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Development and evaluation of social indicators of vulnerability and resiliency for fishing communities in the Gulf of Mexico

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ABSTRACT

With the devastating impacts of Hurricanes Katrina and Rita, and more recently the Deepwater Horizon oil spill, disaster questions about the vulnerability and resiliency of fishing communities in the Gulf of Mexico have been on the minds of local, regional, and national governmental agencies as well as numerous researchers and non-governmental organizations. The continued natural and now technological disasters in the Gulf of Mexico have placed a great deal of strain on communities dependent upon both commercial and recreational fishing. In 2008 a two-year long study to develop social indicators of vulnerability and resiliency for fishing-reliant communities in the Gulf of Mexico was undertaken. In addition, as part of the research design the accuracy of the social indicator descriptions of these places with ethnographic studies was triangulated. Comparisons of the combined ethnographic rankings with the quantitative indicators were positive and statistically significant. The research design thus confirmed that the developed indicators were, in fact, reliable measures for the concepts under consideration.

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1. Introduction

1.1. Potential indicators vulnerability and resilience for fishing communities

Developing empirical measures of vulnerability and resilience has tremendous potential to help identify communities that would be adversely impacted by future disasters, economic challenges, and regulatory decisions. Indices of vulnerability and resiliency might prove useful in disaster response planning before events occur. In addition, this information could be very useful in a social impact assessment framework for local governments, regional agencies, and national planning. The major advantage of this approach is that it does not require an expensive and time consuming ethnographic study. However, the external validity of such an approach has not been established. The purpose of this project is to establish if a social indicator approach to the concepts of vulnerability and resilience has validity and merit in policy applications.

The FAO Technical Guidelines for Responsible Fisheries promotes the use of indicators to monitor sustainability and other measures of well-being [1]. While there has been substantial progress in the development and implementation of sustainability indicators for marine fisheries at the national and regional levels, "there has been little attention paid to establishing frameworks at the local or community level" [1:238]. Associated with the idea of sustainability are the concepts of resilience and vulnerability, which have seen increasing use with regard to coastal hazards at the community level [2], but not with regard to fishing communities. Yet, in light of the recent devastation to Gulf Coast fishing communities after hurricanes Katrina and Rita and the Deepwater Horizon oil spill, assessing vulnerability and resilience is especially important for fishing dependent communities [3].

In this work, vulnerability refers to the [4:76] and resiliency refers to the extent to which a system can return to a functional level after a disturbance and the time it takes to do so [5–7]. The concepts of resiliency and vulnerability are often thought of as being linked on a continuum from vulnerable to resilient. Scholars have debated the appropriateness of this coupling [8,9]. Theoretically, vulnerability and resiliency should be different concepts because a vulnerable community does not necessarily lack resilience and vice versa [10]. However, pragmatically they are, in fact, often measured on a continuum with the assumption that vulnerable communities will be less resilient and will need outside resources to recover from disasters [10–12]. This research takes this latter approach.

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Table 1
Factors that comprise community vulnerability and resiliency.

Social vulnerability and resiliency	
	Clusters of indicators
	Population composition
	Poverty
	Housing characteristics
Economic vulnerability and resiliency	
	Economic structure
Ecosystem/natural environment resiliency	
	Natural disasters
	Technological disasters
Social disruption	
	Housing disruptions
	Economic disruptions
	Personal disruptions

The literature identifies four primary forms of vulnerability/resiliency: (1) Social; (2) Economic; (3) Ecosystem/natural environment; and (4) social disruption (Table 1) (see for example [2,13,14]). Several quantitative indicators for each of these constructs are identified below. The cluster of indicators in Table 1 are empirical components of the broader domains of vulnerability/resiliency identified in an extensive review of literature from the project report which forms the basis of this study [19]. The operationalization of these indicators is detailed in the methods section. In the results section the ethnographic findings in comparison to the social indicators to establish the external validity of these measures are described.

2. Methods

A key policy goal of our research was to design a method that fisheries managers could use to assess potential impacts of disruptions on fishing communities which was both reliable and conscious of time and budget constraints. Although National Marine Fisheries Service has conducted ethnographic assessments of fishing communities, these are expensive and comparison among communities is difficult. Assembling a secondary data base, creating indices, and profiling communities through empirical data are techniques that are much faster than conducting traditional community profiling through ethnography. However, secondary data indicators would mean nothing if the results were not representative of community conditions. For these reasons, a separate ethnographic team visited the nine primary study communities. Both the indicator development and ethnography are described below. These descriptions are necessarily brief in the interest of a fuller description of our findings. For a more complete discussion, please see [15,16,19] which describe our methods more fully.

