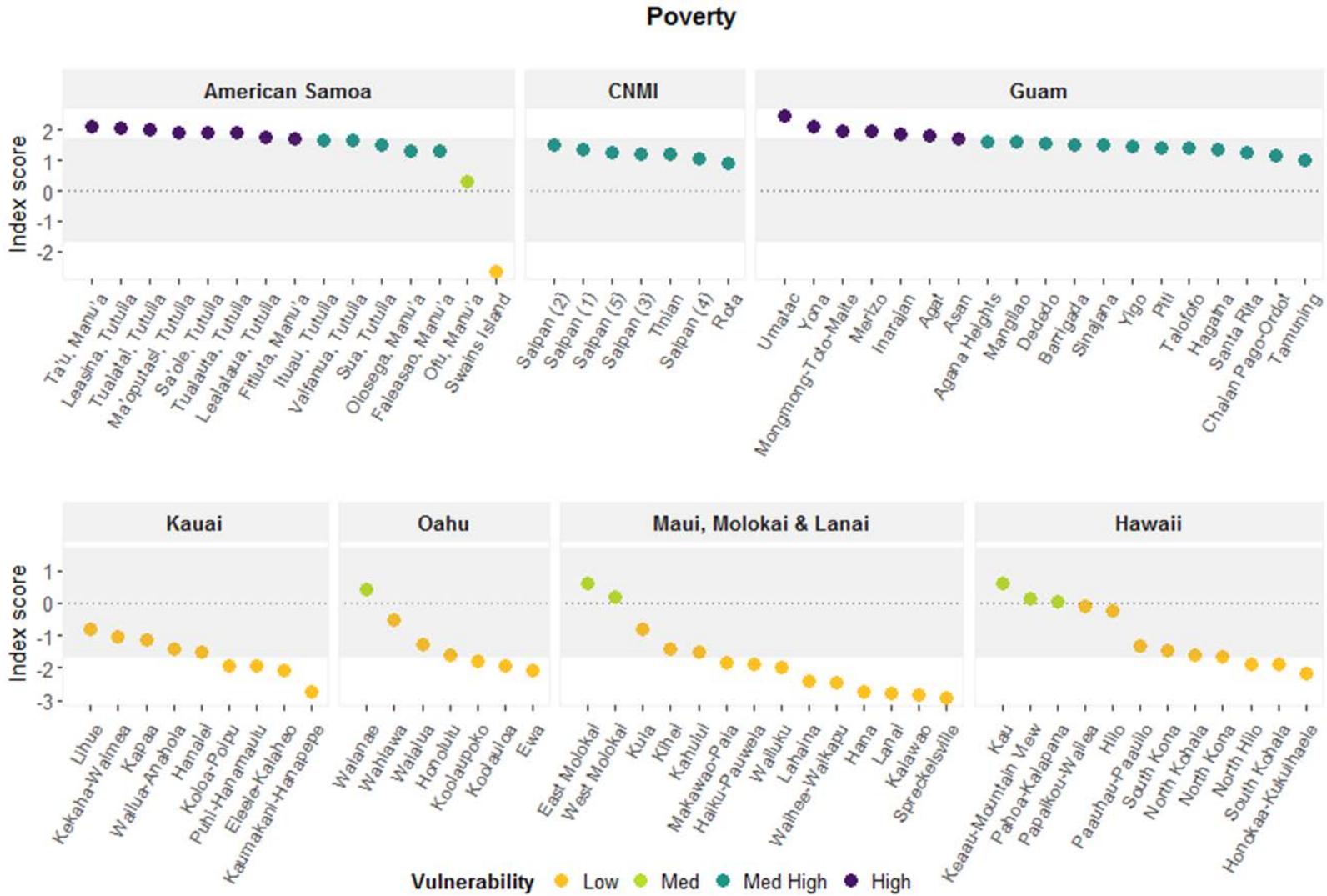


Figure 6. Vulnerability-level based on poverty.

Occupational Diversity Vulnerability

The Occupational Diversity Vulnerability index indicates greater vulnerability in communities with fewer occupation options. The index was calculated and the communities were listed in order of vulnerability by island grouping (Fig. 7). Diverse economies have been shown to adapt more effectively and more completely to disruptions than those reliant on fewer industries or inputs, due to their ability to rely on alternative economic sectors during disruptions or changes (Mileti, 1999).

The index is a measure of the spread of the workforce across five labor categories recorded by the ACS. If workers are concentrated in one or two categories, the occupational diversity goes down and the vulnerability increases. For example North Hilo has high vulnerability in this index. While the percentage of workers in management and sales (Table 9) is comparable to the state averages (29.9% and 23.5% respectively), this community has a much higher than the state average service employment (25.1%), and lower than average employment in natural resources (13.3%) and production (8.2%). Different examples are also apparent throughout the territories. While Olosega’s workers are mostly concentrated in management and natural resources, labor in Rota and Hagåtña are more evenly spread across the five different occupations (Table 9).

Although most communities were not identified as being highly vulnerable, four communities were one standard deviation above the mean. Two of those communities (Swains Island in American Samoa and Kalawao in Hawai‘i) have very small populations, and also may not engage in a market economy to the same degree as other fishing communities in North America. It is also worth noting that in communities such as Olosega, while the economic labor opportunities may be limited, over 60% of the community engages in subsistence activities, suggesting robust engagement in the non-market economy which could mitigate vulnerability (Table 3).

Table 9. Occupational Diversity community examples.

Variable	North Hilo (%)	Olosega (%)	Rota (%)	Hagåtña (%)
Management, business, science, and arts occupations	29.2	40.7	27.3	28.7
Service occupations	38.4	16.7	28.9	23.0
Sales and office occupations	25.0	5.6	17.9	20.8
Natural resources, construction, and maintenance occupations	2.6	31.5	20.2	14.9
Production, transportation, and material moving occupations	4.8	5.6	5.7	12.6
Index score	17.96	14.69	-1.38	-7.38

Commercial Fishing Vulnerability

Commercial Fishing Engagement

The Commercial Fishing Engagement Index indicates greater vulnerability in communities with more commercial permits, more dealers, larger catch volume, and larger catch value (Table 3). The index was calculated and the communities were listed in order of vulnerability by island grouping (Fig. 8A).

The communities scoring highly on the Fishing Engagement index are sites of high levels of commercial fishing, often with ports located within their geographic boundaries. They are also communities with the highest population numbers and include Honolulu, 'Ewa, and North Kona (Fig. 8A). Communities scoring low on this component have smaller populations and lower levels of commercial fishing such as Kalawao where there are no commercial permits (Table 10). Scores on this component suggest higher levels of vulnerability to changes in fishery management or ecological conditions, but changes affecting different fisheries or types of fishing would affect certain communities more than others. For example, charter fishing is a large part of fishing in North Kona and would be severely affected by changes in charter fishing regulations while changes affecting the longline fishery would primarily affect Honolulu.

Table 10. Fishing Engagement community examples.

Variable	Honolulu	North Kona	Hana	Kalawao
Commercial Permits	305	327	15	0
Dealers	21	13	2	0
Landings (lbs.)	18,000,000	1,100,000	78,000	0
Value (USD)	44,000,000	1,700,000	130,000	0
Index score	10.27	3.10	-0.58	-0.94

Commercial Fishing Reliance

The Commercial Fishing Reliance Index indicates greater vulnerability in communities with more per capita commercial permits, more per capita dealers, larger per capita catch volume, and a larger proportion of the population employed in fishing and agriculture (Table 3). The index was calculated and the communities were listed in order of vulnerability by island grouping (Figure 8B). The index scores were reversed so that higher index scores are associated with higher vulnerability.

Commercial Fishing Reliance variables are almost all calculated per capita and therefore they are normalized for population size. Low index scores indicate communities with high levels of fisheries engagement by proportion of overall population, for example in Hana (Table 11). Some communities, such as Honolulu, while scoring highly in terms of engagement, were not listed as highly vulnerable in terms of reliance, while North Kona is listed as highly vulnerable in both indices (Tables 10 and 11). Very large populations could be more resilient to disruptions in commercial fisheries since fishing is only a small portion of the broader economy. The inclusion

of data from dealer reports could mean that these indices underestimate communities with high proportions of commercial fishing but no dealers.

Table 11. Fishing Reliance community examples.

