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1. Introduction

Changing coastal environments can have varying impacts on coastal fishing communities. Much interest today is being directed at potential changes due to projected global climate change as well as variations in availability of the natural resources upon which the communities depend. These variations can be directly related to climate change, but also to factors such as increasing human use or harvesting of the resources, pollution, and/or other natural or anthropogenic influences, including restricted access due to management efforts. Independent of the sources of variation, it is assumed that different coastal communities will manifest varying degrees of vulnerability and resilience to the changes.
Vulnerability and *resilience* to change constitute one commonly understood framework for assessing community response to change. While these terms resonate with the public (e.g., resilience plans have largely replaced sustainability plans for coastal communities, see CNRWG 2014), there have been a wide range of conceptual definitions proposed depending on the context, disciplinary focus or personal preference. Increased concern with the impacts that changing coastal environments can have on coastal fishing communities, led to a recent effort by NOAA Fisheries social scientists to develop a set of indicators of social vulnerability and resilience for the U.S. Southeast and Northeast coastal communities (see Jepson and Colburn 2013, Jacob et al. 2010, Jacob et al. 2013).

The NOAA Fisheries indicators define vulnerability as the pre-existing characteristics of a community that create or negate the potential for harm, including conditions such as powerlessness and marginality of physical, natural, and social systems (re. Cutter et al. 2008, Adger 2006). Resilience, meanwhile, is a social system's ability to cope well prior to a disturbance and its ability to respond to, and recover from, a disturbance (Cutter et al. 2008). This includes returning to a *desirable* state (see Cinner et al. 2012, McClanahan and Cinner 2012, Cutter et al. 2009, Pollnac et al. 2008, Abesamis et al. 2006) rather than simply returning to the same pre-disturbance state (see Gibbs 2009, Folke 2006, Walker et al. 2004, Carpenter et al. 2001).

The use of indicators to measure vulnerability and resilience at the community level facilitates policy decisions aimed to address changing conditions in coastal communities. Quantitative measurements based on secondary data are cost effective and more easily incorporated into policy frameworks than traditional ethnographic methods. Recent focus on holistic approaches, such as ecosystem-based management, have increased interest in the development and use of indicators for efficiently incorporating socioeconomic aspects into fishery regulatory efforts (Gibbs 2009, Jacob et al. 2013). In the United States (US), Social Impact Assessment (SIA) for proposed changes to fishery management regulations is a required component under the National Environmental Protection Act of 1969 (NEPA; 42 U.S.C. § 4321 et seq.) for all Environmental Impact Statements (EISs). Further, National Standard 8 of the Magnuson-Stevens Fishery Conservation and Management Act of 1976 (MSA; 16 U.S.C. § 1801 et seq.) mandates social and economic analysis that takes into account the importance of fishery resources to fishing communities (16 U.S.C. §1851(2)(8)). Until the advent of the NOAA Fisheries indicators, there had been limited quantitative data with which to effectively conduct comparative SIA analysis on a large scale.

Previous analyses show that the vulnerability/resilience indicators developed by NOAA Fisheries manifest a great deal of variability across geographical regions (see Jepson and Colburn 2013, Jacob et al. 2013). Accounting for this variability could potentially result in more effective efforts to manage resources and improve coastal communities' response to changes. For this reason, it is important to determine if any patterns exist to the observed variations. Recognition of patterns may enable managers to more efficiently obtain data for management decision making (cf. Smith et al. 2011) and to develop policy plans appropriate for groups of communities that exhibit similar levels of resilience/vulnerability based on comparable indicators.

In this paper, methods of numerical taxonomy based on cluster analysis are used to combine fishing communities into relevant subgroups, i.e., clusters based on the communities' scores on the vulnerability/resilience indices developed by NOAA Fisheries (Jepson and Colburn 2013). However, as Smith et al. (2011) point out, numerical taxonomy techniques can sometimes provide unreliable results. There are two primary reasons for this: first, unless all attributes of the element to be classified are used (which is impractical), human decision making is involved in the process; second, there are many techniques used in numerical taxonomy, and the method selected can influence the results (e.g., Brusco and Kohn 2008, Frey and Duek 2007). For this reason, it was considered essential to establish the external validity of the cluster analysis obtained in the present study against several independent data sets, a process herein referred to as "ground-truthing."

The main purpose of this paper is to demonstrate the utility and validity of using a set of previously developed vulnerability and resilience indicators derived from secondary data to classify a very large sample of commercial and/or recreational fishing communities into subgroups composed of communities manifesting similar profiles with regard to the vulnerability and resilience indicators. Our purpose is not to discuss the details and implications of the profiles, but to determine the validity of the subgroupings by ground-truthing a sub-set of clusters that were characterized by varying social vulnerability/resilience profiles and dependence on commercial and/or recreational fishing activity. The assumption is that if the subgroupings are composed of communities manifesting very similar social vulnerability/resilience profiles then the clusters could be used to stratify sampling to efficiently select a sub-set of communities representing social vulnerability/resilience profiles of interest for in-depth analysis. This is an important consideration given the frequently limited time frame within which SIAs are conducted.