2.1. Social indicator indices development strategy

Three steps were taken to develop the social indicator indices that were identified in the review of literature (Table 1). First, Pearson's r correlation coefficients of potential variables were examined to find underlying patterns of variation that suggested that individual variables might be used to compose a concept of interest. Second, the variables that were most highly intercorrelated and reflected the range of ideas of interest were placed in a principal components analysis, where these variables were then determined to be measuring a single latent construct with sufficient association to be reliable. Last, the variables were standardized and weighted for their effects in the model. Index factor scores were used. Factor scores are similar to composite scores with the exception that the items are standardized and weighted in regard to their factor loadings. The factor loadings are a rough indication of correlation of the domain concept's latent structure to the single variable. Therefore items that are most important in an index receive a higher weighting than a less important item. In principal components, factor loadings less than .350 are generally not considered to be significant and, in most cases, should be removed from a factor scale [17]. One advantage of factor scaling is that negative relationships do not have to be reverse coded before scaling. This means that negative factor loadings work to reduce the overall score and the absolute number conveys the strength of relationship regardless of being negative or positive. The interpretation of a negative factor loading is similar to a negative Pearson's r bivariate correlation. The factor scores were standardized with a mean of zero and the scores reflecting standard deviations from that mean. Scales were subsequently tested for internal consistency by using [17] theta reliability for factor scales. The theta coefficient is interpreted similarly to Cronbach's Alpha, and is used for factor scales because it does not assume that all items are weighted equally in the scale. Theta is calculated as: $\theta=[p/(p-1)]*[1-(1/\lambda)]$, where p=the number of items in the scale and where λ denotes the largest eigenvalue from the principal component analysis.

To establish internal reliability, multiple indicators for each concept are necessary. At a minimum, it is necessary to include enough variables to fully cover the range of the concept, while maintaining unidimensionality (only measuring one central concept). In general, multiple measures are preferred and do increase internal validity when the items are significantly intercorrelated. However, as more variables are added to the index it is harder to maintain unidimensionality. Unidimensionality, in part is established by principal components analysis. In a principal components analysis, a single factor solution provides evidence that the various index items only measure a single concept. The indices in this study range from a low of four items to a high of seven items. Indices with three or fewer items are generally thought to be insufficient to establish internal validity through Cronbach's Alpha or Armor's Theta. Description of the components of each index, the principal components analysis and factor loadings, and measures of internal validity including the eigenvalue, percentage explained variation, and Armor's Theta Reliability is given below.

2.2. Community selection and inclusion in the data set

There were two groupings of communities primarily based on estuaries that were selected for study. In the Gulf of Mexico, on or near Galveston Bay, were the communities of Seabrook, San Leon, Galveston, Texas City, and Bacliff. In the Gulf of Mexico, on or near San Antonio Bay, were the communities of Port Lavaca, Sea Drift, Port O'Connor, and Palacios on Matagorda Bay. Because ethnographic studies are time intensive and expensive only nine communities are included in the qualitative research design. However, nine communities would not provide sufficient variation in the data for reliable index development, it was decided to include all communities in the county and adjacent counties to the nine primary study sites. This resulted in a data set with 122 different communities and provided sufficient variation for index development. All 122 communities were scored for each index. Only the scores for the nine study communities are reported. The low to high rankings are among the nine communities only and based on the factor score for each community for the tabled index. These nine communities that are reported in the tables are also the location of the ethnographic study sites.

2.3. Data set characteristics and sources

The data set in this research was compiled from four separate data sources. The primary source for population and housing

information was the U.S. Bureau of the Census 1990 and 2000 Decennial Census, Summary Tape File 3. Very current population estimates and real estate value was downloaded from the website "City-Data.com" which uses proprietary estimates based on U.S. Census data for inter-decennial population estimates and local tax records for estimating real estate values. The data for natural disaster risks was downloaded from "Moving.com" using a proprietary insurance database. Last, the data for technological disasters was downloaded from the Environmental Protection Agency's (EPA) website from the "EnviroMapper" store front.

2.4. Triangulation: Ethnographic assessment

The research design of this project called for triangulating the concepts of vulnerability/resiliency through comparing grounded ethnographic results with quantitative social indicators. The ethnography part of the project was designed to independently test for resilience and vulnerability of the communities in terms of the place and importance of the commercial and recreational fishing sectors within them. Ethnographic field research consisted of unstructured interviews with fishers, individuals whose businesses were related to fishing, community officials, and economic and real estate developers; compilation of historical and contextual background information; and a survey of fishing infrastructure.

2.5. The evaluation of the indicators strategy

The purpose of this project was to develop and evaluate social indicators based on secondary data to measure the concepts of vulnerability and resiliency. The evaluation strategy relied upon two simultaneous and independent processes. The social indicators were developed concurrent with field work. The field work was a grounded emergent process of discovery of the concepts of vulnerability and resiliency as they relate to each study site.