Variable	Hana	North Kona	Honolulu	Kalawao
Commercial Permits / 1000 capita	6.53	8.68	0.81	0
Dealers per capita / 1000 capita	0.88	0.34	0.06	0
Landings (lbs.) / 1000 capita	34,406	30,217	47,174	0
Fishing & agriculture employment (%)	18.1	2.6	0.5	0
Index score	4.40	2.28	0.25	-2.14

Also significant to note is that all of the fisheries data used for this analysis is based on reports of commercial fishing. The lack of non-commercial fishing indices is due to difficulties in the extrapolation of non-commercial fishing data to the general population. The data collected is site specific, but given current data collection methods we are unable to estimate the total numbers of non-commercial fishers or their catch. However, non-commercial fishing is a large part of many communities in Hawai‘i both for food and cultural practices and, therefore, these indices cannot be assumed to represent overall fishing engagement in Hawai‘i. This would also be true of the other island groups in this region.

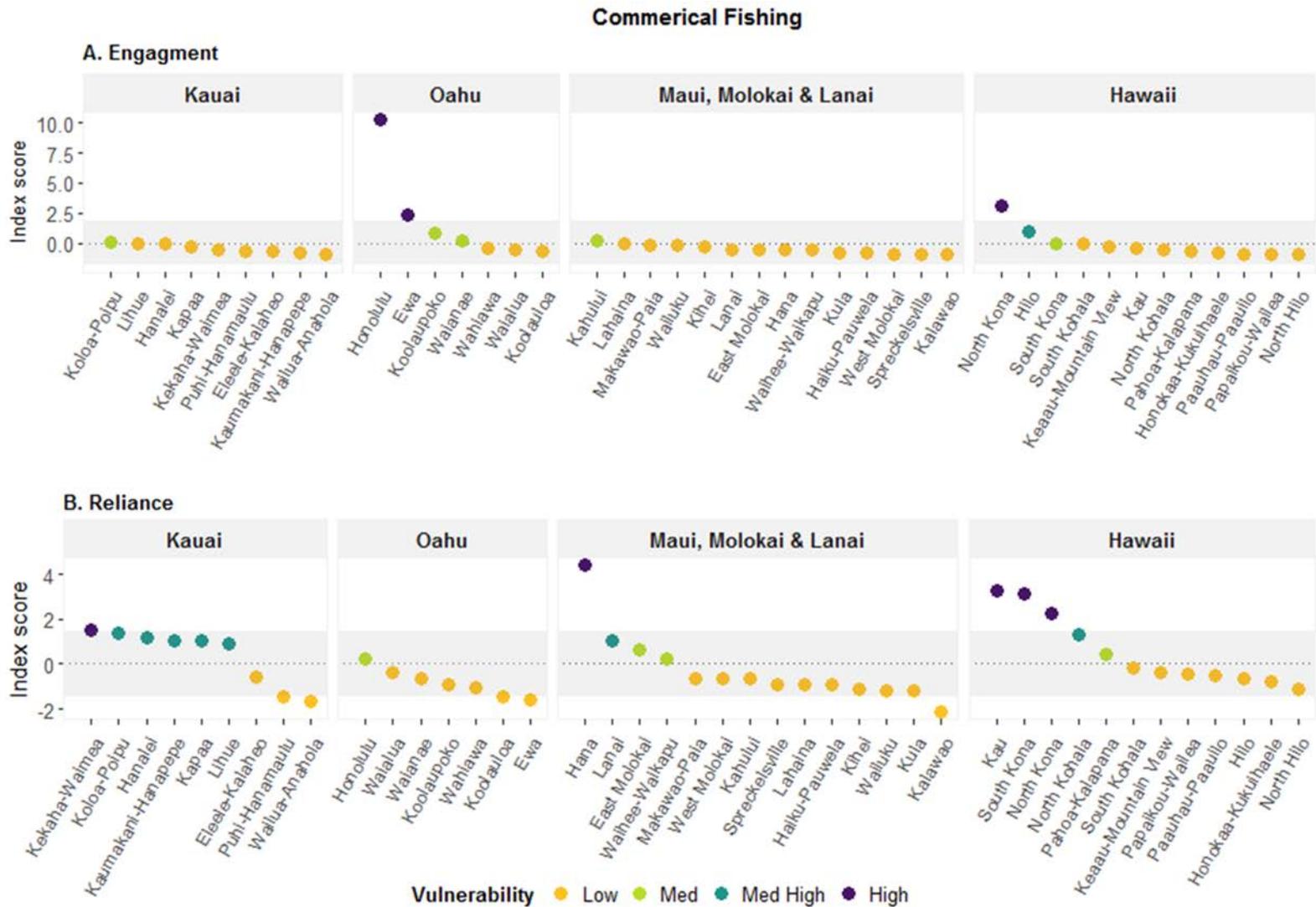


Figure 8. Fishing Engagment and Reliance indices.

Natural Hazard Vulnerability

The Natural Hazard Vulnerability Index indicates greater vulnerability in communities with greater risk of tsunamis, stream flooding, high waves, storms, erosion, sea level, and volcanic activity (Fletcher et al., 2002; Appendix A. Variables) The communities were listed in order of vulnerability by island grouping (Fig. 9).

Fishing communities are likely to be more severely affected by coastal hazards such tsunamis, high waves, erosion and sea level rise risk (Pomeroy et al., 2006). Risk from storms and flooding streams may affect coastal and terrestrial areas and are common throughout Hawai‘i, posing a high likelihood of affecting communities.

On this index, Keaau-Mountain View and Hilo on Hawai‘i Island are the most vulnerable, and Waialua on O‘ahu is the least vulnerable to natural hazards. Hilo, with the second highest score has experienced severe damage from tsunamis in the past and is therefore likely to be affected by a tsunami in the future. On the other end of the index, Wahiawa does not have any coastal area within its geographic boundaries and since three of the seven factors included in overall risk primarily affect coastal areas (tsunamis, high waves and sea-level rise), Wahiawa would be less vulnerable.

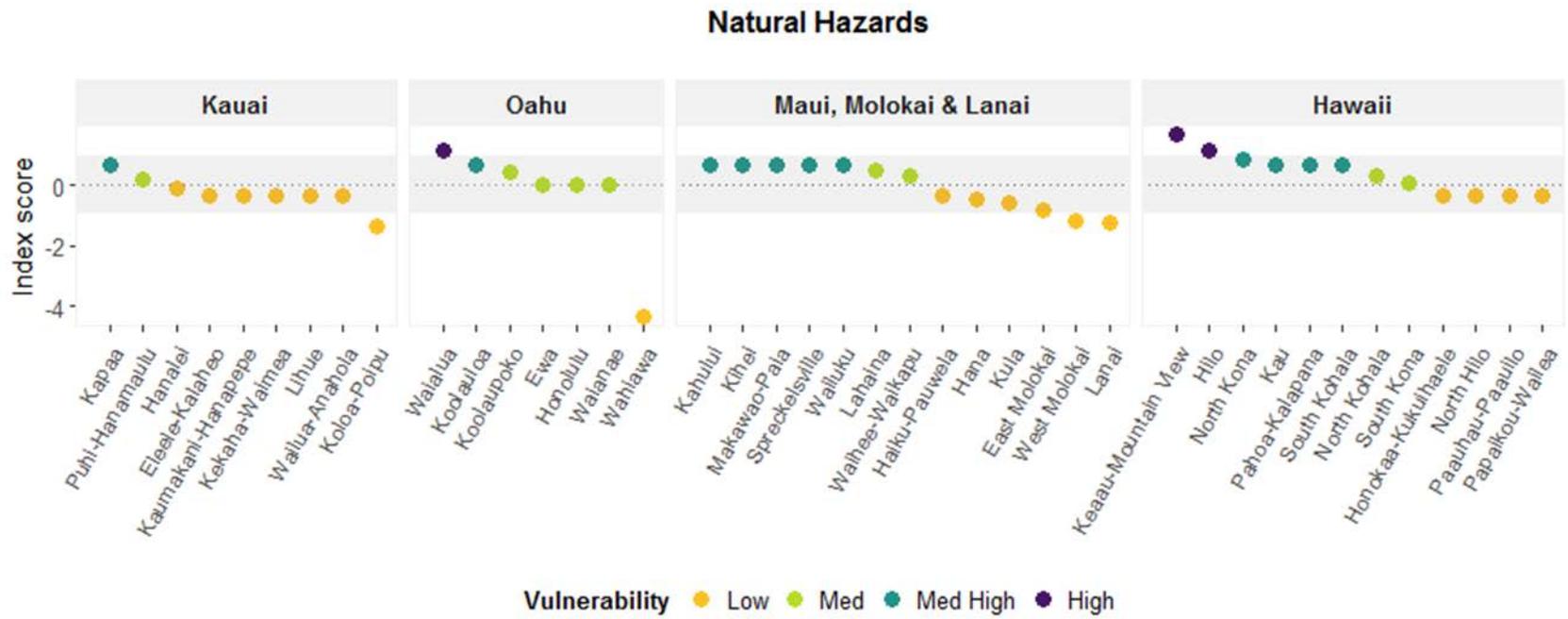


Figure 9. Natural hazards.