The processes for development of the initial dataset using the vulnerability/resilience indicators, as well as the cluster analysis and ground-truthing methods are described in the following section. Results of the cluster analysis and ground-truthing processes are presented separately. Finally, findings derived from the two processes are compared and discussed, emphasizing the applicability of the numerical taxonomic methodology to policy making in coastal fishing communities.

2. Methods

2.1. The Initial Dataset

The initial dataset for the cluster analysis was developed by NOAA Fisheries social scientists by taking a set of social, demographic, and fishery variables (listed in Table 1) and transforming them via a factor analysis (see Jepson and Colburn 2013). The grouped indicators comprise 12 vulnerability/resilience indices (see Table 1) for 1,130 fishing communities along the U.S. coast from Maine to Texas reporting commercial and/or recreational fishery landings in 2010. Factor analyses were then conducted on all 12 variable sets (indices), each resulting in a single factor. Because the factor analyses are of previously constructed indices, the scales are not necessarily unrelated unlike what would be expected in an orthogonally rotated principal component analysis of the raw vulnerability/resilience data.

Table 1
The 12 Vulnerability/Resilience Indices developed by NOAA Fisheries social scientists and indicators comprising each index

Personal Disruption Index	**Population Composition Vulnerability Index**
Percent unemployed	Percent white alone
Percent in poverty	Percent female single headed households
Crime index	Population age 0-5
Percent females separated	Percent that speak English less than well
Percent with no diploma	
Labor Force Structure Index	**Poverty Index**
Percent females employed	Percent receiving assistance
Percent population in the labor force	Percent of families below poverty level
Percent self employed	Percentage over 65 in poverty
Percent people receiving social security	Percentage under 18 in poverty
Housing Characteristics Index	**Urban Sprawl Index**
Median rent in dollars	Population density
Median mortgage in dollars	Nearest city w/50k population in miles
Median number of rooms	Cost of living index
Percent mobile homes	Median home value
Retiree Migration Index	**Natural Amenities Index**
Households with one or more over 65	Rental vacancy rate
Percent receiving social security	Percent homes vacant
Percent receiving retirement income	Boat launches by population
Percent in labor force	Percentage water cover
Recreational Fishing Reliance Index	**Recreational Fishing Engagement Index**
Recreational fishing mode charter by population	Recreational charter fishing pressure
Recreational fishing mode private by population	Recreational private fishing pressure
Recreational fishing mode shore by population	Recreational shore fishing pressure
Commercial Fishing Reliance Index	**Commercial Fishing Engagement Index**
Value of landings by population	Value of landings
Number of commercial fishing permits by population	Number of commercial fishing permits
Dealers with landings by population	Number of dealers with landings
Percent in forestry, farming and fishing occupation	Pounds of landings

The factor scores (standardized) for each vulnerability/resilience index for each community are used as the measures of vulnerability and resilience in the analysis presented here. Due to skewing, most of the indicators had to be transformed before conducting further analysis (Tabachnik and Fidell 2007; see *Supplementary Materials*, Appendix I for details).

The transformed indices were then reduced using factor analysis to facilitate interpretation of results involving the ground-truthed communities. The patterns of relationships between the index scales can be seen in Table 2. The principal component analysis of the indices demonstrated that 4 components accounted for 75 percent of the variance in the data set. Indices with the highest loadings for each component are identified as shaded cells. Variables on each component are coherent with each index's component variables. Each component was named to reflect the content of highly loading vulnerability/resilience indices. The *Social Problems* component includes indices composed of variables such as high levels of poverty, crime, low education, high unemployment, inadequate affordable housing conditions, low English proficiency, high numbers of single parent households, etc. The *Gentrification* component includes high levels of employment (both male and female), high levels of retirees receiving retirement income and social security, the presence of natural and manmade amenities that attract tourists such as boat ramps, seasonal rentals, more water frontage, etc. The *Commercial* and *Recreational Fishing* components reflect different aspects of dependence on fishing (Table 2).

Table 2
Results of a principal component analysis of transformed (T) vulnerability/ resilience indices (varimax rotation).

Transformed Indices	**Social Problems**	**Gentrification**	**Recreational Fishing**	**Commercial Fishing**
Poverty T	0.848	-0.054	-0.041	0.153
Personal Disruption T	0.817	-0.207	0.058	-0.001
Housing T	-0.661	-0.200	0.246	-0.475
Population Vulnerability T	0.617	-0.547	0.031	-0.107
Labor Force T	0.004	0.919	0.020	0.029
Retiree Migration T	-0.100	0.899	0.076	-0.089
Natural Amenities T	-0.124	0.611	0.222	0.336
Recreational Fishing Engagement T	-0.072	0.100	0.941	0.015
Recreational Fishing Reliance T	0.010	0.135	0.930	0.032
Commercial Fishing Reliance T	0.031	0.108	-0.116	0.895
Commercial Fishing Engagement T	0.150	-0.082	0.283	0.775
Urban Sprawl T	-0.469	-0.221	0.389	-0.502
Percent Variance	**20.652**	**20.873**	**17.645**	**16.973**

2.2. The Cluster Analysis

As a means of combining the fishing communities into relevant subgroups to be used for efficiently obtaining data for management decision making, K-means cluster analysis (Hartigan and Wong, 1979) was used. The K-means procedure categorizes the communities into a selected number of groups by simultaneously maximizing between group (or cluster) variation and minimizing within group variation. The transformed vulnerability/resilience indices data was used as input to the cluster analysis. The procedure first selects the same number of "seeds" as the number of groups desired. The "seeds" selected are as far (1-Pearson's r used as distance measure) as possible from the center of all the cases, or centroid[1]. Then all cases are assigned to the nearest "seed," and cases are reassigned to other clusters, as needed, to reduce within-groups sum-of-squares.

The number of clusters selected was based on an iterative procedure starting with a relatively low number, examining the output, then increasing the number if it was believed, based on the authors' knowledge, that a number of communities considered dissimilar were categorized into a single cluster. This iterative procedure resulted in the use of 35 clusters as the requested number. Detailed results of the analysis are in the *Supplementary Materials* Appendix II. The f-ratios in the first table in the *Supplementary Materials* Appendix II indicate that differences for each vulnerability/resilience index across the 35 clusters are statistically significant, which is expected given the procedure used. The remaining tables in Appendix II provide basic statistics for each community in each cluster for each of the 12 transformed vulnerability/resilience indices (maximum, minimum, mean, and standard deviation) as well as a "distance" of each community from the centroid of the cluster. This information can be used to compare the communities with others in the same cluster and can be used to efficiently select communities for more in-depth SIA analysis. The distance from the centroid can explain some differences in characteristics between communities within the same cluster.

2.3. Ground-truthing the Clusters

The ground-truthing method used here is similar to that used in Smith et al. (2011). Communities were selected from a sub-set of clusters that were characterized by varying degrees of social vulnerability/resilience and dependence on commercial and/or recreational fishing activity. They were selected to represent clusters containing major communities from both the North and South Regions and were chosen based on expert knowledge and secondary data of communities' characteristics. The ten ground-truthed communities were located in nine different clusters identified in Table 3, along with background variables for mean age, gender, percent of commercial fishermen (commercial fisherman, boat owner, fleet manager), and percent of respondents in fishing related occupations[2]. A series of open-ended questions were posed to a sample of approximately 40 individuals in each of the ten communities (Sample size ranges from 22 to 69 with a total sample of 391, see Table 3).

[1] The centroid is the average of all variables for all cases in the cluster and is used as the reference point for calculating the distances to other clusters or objects in the cluster.
[2] Recreational charter boat owners, operators; seafood dealers, processors; fishing supply shop owners, workers; fishing vessel dealers, builders, repair; etc.

Table 3
Selected background variables for the 10 ground-truthed communities

Community	Cluster	Male %	Comm. Fishers %	Fishing Related %	Age (mean)	N
Barnegat Light, NJ	22	83.0	17.0	25.5	49.1	47
Cushing, ME	4	81.8	18. 2	13.6	46.3	22
Narragansett/Point Judith, RI	22	69.6	30.4	17.4	48.1	69
New Bedford, MA	34	86.7	13.3	03.3	50.8	30
Newport, RI	21	73.0	24.3	05.4	49.7	37
Ocean City, MD	14	70.8	22.9	31.3	44.67	48
Seabrook, NH	25	80.6	19.4	16.1	50.27	31
Stonington, ME	10	70.0	30.0	13.3	53. 7	30
Virginia Beach, VA	18	73.3	26. 7	23.3	44.8	30
Wanchese, NC	32	83.0	14.9	19.1	43.8	47
N	-	-	-	-	-	**391**

The questions analyzed in this paper are found below. They are based, for the most part, on open-ended questions successfully used in Smith et al. (2011). Questions in parenthesis were used as clarifying prompts if a respondent could not readily answer the initial question.

1. If you were to list a few things that characterize this community, what would they be? (Or when you think about this community, what comes to mind?)
2. What are three important issues facing this community today?
3. Has the community tried to make adjustments (i.e. laws, zoning, or regulations) to address the issues that you have mentioned? How so?
4. Has this community changed over the past 5-10 years? How? What are the most significant changes in your estimation?
5. Has the community addressed the changes you mentioned? How? Or have they promoted this change?
6. IF NO CHANGES ARE MENTIONED: Why do you think this community hasn't changed?
7. Would you say that this community is a fishing community? On a scale of 1 to 10 how much do you think this community depends upon fishing economically?

As a first step in the analysis, responses to questions 1 through 6 were content analyzed. Distinct responses were coded separately then sub-categorized into nine categories reflecting the content of the response: 1) fishing, 2) physical environment, 3) social, 4) infrastructure, 5) economic, 6) tourism, 7) recreation, 8) retirement, and 9) other (containing relatively rare or idiosyncratic responses that fit into none of the preceding 8 categories). Open-ended responses to each of the 6 questions resulted in multiple statements, each being coded separately into the appropriate category for that question. For example, in response to one question, a person could state six aspects that they felt characterized their community, and all six would be coded into the appropriate categories. All six responses could refer to one category, or each could refer to a different category. Hence, for each question, each respondent was evaluated with regard to the number of responses referring to each of the nine categories. Values for questions 1 through 6 were summed into total values, which reflect the total number of times the respondent referred to each of the nine categories described above. Values were not normally distributed; therefore comparisons between distributions of the categories across the ten communities were analyzed using Kruskal-Wallis H, a non-parametric analysis of variance.