IV. DISCUSSION

This research used factor analysis and principal components to identify indices that describe different aspects of vulnerability in fishing communities in Hawai‘i, Guam, the Commonwealth of the Northern Mariana Islands, and American Samoa. While it is clear that many of the indicators that were developed for the North and South east coast fishing communities are either not available in or relevant to the Pacific region, this process was still an important first step. These underlying concepts, when developed for the Pacific context and verified through field work, could provide information about relative vulnerability of fishing communities to a given threat, disruption or proposed policy change.

Constraints of the Data

Vulnerability indices for fisheries communities in the United States, including Hawai‘i, are currently calculated and mapped, and available to the public (NOAA, 2017). However, the indices were developed for a Northeast and Southeast coast fishing community context. To examine if these measures were relevant and replicable in the Pacific region we opted to replicate the Jepson and Colburn (2013) index development. We did this at a regional scale, which in our case includes the state of Hawai‘i, and the western Pacific Territories of Guam, the Commonwealth of the Northern Mariana Islands, and American Samoa. By adding the territories we increased the number of communities and thereby improved the subject-to-item ratios which increased the ability to find single factor solutions in PCA analysis. We also broadened the application of the indices so they could be incorporated into region-wide models of ecological and social vulnerabilities. However this also adds a wider range of socioeconomic profiles, making certain variables more or less relevant.

Missing Variables

The first and most obvious limitation when including the territories in a region wide assessment is that certain variables are not available in the territories. The crime index and cost of living index, both of which were found to be robust additions to social vulnerability indices in the Northeast and Southeast (Jepson and Colburn, 2013), were not available in territories. The crime index data is collected, but would require working with local police departments to localize the incidents for index calculation at a CCD level. New data sets purchased by the national socioeconomic group for more recent years are similarly limited to the U.S. states. However, even if we are able to calculate crime rates at a CCD level we would have to contend with rate inflation for small populations.

Decennial data are available in the territories, but direct comparisons are also limited by several issues. The first is that decennial data are only collected in the territories every 10 years. This would limit examination of finer scale temporal changes in vulnerability. There were also differences in how certain questions were asked which makes direct comparison impossible. For example in the States the measure “Speaks English less than well” is used, while in the territories the measure is “Does not speak English”. In other cases measures of wealth are different. In Hawai‘i the first categorization of annual income is \$5,000 or below, whereas in the territories it is \$2,500 or below. These data limitations meant that we were unable to develop certain indices

(such as Housing Disruption). Finding new sources of data would be important for being able to develop these indices as a regional level.

Irrelevant Variables and Indices

It is also important to recognize that many of the measures developed for the Northeast and Southeast regions are not universally applicable within this region. For example measures related to a commercial economy may be a good indicator of vulnerability in some communities, but be less indicative of vulnerability in non-market based economies. This could include the indices that describe housing characteristics, housing disruption, poverty, and for some variable used to describe labor force characteristics (Appendix A. Variables). This could include variables related to income, poverty, rent, mortgage, housing values, or rates of employment.

In other cases measures of infrastructure or access to urban areas are also problematic. For example the number of mobile homes is not a good variable because they are uncommon enough in this region to be a good variable. Another is example is the distance to the nearest city with a 50k+ population is less meaningful for in the Pacific where access to air travel, rather than driving distance, is the main barrier.

Ethnicity, race, and language are all important variables when it comes to vulnerability (Cutter, Boruff, and Shirley, 2003). While these variables are important and available in the Hawai‘i and the western Pacific territories, we were unable to find a single variable of ethnicity or race that could be easily attributed to vulnerability in all the island groupings. Similarly the lack of English speaking skills may be a limitation in some contexts, but not others because it is not the predominant language in many western Pacific communities.

Variables that Could be Considered

As stated before, one of the limitations of the region wide analysis is the differences between island groups. In particular Hawai‘i may be closer in terms of urbanization and market economy to mainland U.S. communities, than the communities in Guam, CNMI, or American Samoa.

For example, when measuring poverty, a global poverty threshold may be more relevant than a U.S. poverty threshold. Another alternative would be to include variables such as subsistence practices which are collected by the U.S. Census in the territories. However, data available through the U.S. Census may not be the best measure of vulnerability, in which case Wongbusarakum (pers. comm., 2017) recommends measures related to access to resources where livelihood can be depended on, skills and knowledge to make use of the resource for livelihood purposes, and social networks that support those livelihoods. The limiting factor would be being able to collect this data broadly and consistently.

It may also be worth going back to the indicator literature more broadly to examine other vulnerability indicators being used. For example in a review of social vulnerability indicators in disasters, Fatemi et al. (2017) found four main indices used in the literature: gender, public health conditions, public infrastructures, and migration. While these do not match well with the indices developed for fishing communities in the United States (see Jepson and Colburn, 2013; Jacob et al., 2013), they may be more relevant to fishing communities in the western Pacific.

Integrating the Data into Socio-ecological Assessments

The social vulnerability indices developed during this process were used in island reports on coral reef resilience and social vulnerability (Oliver et al., in review). Measures of vulnerability were mapped onto the land, and measures of coral resilience were mapped on corresponding water areas. The purpose of this visual juxtaposition is to allow managers to integrate social and biological information into spatial planning. The process of including social vulnerability indices also brought up some important considerations for future use of this data.

The main issue raised was the utility of using region wide vulnerability scores when reporting to individual island groups. In particular the high levels of overall vulnerability in American Samoa and low levels in Hawai‘i was a concern. The project lead felt that local collaborators in American Samoa would dispute the suggestion that their communities are socially vulnerable. This is not an unfounded response. Throughout this report we have also highlighted ways in which these measures of social vulnerability may not be appropriate when applied to the non-market based economy and land tenure traditions of American Samoa. Furthermore, when index scores are presented at the regional scale, variation among communities within American Samoa, and within Hawai‘i is lost in the simplified four categories of vulnerability.

To present data that is relevant for the local context, the index scores were re-centered at the island group level. In this case the grouping was American Samoa, Hawai‘i, and Guam and CMNI (Fig. 10). The outlier communities of Swain’s Island in American Samoa, and Kalawao in Hawai‘i were also removed. The result is more localized measures of vulnerability. For example when examining the poverty index at the regional scale over half of communities in American Samoa would be considered highly vulnerable (an index score of more than one SD above the \$83,037, in American Samoa it was \$29,213, and hence what it means to live in poverty could be quite different. In the localized score only one community fits that category (Fig. 10). Conversely regional scores showed not highly vulnerable Hawaiian communities (Fig. 6), whereas localized scores found eight highly vulnerable (Fig. 10).