3. Results

Methods of numerical taxonomy were used as a data reduction technique to combine 1,130 fishing communities into 35 clusters each representing a unique combination of social vulnerability/resilience and commercial and/or recreational fishing dependence characteristics. Select communities from nine different clusters were ground-truthed to establish the external validity of the taxonomy method. The results of the cluster analysis and ground-truthing exercise are discussed separately.

3.1. Cluster Analysis

Thirty-five clusters are challenging to compare for an overall view of the results. To facilitate this comparison, we conducted a second hierarchical cluster analysis using the initial 35 K-means clusters (distance measure 1-Pearson's r, average link) (Figure 1). The numbers on the left in Figure 1 are those associated with the initial clusters listed in the *Supplementary Materials* Appendix II. For example, starting with clusters containing many communities familiar to the authors, we can examine aspects of the three clusters grouped together at the bottom of Figure 1: Cluster 21 (*15 communities, including Newport, RI, Boston, MA, and Portsmouth, NH*), Cluster 22 (*8 communities, including Narragansett/Point Judith, RI, Gloucester, MA, and Montauk, NY*), and Cluster 34 (*8 communities, including Miami, FL, New Bedford, MA, and Portland, ME*). All the communities in the clusters are contained in the *Supplementary Materials* Appendix II.

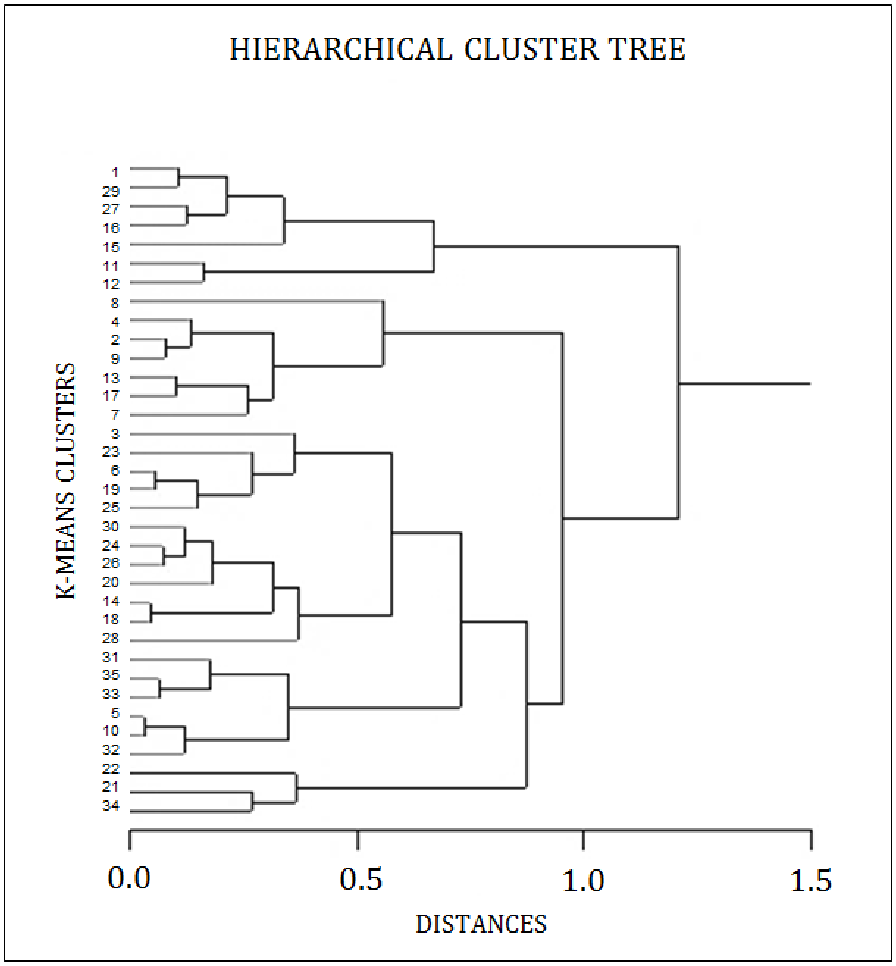

Figure 1.
Hierarchical cluster analysis of the 35 K-means clusters of communities (Distance measure 1-Pearson's r, average link)

Patterns of similarity between the clusters, as well as their differences, can clearly be observed in the mean, non-transformed values for the 12 vulnerability/resilience indices for these three clusters (Figure 2). The plots are meant to illustrate that the cluster technique functioned to group communities that were different with regard to the secondary data and that the technique can be used to select communities representative of the different levels of measurement on the complex combinations of secondary data based indicators included in the analysis as described above. Clusters 34 and 21 manifest the smallest differences on all but commercial fishing engagement—supporting the greater level of similarity indicated in Figure 1. Cluster 22, in contrast, is high on all of the four fishery indicators.