Localized Poverty Index Scores

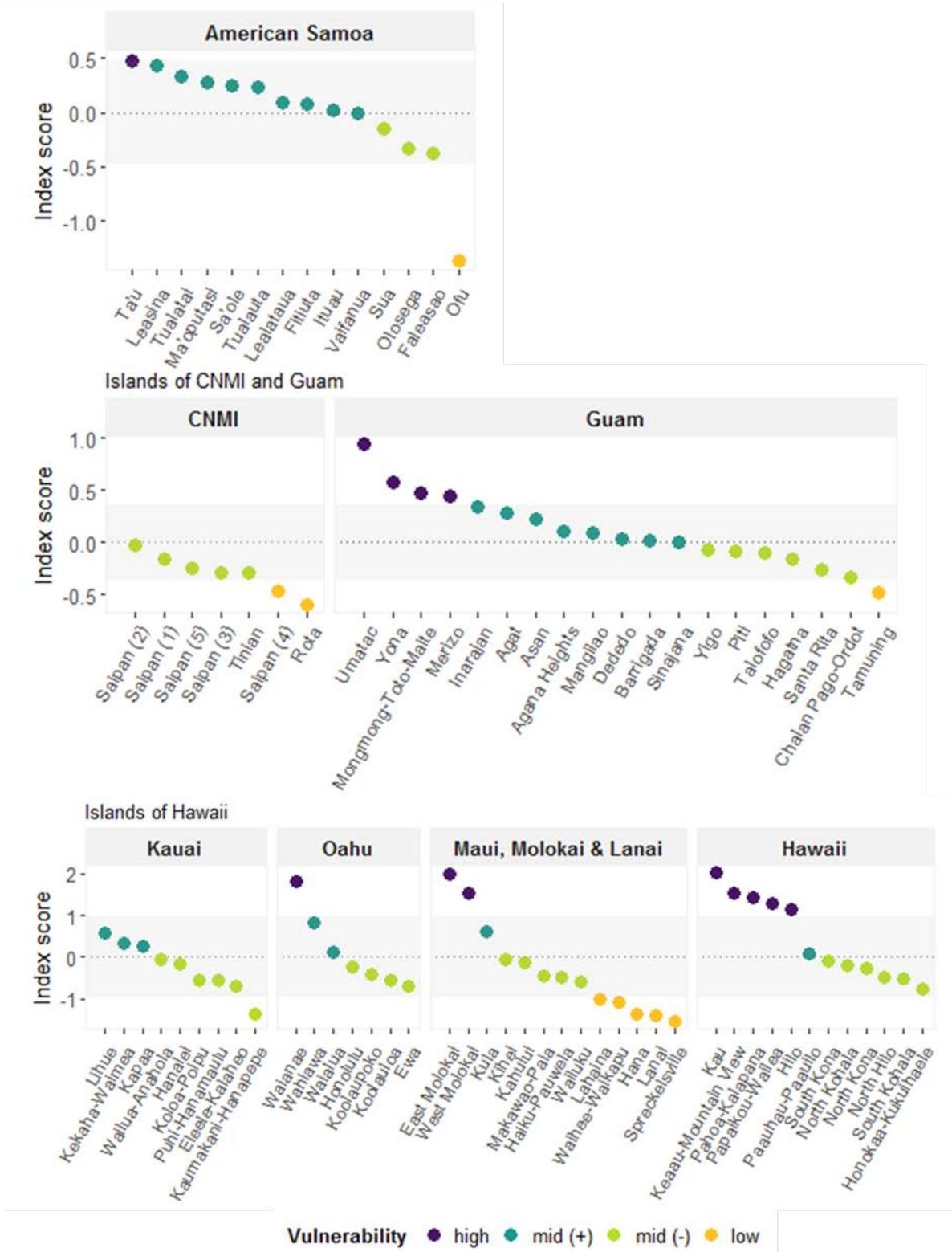


Figure 10. Localized poverty index scores.

Next Steps

Considering the constraints of the data (i.e., a small subject sample with low subject-to-item ratios) the results of this analysis should be tested with confirmatory factor analysis. More recent secondary data has been collected for Hawai'i communities to include all ACS 5-year average data series between 2005–2009 and 2012–2016. These additional data could be used in confirmatory factor analysis to assess the validity of the factors produced in this research, and to derive time-series indicator values to understand the temporal scale of community dynamics and vulnerabilities. Secondly, these results should be validated using qualitative data from select communities to compare with results of this analysis (e.g., Jacob et al., 2013). Finally the index scores generated from the national data set should be compared with the regionally developed indices. This comparison could only be done in Hawai'i communities.

Given the problems with variation in applicability of specific variables and indices, future analyses should separate the territories and Hawai'i. This would allow for a greater number of variables to be used in Hawai'i that aren't available in the territories (such as crime, or cost of living indices). It would also mean that variables that could be very relevant to Hawai'i, such as rent costs, would not be misapplied to context where they are not relevant. It would be important to develop new relevant indices that could capture vulnerability in the rural and non-market economies of the Pacific territories.

One noted area lacking data in this analysis is non-commercial (or recreational) fishing. Fisheries catch-and-effort information is collected for Hawai'i from non-commercial fishers both in person and by phone, but has not yet been integrated. Efforts are being made to find ways to integrate these data to support noncommercial fishing engagement and reliance indicators. Additional applications in the future could be to explore fishery-specific analyses to determine community engagement and reliance on fisheries or species of management interest. This framework could also be integrated with species vulnerability assessments or with forecasts of climate change (Colburn et al., 2016).

V. CONCLUSION

The results presented above are meant as a first step in establishing social vulnerability indicators for fishing communities in Hawai'i, Guam, the Commonwealth of the Northern Marianas Islands, and American Samoa. This analysis draws on Jepson and Colburn's (2013) work identifying social indicators for fishing communities in the northeast and southeast regions. If developed further, and with specific attention to using relevant variables and indices in the western Pacific territories, social indicators could allow us to compare vulnerability levels of different communities within this region. These indices describe factors of social cohesion in communities that have been associated with greater adaptive capacity to abrupt or gradual changes (Cutter, Boruff, and Shirley, 2003). However, some of the data used in that analysis is unavailable, of questionable validity, or not applicable for this region. With more data and more iterations of this analysis, these indicators can be further refined and improved over time.

VI. REFERENCES

- Armor, D. J.
1973. "Theta Reliability and Factor Scaling."
Sociol. Methodol. 5, 17–50. <https://doi.org/10.2307/270831>
- Atlas of Natural Hazards in the Hawaiian Coastal Zone | USGS I Map 2761 [WWW Document],
n.d. URL <https://pubs.usgs.gov/imap/i2761/index.html> (accessed 6.23.17).
- Bartlett, M. S.
1937. "Properties of Sufficiency and Statistical Tests."
Proc. R. Soc. Lond. Ser. Math. Phys. Sci. 160, 268–282.
- Bigford, T. E.
1991. "Sea-level rise, nearshore fisheries and the fishing industry".
Coast. Manag. 19, 417–437.
- Boyd, H. and A. Charles
2006. "Creating community-based indicators to monitor sustainability of local fisheries."
Ocean Coast. Manag. 49, 237–258. <https://doi.org/10.1016/j.ocecoaman.2006.03.006>
- Clay, P. M. and J. Olson
2007. "Defining Fishing Communities: Issues in Theory and Practice."
NAPA Bull. 28, 27–42. <https://doi.org/10.1525/napa.2007.28.1.27>
- Colburn, L. L. and M. Jepson
2012. "Social Indicators of Gentrification Pressure in Fishing Communities: A Context for
Social Impact Assessment."
Coast. Manag. 40, 289-300.
- Colburn, L. L., M. Jepson, C. Weng, T. Seara, J. Weiss, and J. A. Hare
2016. "Indicators of climate change and social vulnerability in fishing dependent
communities along the Eastern and Gulf Coasts of the United States."
Mar. Policy. 74, 323-333.
- Cutter, S. L., B. J. Boruff, and W. L. Shirley
2003. "Social Vulnerability to Environmental Hazards."
Soc. Sci. Q. 84, 242–261. <https://doi.org/10.1111/1540-6237.8402002>
- Cutter, S. L., J. T. Mitchell, and M. S. Scott
2000. "Revealing the Vulnerability of People and Places: A Case Study of Georgetown
County, South Carolina."

- Ann. Assoc. Am. Geogr. 90, 713–737. <https://doi.org/10.1111/0004-5608.00219>
- Fatemi, F., A. Ardalan, B. Aguirre, N. Mansouri, and I. Mohammadfam
2017. “Social vulnerability indicators in disasters: Findings from a systematic review.”
Int. J. Disaster Risk Reduct. 22, 219–227. <https://doi.org/10.1016/j.ijdrr.2016.09.006>
- Fletcher, C. H., E. E. Grossm, B. M. Richmond, and A. E. Gibbs
2002. “Atlas of Natural Hazards in the Hawaiian Coastal Zone, Geologic Investigations
Series 1-2761.”
University of Hawaii, State of Hawaii Office of Planning, National Oceanic and
Atmospheric Administration.
- Gulf & South Atlantic Fisheries Foundation, Inc.
2010. “Development of Social Indicators for Fishing Communities of the Southeast:
Measures of Dependence, Vulnerability, Resilience, and Gentrification (No. NA0 8NMF4
270 412).
- Jacob, S., and M. Jepson
2009. “Creating a Community Context for the Fishery Stock Sustainability Index.”
Fisheries 34, 228–231. <https://doi.org/10.1577/1548-8446-34.5.228>
- Jacob, S., P. Weeks, B. Blount, and M. Jepson
2013. “Development and evaluation of social indicators of vulnerability and resiliency for
fishing communities in the Gulf of Mexico.”
Mar. Policy, 37, 86–95. <https://doi.org/10.1016/j.marpol.2012.04.014>
- Jacob, S., P. Weeks, B. Blount, and M. Jepson
2010. “Exploring fishing dependence in gulf coast communities.”
Mar. Policy 34, 1307–1314. <https://doi.org/10.1016/j.marpol.2010.06.003>
- Jepson, M., and L. L. Colburn
2013. “Development of social indicators of fishing community vulnerability and resilience in
the US southeast and northeast regions.”
NOAA Tech. Memo. NMFS-FSPO-129.
- Kaiser, H. F.
1974. “An index of factorial simplicity*.”
Psychometrika 39, 31–36.
- Kasearu, K., L. Maestripieri, and C. Ranci
2017. “Women at risk: the impact of labour-market participation, education and household
structure on the economic vulnerability of women through Europe.”
Eur. Soc. 19, 202–221. <https://doi.org/10.1080/14616696.2016.1268703>
- Levine, A., and S. Allen