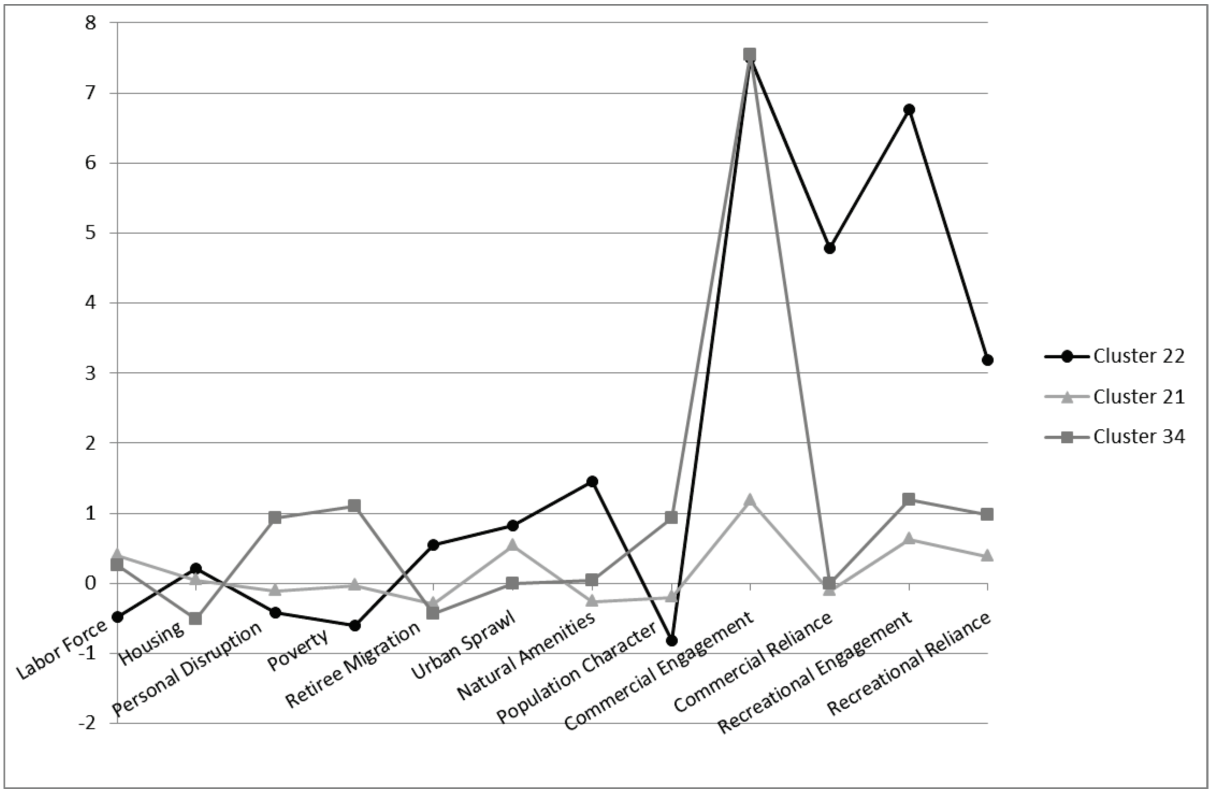

Figure 2.
Non transformed mean values for the 12 vulnerablity/resilience indices for K-means clusters 21, 22 and 34

For those interested in greater detail, the *Supplementary Materials* Appendix III provides additional plots of mean values for the indices for K-Means clusters within selected hierarchically derived clusters.

The analyses above indicate that the cluster analysis performed is internally consistent with the indices used, suggesting that the NOAA Fisheries vulnerability/resilience indices can be successfully used to classify communities into meaningful groups. However, further evaluation of the methodology is required through testing it against a different set of data. In this study, a method referred to as ground-truthing is used (cf. Smith, et al. 2011).

3.2. Ground-truthing

As noted above, ten communities, representing nine of the initial 35 K-means clusters were chosen for ground-truthing. Analysis comparing the ten communities with regard to the eight categories of responses to the ground-truthing questions indicates that the communities are statistically significantly different from each other in all categories, with all probabilities equal to or less than 0.001 (Table 4).

Table 4
Mean values for total number of times selected categories were mentioned by community members in response to ground-truthing questions

Community	Fishing	Physical Environ.	Social	Infra-structure	Economic	Tourism	Recreation	Retirement
Barnegat Light, NJ	1.319	0.553	1.872	1.106	0.277	0.596	0.064	0.000
Cushing, ME	0.773	0.318	3.000	0.636	0.455	0.182	0.045	0.182
Narragansett/ Point Judith, RI	0.928	1.159	1.072	1.333	0.768	0.870	0.275	0.000
New Bedford, MA	1.767	0.267	2.200	1.100	1.367	0.133	0.067	0.000
Newport, RI	0.649	0.730	1.189	1.595	1.135	1.324	0.243	0.000
Ocean City, MD	1.708	0.813	1.438	1.688	0.979	1.729	0.167	0.063
Seabrook, NH	0.839	0.645	1.935	2.258	1.323	0.194	0.000	0.000
Stonington, ME	1.533	0.367	2.533	0.700	0.733	0.600	0.000	0.233
Virginia Beach, VA	0.600	1.300	1.133	2.200	1.433	1.000	0.167	0.033
Wanchese, NC	3.319	0.128	1.830	0.532	1.213	0.064	0.064	0.000
Kruskal-Wallis H	**93.216**	**79.961**	**50.327**	**49.174**	**46.704**	**109.012**	**28.266**	**36.921**
p (N=391)	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**0.001**	**<0.001**

Turning to fishery related responses, Table 5 presents an analysis of level of economic dependence on fishing (on a scale of 1 to 10, based on responses to question 7) as well as percent distribution of responses to the direct question: "Would you say that this community is a fishing community?" coded "yes," "somewhat" and "no." Responses to both questions displayed in table 5 can be considered ordered on an ordinal scale, hence non-parametric analysis of variance (Kruskal-Wallis H) was used to test if there were significant differences across the ten communities.

Table 5
Mean values for fishing dependency and percent distribution of community members' perceptions of their town as a fishing community

Community	**Fishing Dependency**	**Perception of town as fishing community**		
	Scale 1-10	% not a fishing community	% somewhat a fishing community	% fishing community
Barnegat Light, NJ	7.489	0.000	8.511	91.489
Cushing, ME	7.682	0.000	22.727	77.273
Narragansett/Point Judith, RI	5.667	15.942	20.290	63.768
New Bedford, MA	7.196	3.333	6.667	90.000
Newport, RI	4.071	54.286	17.143	28.571
Ocean City, MD	6.585	12.500	6.250	81.250
Seabrook, NH	4.464	25.806	22.581	51.613
Stonington, ME	8.867	0.000	0.000	100.000
Virginia Beach, VA	4.571	36.667	10.000	53.333
Wanchese, NC	8.713	0.000	0.000	100.000
N	**374**	**56**	**44**	**289**
Kruskal-Wallis H	**151.805**	**102.944**		
p	**<0.001**	**<0.001**		

Other important descriptive features of the communities that were related to vulnerability and resilience mentioned in response to question 1 include aspects of social solidarity (e.g., "tight knit community," "sense of community," "all work together," etc.) and/or if they regarded the town as being peaceful and quiet ("quiet," "not a party town," "peaceful," "quiet living," "peace and tranquility," etc.). Important issues mentioned in question 2 include crime ("drugs," "crime," "domestic violence," "gangs," etc.), traffic ("traffic congestion," "traffic control," "road construction," "road quality," "need parking space," "illegal parking," etc.), employment ("less jobs," "unemployment rate," "need more work for people," etc.), taxes ("rising taxes," "taxes are high," "property taxes," etc.), and the economy ("economy affecting prices," "the economy in general," "everyone is broke," etc.). Once again, non-parametric analysis of variance (Kruskal-Wallis H) was used to test if there were significant differences across the ten communities (Table 6). Once again, the analysis indicates statistically significant differences between the communities on all selected categories except for Economic Issues (see Table 6). This was not surprising since it referred to the poor state of the U.S. economy in general and therefore was likely to have similar effects on most communities.

Table 6
Mean values for selected town characteristics and issues mentioned by community members in response to ground-truthing questions

Community	Social Solidarity	Peaceful & Quiet	Crime Issues	Traffic Issues	Job Issues	Tax Issues	Economic Issues
Barnegat Light, NJ	0.319	0.404	0.000	0.000	0.000	0.000	0.000
Cushing, ME	0.136	0.500	0.182	0.000	0.000	0.000	0.000
Narragansett/ Point Judith, RI	0.014	0.087	0.000	0.159	0.072	0.087	0.087
New Bedford, MA	0.000	0.000	0.467	0.033	0.000	0.000	0.067
Newport, RI	0.216	0.027	0.000	0.270	0.054	0.108	0.054
Ocean City, MD	0.208	0.042	0.000	0.083	0.063	0.021	0.083
Seabrook, NH	0.194	0.226	0.129	0.161	0.161	0.000	0.032
Stonington, ME	0.300	0.367	0.133	0.100	0.000	0.067	0.067
Virginia Beach, VA	0.000	0.000	0.000	0.300	0.133	0.033	0.133
Wanchese, NC	0.319	0.149	0.128	0.021	0.000	0.000	0.128
Kruskal-Wallis H	18.646	40.657	66.601	32.953	23.181	17.061	10.814
p (N=391)	**0.028**	**<0.001**	**<0.001**	**<0.001**	**0.006**	**0.048**	**>0.050**

Finally, all ten ground-truthed communities were plotted based on the four dimensions defined by the principal component analysis of the 12 transformed vulnerability/resilience indices (social problems, gentrification, and commercial and recreational fishing) (Figures 3 and 4). This was accomplished by calculating scores on each component for each community and plotting their locations in two three-dimensional plots. Figure 3 shows the three dimensional relationship between commercial fishing, gentrification and social problems components for all ground-truthed communities. Figure 4 illustrates relationships between the same two social vulnerability/resilience components and the recreational fishing component.