2009. “American Samoa as a fishing community.”
U.S. Dep. Commer., NOAA Tech. Memo., NOAA-TM-NMFS-PIFSC-19, 74 p.
- Lowe, M. K., M. M. Quach, K. R., Brousseau, and A. S. Tomita
2016. “Fishery Statistics of the Western Pacific.”
Pacific Islands Fisheries Science Center Administrative Report No. H-16-03.
- Magnuson-Stevens Fishery Conservation and Management Act: As Amended Through January 12, 2007.
- Mileti, D. S.
1999. “Disasters by Design: A Reassessment of Natural Hazards in the United States.”
Joseph Henry Press, Washington, D.C.
- Morrow, B. H.
1999. “Identifying and Mapping Community Vulnerability.”
Disasters 23, 1–18. <https://doi.org/10.1111/1467-7717.00102>
- NOAA
2017. Social Indicators [WWW Document]. Indicator Definitions
URL <http://www.st.nmfs.noaa.gov/humandimensions/social-indicators/ind-categories>
(accessed 8.23.17).
- Oliver-Smith, A.
1996. “Anthropological research on hazards and disasters.”
Annu. Rev. Anthropol. 25, 303–328.
- PIFSC
2018. “Western Pacific Community Social Vulnerability Indicators.”
<https://inport.nmfs.noaa.gov/inport/item/47066>
- Pollnac, R. B., S. Abbott-Jamieson, C. Smith, M.L. Miller, P. M. Clay, and B. Oles
2006. “Toward a model for fisheries social impact assessment.”
Mar. Fish. Rev. 68, 1–18.
- Pomeroy, R. S., B. D. Ratner, S. J. Hall, J. Pimoljinda, V. Vivekanandan
2006. “Coping with disaster: Rehabilitating coastal livelihoods and communities.”
Mar. Policy 30, 786–793. <https://doi.org/10.1016/j.marpol.2006.02.003>
- R Core Team
2017. “R: A language and environment for statistical computing.”
R Foundation for Statistical Computing.
- Smith, T. W.
1981. “Social Indicators: A Review Essay.”
J. Soc. Hist. 14, 739–747.

State of Hawaii

n.d. State of Hawaii Office of Planning: Download GIS Data [WWW Document].
URL <http://planning.hawaii.gov/gis/download-gis-%20data/> (accessed 6.23.17).

Tuler, S., J. Agyeman, P. P. da Silva, K. R. LoRusso, and R. Kay

2008. "Assessing vulnerabilities: Integrating information about driving forces that affect risks and resilience in fishing communities."
Hum. Ecol. Rev. 15, 171.

United Nations

1990. "Human development report 1990."
United Nations (New York) Development Programme. Oxford Univ. Press, New York.

United States Census,

2014. "Commonwealth of the Northern Mariana Islands: Detailed Crosstabulation (Part 2)."
(No. DCT2MP/10-1 (RV)).

U.S. Census Bureau

n.d. American FactFinder [WWW Document].
URL <https://factfinder.census.gov/faces/nav/jsf/pages/index.xhtml> (accessed 7.13.17a).

U.S. Census Bureau,

n.d. How the Census Bureau Measures Poverty [WWW Document].
URL <https://www.census.gov/topics/income-poverty/poverty/guidance/poverty-measures.html> (accessed 8.8.17b).

Western Pacific Regional Fishery Management Council

2002. "Magnuson-Stevens Act Definitions and required Provisions: Identification of Fishing Communities."

Western Pacific Regional Fishery Management Council

1998. "Magnuson-Stevens Act Definitions and Required Provisions. Amendment 6 to the Bottomfish and Seamount Groundfish Fisheries Management Plan; Amendment 8 to the pelagic Fisheries management Plan; Amendment 10 to the Crustaceans Fisheries Management Plan; Amendment 4 to the Precious Corals Fisheries Management Plan."

Wickham, H.

2009. "ggplot2: Elegant Graphics for Data Analysis."
Springer-Verlag, New York.

Wongbusarakum, S.

2009. "Report on Project and Research Results: Climate-Related Socioeconomic Assessment in American Samoa."

Wongbusarakum, S. and R. S. Pomeroy

2000. "SEM-Pasifika: Socioeconomic Monitoring Guidelines for Coastal Managers in Pacific Island Countries." SPREP.

World Bank

2017. "World Development Indicators."

|

VII. APPENDICES

Appendix A. Variables

Table A. Full list of variables used in indices.

Vulnerability Indicator	Index	Variable Name	Variable Description	Source
Fishing	Commercial Engagement	COMMPMT ^a	# commercial permits	Fisher Report
		DEALERNUM ^a	# dealers	Dealer Report
		POUNDS ^a	pounds of landings	Fisher Report
		VALUE ^a	value of landings (USD)	Dealer Report
	Commercial Reliance	COMMPRPOP ^a	commercial permits per capita (1000)	Fisher Report
		DEALERNUMPOP ^a	dealers per capita (1000)	Dealer Report
		PCTAGRFRFSH ^a	% in agriculture, forestry, fishing, hunting industries	ACS
		PNDSPRPOP ^a	pounds of landings per capita (1000)	Fisher Report
		VALUPRPOP	value of landings per capita (1000)	Dealer Report
	Social	Housing	HUMNR ^a	median # of rooms
MED_GRRNT ^a			median gross rent	ACS
PCTNOPLBG ^a			% of households lacking complete plumbing facilities	ACS
MEDDWELLAGE			median year structure built	ACS
HMOWNVAC			homeowner vacancy rate	ACS
HOUSUNITNUM_OWNOCC			total owner-occupied housing units	ACS
MDYRSRESID			median years in residence	ACS
MED_MTMRG			median monthly owner costs	ACS
PCTGRPQRTRS_NONINST			% non-institutionalized people living in group quarters	ACS
PCTGRPQRTRS_TOTAL			% all living in group quarters	ACS
PCTHASMORTGAGE			% housing units with a mortgage	ACS
PCTHSMORTGAGELON			% housing units with a second mortgage and home equity loan	ACS
PCTMBLHM			% mobile homes	ACS

Vulnerability Indicator	Index	Variable Name	Variable Description	Source
		PCTNOVHCL	% households with no cars	ACS
		PCTOWNER	% owner	ACS
		PCTRENTER	% renter	ACS
		TOTHU	total housing units	ACS
Labor Force		PCTEMPFE ^a	% females employed	ACS
		PCTHHHUNDR10K ^a	% households with income under \$10,000	ACS
		PCTSERVIND ^a	% in arts, entertainment and recreation industries	ACS
		MEANHHINC	mean household income	ACS
		MEANTRAVTIM	mean travel time to work	ACS
		MEDHHINC	median household income	ACS
		PCTCNSTRCT	% in construction, extraction, installation, maintenance, and repair	ACS
		PCTEMPLOYED	% in employed the civilian labor force	ACS
		PCTHH100K	% household with income \$100,000+	ACS
		PCTLABFEMALE	% females in the civilian labor force	ACS
		PCTSERVOCC ^b	% in service occupations	ACS
		PCTSLFEMP	% self employed	ACS
Personal Disruption		PCTNODIPLOMA ^a	% 9th to 12th no diploma	ACS
		PCTUNEMPLD ^a	% unemployed	ACS
		PCTPOV ^{a,c}	% population in poverty	ACS
		PCTMALESEPARATD	% males separated	ACS
		PCTCHGUNEM	% change in % unemployed 2000-2010	ACS
		PCTFEMALEDIVORCD	% females divorced	ACS
		PCTFEMALESEPARATD	% females separated	ACS
		PCTLIVESMHS	% lived in same house 1 yr ago	ACS
		PCTMALEDIVORCD	% males divorced	ACS