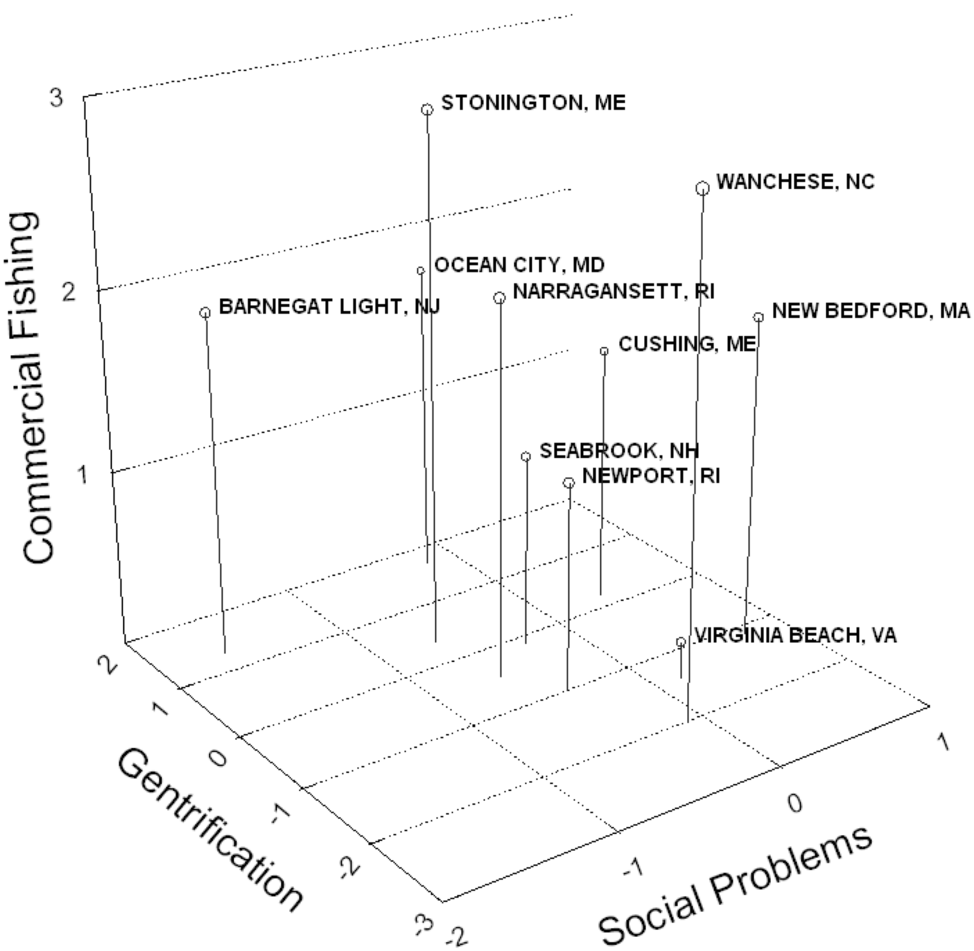

Figure 3
Three dimensional plot of ground-truthed communities' scores on three of the four components derived from the vulnerability/resilience indices defined in table 2: commercial fishing, gentrification, and social problems

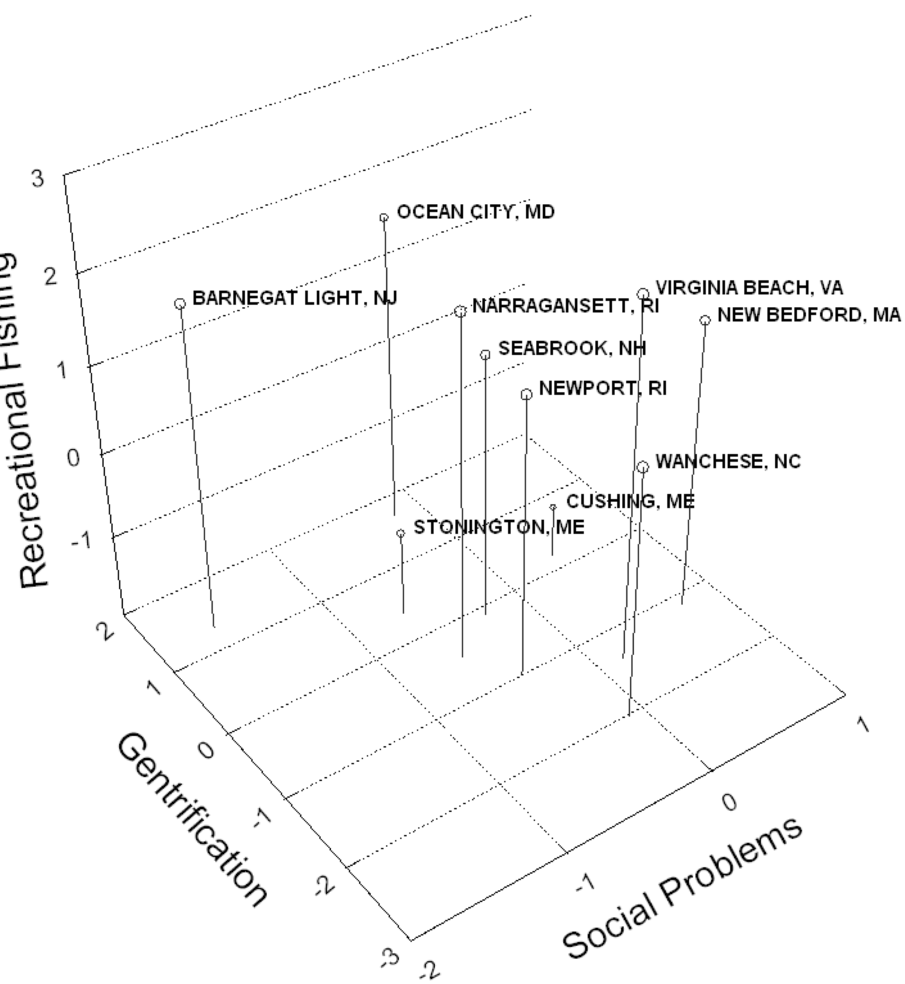

Figure 4
Three dimensional plot of ground-truthed communities' scores on three of the four components derived from the vulnerability/resilience indices defined in table 2: recreational fishing, gentrification, and social problems