Vulnerability Indicator	Index	Variable Name	Variable Description	Source
		PCTPOP9THGRD	% less than 9th grade	ACS
	Population Composition	PCTBATCHLRS ^a	% Bachelor's degree	ACS
		PCTFEMHEADHOUSE ^a	% female single headed households	ACS
		POPO_5PCT ^a	% age 5 or under	ACS
		AVGHHSZE	average household size	ACS
		MEDAGE	median age	ACS
		PCTFEMALE	% females	ACS
		PCTFORBRN	% foreign born	ACS
		PCTHHUNDR18	% households with children under 18	ACS
		PCTMALES	% males	ACS
		PCTNATBORN	% born in the state or territory they currently live in	ACS
		PCTNOSPKENG	% does not speak English (or speaks "less than well")	ACS
		PCTPOPHSGRD	% high school grad	ACS
		POP85PCT	% age 85 plus	ACS
		POPAAPCT	% Asian alone	ACS
		POPBAPCT	% Black alone	ACS
		POPCHPCT	% population change	ACS
		POPHSPCT	% Hispanic	ACS
		POPPAPCT	% Pacific alone	ACS
		POPWAPCT	% White alone	ACS
	Poverty	PCTCHLDPOV ^a	% in poverty under 18	ACS
		PCTFMPOV5 ^a	% of families with children under 5 in poverty	ACS
		PCTFMPOVFEMHH ^a	% of female headed families in poverty	ACS
		PCFMINPOV	% of families below poverty level	ACS
		PCT65POV	% of individuals in poverty 65 plus	ACS

Vulnerability Indicator	Index	Variable Name	Variable Description	Source
		PCTPOV ^c	% population in poverty	ACS
		PCTRECSSI	% households receiving SSI	ACS
	Occupational Diversity	PCTMNGOCC	% in management, business, science, and arts occupations	ACS
		PCTSERVOCC ^b	% in service occupations	ACS
		PCTSALESOCC	% in sales and office occupations	ACS
		PCTCONSOCC	% in natural resources, construction, and maintenance occupations	ACS
		PCTPRODOCC	% in production, transportation, and material moving occupations	ACS
Gentrification	Housing Disruption	PCTCHGMRG	% change median mortgage 2000-2010	ACS
		PCTCHGREENTER	% change in # of renters 2000-2010	ACS
		PCTCHGRNT	% change median rent 2000-2010	ACS
		PCTCHNGHOMVAL	% change in median home values 2000-2010	ACS
		PCTRENTRMTHLYCST	% renters with costs 35% plus of household income	ACS
	Retiree Migration	MEANRETINC	mean household retirement income	ACS
		PCTHHUOVER65	% households with ages 65 plus	ACS
		PCTLABFORCE	% in the civilian labor force	ACS
		PCTRECRET	% households with retirement income	ACS
		PCTRECSOC	% households with social security	ACS
		PCTSERVOCC ^b	% in service occupations	ACS
	Urban Sprawl	LANDAREA	land area (in sq. miles)	ACS
		MEDHOMVAL	median home value	ACS
		POPDENS	population density	ACS
Natural Hazard	Risk	HAILRSKAVG	Damaging Hail Risk Average	moving.com
		HURRSKAVG	Damaging Hurricanes Risk Average	moving.com
		TORNRSKAVG	Damaging Tornadoes Risk Average	moving.com
		WNDRSKAVG	Damaging Winds Risk Average	moving.com

Vulnerability Indicator	Index	Variable Name	Variable Description	Source
		TSUNAMI_USGS	Tsunami Risk	USGS
		STREAMFLOOD_USGS	Streamflood Risk	USGS
		HIGHWAVES_USGS	Highwaves Risk	USGS
		STORMS_USGS	Storm Risk	USGS
		EROSION_USGS	Erosion Risk	USGS
		SEALEVEL_USGS	Sea Level Risk	USGS
		VOLSEIS_USGS	Volcanic Risk	USGS

^aUsed in the Index Score Calculation

^bUsed as Labor Force, Retiree Migration, and Shannon Index variable

^cUsed as Personal Disruption and Poverty Index variable

Appendix B. Secondary Data Collection

Table B. Hawai'i zip code and CCD relationships and allocation.

Zip Code	CCD	% Allocation	Rationale
96720	Hilo, Hawai'i	100	
96721	Hilo, Hawai'i	100	
96727	Honokaa-Kukuihaele, Hawai'i	90	Google Map
96718	Kau, Hawai'i	100	
96737	Kau, Hawai'i	100	
96772	Kau, Hawai'i	100	
96777	Kau, Hawai'i	100	
96749	Keaau-Mountain View, Hawai'i	100	
96760	Keaau-Mountain View, Hawai'i	100	
96771	Keaau-Mountain View, Hawai'i	100	
96785	Keaau-Mountain View, Hawai'i	100	
96710	North Hilo, Hawai'i	49	Google Map
96764	North Hilo, Hawai'i	100	
96773	North Hilo, Hawai'i	100	
96780	North Hilo, Hawai'i	100	
96719	North Kohala, Hawai'i	100	
96743	North Kohala, Hawai'i	10	CDP population distribution: Waimea, Puako and Google Map
96755	North Kohala, Hawai'i	100	
96725	North Kona, Hawai'i	100	
96739	North Kona, Hawai'i	100	
96740	North Kona, Hawai'i	100	
96745	North Kona, Hawai'i	100	
96750	North Kona, Hawai'i	100	
96727	Paauhau-Paauilo, Hawai'i	10	Google Map
96743	Paauhau-Paauilo, Hawai'i	10	CDP population distribution: Waimea, Puako and Google Map
96774	Paauhau-Paauilo, Hawai'i	100	
96775	Paauhau-Paauilo, Hawai'i	100	
96776	Paauhau-Paauilo, Hawai'i	100	
96778	Pahoa-Kalapana, Hawai'i	100	
96710	Papaikou-Wailea, Hawai'i	51	Google Map
96728	Papaikou-Wailea, Hawai'i	100	
96781	Papaikou-Wailea, Hawai'i	100	
96783	Papaikou-Wailea, Hawai'i	100	
96738	South Kohala, Hawai'i	100	
96743	South Kohala, Hawai'i	80	CDP population distribution: Waimea, Puako and Google Map
96704	South Kona, Hawai'i	100	
96726	South Kona, Hawai'i	100	

Zip Code	CCD	% Allocation	Rationale
96701	Ewa, O'ahu	100	
96706	Ewa, O'ahu	100	
96707	Ewa, O'ahu	100	
96709	Ewa, O'ahu	100	
96759	Ewa, O'ahu	100	
96782	Ewa, O'ahu	100	
96789	Ewa, O'ahu	100	
96797	Ewa, O'ahu	100	
96853	Ewa, O'ahu	100	
96860	Ewa, O'ahu	100	
96861	Ewa, O'ahu	100	
96801	Honolulu, O'ahu	100	
96802	Honolulu, O'ahu	100	
96804	Honolulu, O'ahu	100	
96805	Honolulu, O'ahu	100	
96806	Honolulu, O'ahu	100	
96807	Honolulu, O'ahu	100	
96808	Honolulu, O'ahu	100	
96809	Honolulu, O'ahu	100	
96810	Honolulu, O'ahu	100	
96811	Honolulu, O'ahu	100	
96812	Honolulu, O'ahu	100	
96813	Honolulu, O'ahu	100	
96814	Honolulu, O'ahu	100	
96815	Honolulu, O'ahu	100	
96816	Honolulu, O'ahu	100	
96817	Honolulu, O'ahu	100	
96818	Honolulu, O'ahu	100	
96819	Honolulu, O'ahu	100	
96820	Honolulu, O'ahu	100	
96821	Honolulu, O'ahu	100	
96822	Honolulu, O'ahu	100	
96823	Honolulu, O'ahu	100	
96824	Honolulu, O'ahu	100	
96825	Honolulu, O'ahu	100	
96826	Honolulu, O'ahu	100	
96827	Honolulu, O'ahu	100	
96828	Honolulu, O'ahu	100	
96830	Honolulu, O'ahu	100	
96835	Honolulu, O'ahu	100	
96836	Honolulu, O'ahu	100	
96837	Honolulu, O'ahu	100	
96838	Honolulu, O'ahu	100	

Zip Code	CCD	% Allocation	Rationale
96839	Honolulu, O'ahu	100	
96840	Honolulu, O'ahu	100	
96841	Honolulu, O'ahu	100	
96843	Honolulu, O'ahu	100	
96844	Honolulu, O'ahu	100	
96846	Honolulu, O'ahu	100	
96847	Honolulu, O'ahu	100	
96848	Honolulu, O'ahu	100	
96849	Honolulu, O'ahu	100	
96850	Honolulu, O'ahu	100	
96859	Honolulu, O'ahu	100	
96712	Koolauloa, O'ahu	53.4	CDP population distribution: Haleiwa, Pupukea
96730	Koolauloa, O'ahu	100	
96731	Koolauloa, O'ahu	100	
96762	Koolauloa, O'ahu	100	
96717	Koolaupoko, O'ahu	100	
96734	Koolaupoko, O'ahu	100	
96744	Koolaupoko, O'ahu	100	
96795	Koolaupoko, O'ahu	100	
96863	Koolaupoko, O'ahu	100	
96786	Wahiawa, O'ahu	100	Google Map – Overlap with Waialua, but population in Wahiawa
96854	Wahiawa, O'ahu	100	
96857	Wahiawa, O'ahu	100	
96712	Waialua, O'ahu	46.6	CDP population distribution: Haleiwa, Pupukea
96791	Waialua, O'ahu	100	
96792	Waianae, O'ahu	100	
96742	Kalawao, Molokai	100	
96705	Eleele-Kalaheo, Kauai	100	
96741	Eleele-Kalaheo, Kauai	100	
96714	Hanalei, Kauai	100	
96722	Hanalei, Kauai	100	
96754	Hanalei, Kauai	100	
96746	Kapaa, Kauai	90	CDP population distribution: Kapaa, Wailua-Anahola
96716	Kaumakani-Hanapepe, Kauai	100	
96747	Kaumakani-Hanapepe, Kauai	100	
96769	Kaumakani-Hanapepe, Kauai	100	No CML fishermen reporting on Ni'ihau
96752	Kekaha-Waimea, Kauai	100	
96796	Kekaha-Waimea, Kauai	100	
96756	Koloa-Poipu, Kauai	100	
96765	Koloa-Poipu, Kauai	100	
96766	Lihue, Kauai	85	CDP population distribution: Lihue, Puhi
96769	Ni'ihau, Kauai	0	No CML fishermen reporting on Ni'ihau
96715	Puhi-Hanamaulu, Kauai	100	

Zip Code	CCD	% Allocation	Rationale
96766	Puhi-Hanamaulu, Kauai	15	CDP population distribution: Lihue, Puhi
96703	Wailua-Anahola, Kauai	100	
96746	Wailua-Anahola, Kauai	10	CDP population distribution: Kapaa, Wailua-Anahola
96751	Wailua-Anahola, Kauai	100	
96748	East Molokai, Molokai	100	
96708	Haiku-Pauwela, Maui	95	Google Map
96708	Hana, Maui	5	Google Map
96713	Hana, Maui	100	
96732	Kahului, Maui	98	Population Distribution: Kahului, Sprecklesville
96733	Kahului, Maui	100	
96753	Kihei, Maui	100	
96790	Kula, Maui	100	
96761	Lahaina, Maui	100	
96767	Lahaina, Maui	100	
96763	Lanai, Lanai	100	
96768	Makawao-Paia, Maui	100	
96779	Makawao-Paia, Maui	100	
96784	Makawao-Paia, Maui	100	No residents in Puunene, assigned to neighboring Makawao-Paia
96788	Makawao-Paia, Maui	100	
96732	Puunene, Maui	0	No residents in Puunene
96784	Puunene, Maui	0	No residents in Puunene, assigned to neighboring Makawao-Paia
96732	Spreckelsville, Maui	2	Population Distribution: Kahului, Sprecklesville
96793	Waihee-Waikapu, Maui	32.6	CDP Population Distribution: Waihee-Waikapu, Wailuku
96793	Wailuku, Maui	67.4	CDP Population Distribution: Waihee-Waikapu, Wailuku
96729	West Molokai, Molokai	100	
96757	West Molokai, Molokai	100	
96770	West Molokai, Molokai	100	

Appendix C. Index Scores

Table C. Index score values.

Community	Island Group	Housing Char.	Labor Force	Personal Disruption	Population Comp.	Poverty	Occupation Diversity	Fishing Engagement	Fishing Reliance	Natural Hazard Risk
Hilo, Hawai'i	HI	-0.74	0.24	-0.48	-1.29	-0.23	-3.22	0.98	-0.67	1.17
Honokaa-Kukuihaele, Hawai'i	HI	-0.66	-1.52	-0.34	-0.68	-2.15	-5.08	-0.75	-0.80	-0.33
Kau, Hawai'i	HI	-0.23	0.26	0.13	0.47	0.63	5.93	-0.36	3.25	0.67
Keaau-Mountain View, Hawai'i	HI	-0.33	0.03	-0.05	-0.62	0.14	5.04	-0.27	-0.34	1.67
North Hilo, Hawai'i	HI	-0.61	-0.39	-0.68	-2.32	-1.88	-17.96	-0.91	-1.08	-0.33
North Kohala, Hawai'i	HI	-1.20	-1.95	-1.50	-1.05	-1.59	0.05	-0.59	1.30	0.33
North Kona, Hawai'i	HI	-0.70	-1.35	-0.96	-1.66	-1.65	4.30	3.09	2.28	0.87
Paauihau-Paauilo, Hawai'i	HI	-0.65	-1.85	-1.21	-1.41	-1.30	-2.14	-0.87	-0.52	-0.33
Pahoa-Kalapana, Hawai'i	HI	-0.49	1.04	-0.21	-0.20	0.04	7.11	-0.69	0.43	0.67
Papaikou-Wailea, Hawai'i	HI	-0.63	0.27	-0.62	-0.84	-0.10	1.17	-0.88	-0.43	-0.33
South Kohala, Hawai'i	HI	-1.32	-2.11	-1.52	-1.06	-1.88	-4.39	-0.04	-0.18	0.67
South Kona, Hawai'i	HI	-0.28	-0.53	-1.09	-1.82	-1.47	1.72	0.03	3.14	0.07
Ewa, O'ahu	HI	-1.97	-0.59	-1.70	-1.03	-2.07	1.85	2.38	-1.57	0.00
Honolulu, O'ahu	HI	-0.43	-0.41	-1.59	-1.94	-1.61	-7.57	10.27	0.25	0.00
Koolauloa, O'ahu	HI	-1.46	-1.23	-1.55	-1.34	-1.93	-0.97	-0.63	-1.46	0.67
Koolaupoko, O'ahu	HI	-2.47	-0.42	-1.68	-1.13	-1.79	-5.41	0.91	-0.88	0.42
Wahiawa, O'ahu	HI	-1.96	0.57	-0.88	0.44	-0.54	6.23	-0.42	-1.02	-4.33
Waialua, O'ahu	HI	-1.75	-0.54	-0.77	0.23	-1.28	1.85	-0.55	-0.39	1.17
Waianae, O'ahu	HI	-0.99	0.17	0.96	1.61	0.43	8.91	0.18	-0.64	0.00
Kalawao, Molokai	HI	1.94	-1.96	-2.49	-2.63	-2.84	-34.21	-0.94	-2.14	NA
Eleele-Kalaheo, Kauai	HI	-1.16	-1.72	-1.72	-0.49	-2.07	-1.04	-0.70	-0.57	-0.33
Hanalei, Kauai	HI	-1.10	-0.78	-1.36	-1.48	-1.53	-5.05	-0.05	1.20	-0.08
Kapaa, Kauai	HI	-0.78	-0.68	-1.28	-0.24	-1.14	3.92	-0.26	1.02	0.67
Kaumakani-Hanapepe, Kauai	HI	-0.37	-1.92	-1.31	-1.43	-2.74	10.18	-0.82	1.02	-0.33
Kekaha-Waimea, Kauai	HI	-1.07	-0.96	-1.53	-0.99	-1.04	2.53	-0.53	1.49	-0.33