4. Discussion

Application of the NOAA Fisheries social vulnerability/resilience indices to classify coastal communities was used to create a numerical taxonomy of fishing communities. The initial K-means cluster analysis resulted in grouping 1,130 fishing communities along the coast from Maine to Texas into 35 clusters. An examination of the distributions of the vulnerability/resilience indicators across the clusters indicated that the clustering process formed groupings of communities that were similar in terms of the variables used. Nevertheless, it was important to determine if the clusters manifested some external validity—if members of clusters are also distinct from members of other clusters with regard to important variables not included in, or determined in a different manner (ethnographic interview) than the indices used in the cluster analysis. To this end, a group of communities from nine different clusters were visited and open-ended questions were posed to obtain community members' perceptions of important aspects of their community (ground-truthing). The content analyses of their responses clearly indicated that the communities are, in fact, different along dimensions deemed important in assessing community vulnerability/resilience—issues concerning fishing, tourism, crime, social solidarity, and infrastructure, among others.

A comparison between results of the ground-truthing and the community scores on the four dimensions developed through a principal component analysis of the NOAA Fisheries vulnerability/resilience indices (see figures 3 and 4) reveal important similarities that further support the classification of communities proposed in this study. For example, New Bedford, MA which presents the highest score for the component social problems is also the community that presents the highest frequency of community members' responses mentioning crime issues. Stonington, ME and Wanchese, NC, the communities with the highest scores in the commercial fishing component were the only two communities that were characterized as being "a fishing community" by every community member interviewed. Ocean City, MD and Barnegat Light, NJ, the communities with the highest scores on the gentrification component, present high combined frequency of responses mentioning aspects of physical environment, tourism, and recreation, factors that can be associated with gentrification pressure.

Two of the communities ground-truthed, Narragansett/Point Judith, RI and Barnegat Light, NJ, belonged to the same cluster (cluster 22, see *Supplementary Materials* Appendix II). In figures 3 and 4 it is clear that these two communities presented virtually identical scores in both the commercial and recreational fishing components derived from the NOAA indicators, which most likely contributed to the grouping of the two communities in the same cluster. However, ground-truthing results revealed some differences in how these communities were characterized by residents. Narragansett/Point Judith was more frequently characterized by aspects related to recreation, tourism, economy, infrastructure and physical environment (see table 4) and "traffic issues" (see table 6), while Barnegat Light was more frequently described by fishing and social aspects (see table 4 and 5) and aspects of "social solidarity" and "peace and quiet" (see table 6). Some differences between communities belonging to the same cluster can be expected. Ground-truthing results are based solely on community members' subjective perceptions of aspects that characterize their town and can differ from results using the more objective NOAA vulnerability/resilience indices. Further, Narragansett/Point Judith is almost twice as distant from the centroid of cluster 22 as is Barnegat Light, which could account for some of the differences observed.

The statistically significant differences found between the ten communities based on ground-truthing results, as well as similarities found between community characteristics from the ground-truthing analysis and communities' scores on the vulnerability/resilience indices, support the use of the taxonomic method presented in this study. The few differences found between the ground-truthing results and the vulnerability/resilience indices reflect differences between community members' perceptions of the conditions in their community and the more objective NOAA indicators derived from secondary data. People's perceptions can be influenced by sudden and temporary changes. Also, and not unexpectedly, community members value aspects and issues that are different from those identified by researchers and policy makers. Nonetheless, collecting ethnographic information on community members' perceptions of issues and aspects important to them and their communities is valuable and can guide the development of new indicators that will improve objective measures in the future.

5. Conclusions

This study examined the effectiveness of grouping communities by comparing results of cluster analysis with ground-truthing data collected by interviews and survey instruments. A goal of the NOAA Fisheries social vulnerability/resilience indicators program is to support efficient use of available data in furtherance of effective SIAs and climate change adaptation planning. The use of the vulnerability/resilience indicators to predict the response to change in coastal communities can be enhanced by effectively grouping community level analyses.

Creation and validation of 35 clusters indicates that the clusters are adequate to be used to select communities for in-depth research. When structuring SIAs for management purposes, where the management impacts should take into account community vulnerability and resilience, this set of clusters will prove invaluable. Reduction of 1,130 communities to 35 clusters of similar communities will allow NOAA Fisheries researchers and managers to allocate more time to obtaining in-depth information (e.g. surveys, ethnographies), facilitating more accurate and timely SIAs concerning projected changes in the fishery, and implementing and improving climate change adaptation planning.

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