Community	Island Group	Housing Char.	Labor Force	Personal Disruption	Population Comp.	Poverty	Occupation Diversity	Fishing Engagement	Fishing Reliance	Natural Hazard Risk
Koloa-Poipu, Kauai	HI	-0.60	-1.31	-1.33	-0.87	-1.93	-0.18	0.09	1.36	-1.33
Lihue, Kauai	HI	-0.60	0.26	-1.28	-1.39	-0.81	-0.17	-0.04	0.89	-0.33
Puhi-Hanamaulu, Kauai	HI	-1.16	-1.45	-1.10	-1.13	-1.94	1.83	-0.70	-1.43	0.17
Wailua-Anahola, Kauai	HI	-1.48	-1.01	-1.05	-1.91	-1.42	1.36	-0.86	-1.69	-0.33
East Molokai, Molokai	HI	-0.10	0.44	1.31	-1.21	0.61	3.88	-0.56	0.60	-0.83
Haiku-Pauwela, Maui	HI	-1.11	-1.22	-0.78	-0.29	-1.88	-3.01	-0.77	-0.91	-0.33
Hana, Maui	HI	0.10	-1.67	-1.04	-0.14	-2.73	-1.36	-0.57	4.40	-0.47
Kahului, Maui	HI	-0.53	-0.94	-0.99	-0.42	-1.52	2.43	0.25	-0.68	0.67
Kihei, Maui	HI	-0.37	-2.17	-1.25	-1.54	-1.42	-3.27	-0.25	-1.12	0.67
Kula, Maui	HI	-1.07	-0.58	-1.65	-3.02	-0.79	-6.51	-0.77	-1.18	-0.58
Lahaina, Maui	HI	0.11	-2.58	-0.98	-1.43	-2.40	-0.82	-0.10	-0.91	0.47
Lanai, Lanai	HI	-0.41	-3.09	-1.43	-0.93	-2.80	-4.88	-0.56	1.06	-1.21
Makawao-Paia, Maui	HI	-1.35	-0.84	-0.84	-1.04	-1.84	1.83	-0.13	-0.63	0.67
Spreckelsville, Maui	HI	-2.20	-0.90	-1.95	-2.02	-2.93	1.83	-0.93	-0.89	0.67
Waihee-Waikapu, Maui	HI	-1.68	-1.52	-1.48	-1.34	-2.45	-3.64	-0.58	0.22	0.33
Wailuku, Maui	HI	-0.84	-1.17	-0.60	-0.24	-1.96	1.97	-0.21	-1.16	0.67
West Molokai, Molokai	HI	-0.17	-0.20	-0.20	-0.67	0.17	-0.30	-0.88	-0.63	-1.19
Agana Heights, Guam	GU	0.01	-0.18	0.20	0.87	1.62	-1.55	NA	NA	NA
Agat, Guam	GU	0.42	0.91	1.88	1.38	1.80	4.54	NA	NA	NA
Asan, Guam	GU	-0.51	-0.05	-0.12	0.61	1.73	-0.52	NA	NA	NA
Barrigada, Guam	GU	-0.44	-0.06	0.02	0.49	1.53	2.49	NA	NA	NA
Chalan Pago-Ordot, Guam	GU	-0.29	0.03	0.29	0.79	1.18	1.37	NA	NA	NA
Dededo, Guam	GU	0.16	-0.43	0.90	0.54	1.54	5.63	NA	NA	NA
Hagåtña, Guam	GU	0.65	0.06	1.00	1.16	1.35	7.38	NA	NA	NA
Inarajan, Guam	GU	0.53	0.27	0.70	1.11	1.84	4.65	NA	NA	NA
Mangilao, Guam	GU	0.10	-0.08	0.86	0.75	1.60	3.82	NA	NA	NA
Merizo, Guam	GU	-0.06	0.30	2.07	1.89	1.96	2.10	NA	NA	NA
Mongmong-Toto-Maite, Guam	GU	0.07	0.27	1.51	1.77	1.99	4.58	NA	NA	NA
Piti, Guam	GU	-1.58	-0.13	-0.61	0.31	1.42	-5.52	NA	NA	NA
Santa Rita, Guam	GU	-1.20	0.58	-0.80	-0.26	1.25	-0.75	NA	NA	NA

Community	Island Group	Housing Char.	Labor Force	Personal Disruption	Population Comp.	Poverty	Occupation Diversity	Fishing Engagement	Fishing Reliance	Natural Hazard Risk
Sinajana, Guam	GU	-0.13	0.21	0.74	1.22	1.52	3.92	NA	NA	NA
Talofofo, Guam	GU	-0.83	0.04	0.43	0.47	1.41	2.37	NA	NA	NA
Tamuning, Guam	GU	0.12	-0.50	-0.40	-0.44	1.02	3.51	NA	NA	NA
Umatac, Guam	GU	0.42	1.18	2.52	2.82	2.45	5.80	NA	NA	NA
Yigo, Guam	GU	0.06	-0.18	0.54	0.40	1.44	6.78	NA	NA	NA
Yona, Guam	GU	-0.49	0.23	0.99	1.27	2.09	-0.83	NA	NA	NA
Rota	MP	1.27	-0.25	0.53	0.07	0.91	1.37	NA	NA	NA
Saipan (1)	MP	1.75	1.04	2.49	0.75	1.36	5.71	NA	NA	NA
Saipan (2)	MP	2.06	0.68	2.32	0.71	1.48	6.06	NA	NA	NA
Saipan (3)	MP	1.96	0.01	1.05	0.12	1.22	0.36	NA	NA	NA
Saipan (4)	MP	1.17	-0.14	1.90	0.42	1.04	1.68	NA	NA	NA
Saipan (5)	MP	1.31	0.60	2.12	0.60	1.25	0.97	NA	NA	NA
Tinian	MP	2.01	-1.70	1.11	0.44	1.21	-6.18	NA	NA	NA
Ituau, Tutuila	AS	1.14	1.83	1.26	1.86	1.67	9.11	NA	NA	NA
Ma'oputasi, Tutuila	AS	1.26	2.05	1.51	2.03	1.93	10.64	NA	NA	NA
Sa'ole, Tutuila	AS	1.62	2.12	1.61	1.90	1.89	9.56	NA	NA	NA
Sua, Tutuila	AS	0.92	1.87	0.41	1.66	1.50	7.87	NA	NA	NA
Vaifanua, Tutuila	AS	2.01	2.04	1.09	1.92	1.65	6.66	NA	NA	NA
Faleasao, Manu'a	AS	1.70	2.18	0.54	2.05	1.28	1.06	NA	NA	NA
Fitiuta, Manu'a	AS	1.81	3.31	2.53	1.40	1.73	3.21	NA	NA	NA
Ofu, Manu'a	AS	1.91	2.42	1.65	1.03	0.29	-0.80	NA	NA	NA
Olosega, Manu'a	AS	2.07	3.20	2.39	1.74	1.32	-14.69	NA	NA	NA
Ta'u, Manu'a	AS	-0.65	3.58	0.92	2.07	2.13	-4.73	NA	NA	NA
Swains Island	AS	7.25	3.62	-3.02	-1.98	-2.67	-85.06	NA	NA	NA
Lealataua, Tutuila	AS	1.22	1.82	1.54	1.55	1.75	8.74	NA	NA	NA
Leasina, Tutuila	AS	1.43	1.95	2.74	1.82	2.08	8.19	NA	NA	NA
Tualatai, Tutuila	AS	1.52	1.93	1.68	1.63	1.99	8.25	NA	NA	NA
Tualauta, Tutuila	AS	1.12	1.61	0.97	1.55	1.89	7.47	NA	NA	NA

Availability of NOAA Technical Memorandum NMFS

Copies of this and other documents in the NOAA Technical Memorandum NMFS series issued by the Pacific Islands Fisheries Science Center are available online at the PIFSC Web site <http://www.pifsc.noaa.gov> in PDF format. In addition, this series and a wide range of other NOAA documents are available in various formats from the National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161, U.S.A. [Tel: (703)-605-6000]; URL: <http://www.ntis.gov>. A fee may be charged.

Recent issues of NOAA Technical Memorandum NMFS–PIFSC are listed below:

- NOAA-TM-NMFS-PIFSC-64 A survey design performance analysis examining linkages between reef fish assemblages and benthic morphologies in the main Hawaiian Islands.
K. D. GOROSPE and T. S. ACOBA
(November 2017)
- 63 Economic and social characteristics of the Hawaii small boat fishery 2014.
H. I. CHAN and M. PAN
(May 2017)
- 62 Injury determinations for marine mammals observed interacting with Hawaii and America Samoa longline fisheries during 2010-2014.
A. L. BRADFORD and K. A. FORNEY
(March 2017)