The social indicator process was quantitative, relying solely on secondary numerical data. There were no field visits and no interviews with local residents in this process. As such, the indicators lost some of the context of place and the complexity that exists in the local milieu. However, it was possible to develop indicators for over 120 places in a relatively short time period (though only the results of the nine ethnographic study sites are reported here). Quantitative measures usually have a high degree of reliability. In this case, the constructs were measured identically in all communities. However, external validity can suffer in these circumstances, in as much as the constructs or concepts may not relate to actual community conditions.

This research sought to develop indicators that were generalizable to all study communities in regard only to the specific concepts of interest and to combine information on areas of agreement across all communities to develop commonality in the concepts. Such an approach downplays the differences, often treating them as errors or outliers, a sacrifice made so that generalizability can be achieved. Reducing community processes to a few key measures can obscure reality in a reductionist simplification. All of the above criticisms are not particular to this research but part of the general critique of normative science that is typically deductive, quantitative, and nomothetic.

The ethnographic process began with observations based upon open-ended interviews with key informants. In this sense, it fleshed out the concepts of vulnerability and resiliency in a grounded emergent process based on the reality of the interviewees. These observations were turned into summaries and then generalizations that appeared in the Summary of Ethnographic Results (Table 9).

The ethnographic process is also qualitative and descriptive of each community site. The data in this process consisted entirely of words based on interviews and personal observations. A major drawback to this process is that it is time consuming, expensive, and offers difficulty in both analysis and interpretation. A major advantage of a qualitative case study approach is that it has a high degree of external validity. That is to say the results reflect what is actually happening in the community. The emphasis on complete understanding implies intensive observation and data collection. As such, relatively few places can be studied and, therefore, generalizability to broader populations is sacrificed. While such case studies excel at providing converging emergent evidence of constructs, there may be issues with internal validity in as much as the link to the construct or concept of interest may not have been measured in a repeatable, reliable fashion. Thus there is a tension in research between validity and reliability. Quantitative research tends to be more reliable in that it uses repeated measures in a consistent way. This is less true of qualitative research which tends to build constructs from emergent findings.

A key concept in the measurement of constructs is the interchangeability of indicators. Any reasonable indicator of a construct should be correlated to other indicators of that same construct. In other words, if they are both measuring the same thing they should also strongly relate to one another in the same directional pattern. The degree that two differing indicators of the same construct relate to reality is usually referred to as construct validity. To establish construct validity, ideally the quantitative data in our project should be highly correlated with the qualitative data, which best reflects the objective conditions in the community.

2.6. Inter-rater agreement

Inter-rater agreement is the degree to which independent observers evaluate the characteristics of a subject and reach the same conclusion [18]. High level of agreement in ratings generally reflects the reliability of the standards and process. This is true especially if two different raters are applying the same criteria and reaching the same results. However, in this case there are two completely differing sets of criteria and processes. Here a high level of agreement reflects convergence of a construct with reality. In other words, rather than being a reflection of reliability (receiving the same results from repeated measures using the same criteria) it is a reflection of both construct and external validity (the link between a construct and observed reality).

There are some widely reported measures of agreement used to assess inter-rater reliability or agreement. They are percentage agreement, correlations based indicators such as Pearson's r or Spearman's rho, and Cohen's kappa. Each of these measures has some significant advantages and drawbacks but taken together they allow for a more complete assessment of inter-rater agreement. Percentage agreement is easily understood and has a straight forward interpretation but can be misleading. The percentage agreement is often inflated because a portion of agreement could be directly due to random matching. This is especially true with constructs with relatively few categories. For example, with three categories up to 11.1% (.333*.333 or 1 in 3*1 in 3) of agreement could be due to random matching. Correlational techniques measure covariation but not the extent in which there is identical agreement in the categories. Bivariate correlations are generally interpreted in analysis to be substantial above 0.6. The last statistic used is Cohen's kappa that measures inter-rater agreement and ranges from -1.0 to 1.0. The closer the number is to 1.0 the greater agreement is above and beyond random matching. If the number is approaching zero then the level of agreement is close to what would be expected by chance.

If the number is below zero and approaching −1 then the agreement is less than what would be expected by just random matching.

Cohen's kappa is calculated by taking the percentage of agreement [Pr(a)] and subtracting the probability of random agreement [Pr(b)], divided by one minus the probability of random agreement [Pr(a)-Pr(e)/1-Pr(e)]. The probability of random agreement is calculated by dividing 1 by the number of categories for rater one and multiplying it by 1 divided by the number of categories [Pr(e)=1/k*1/k where k=the number of categories for the rater]. Cohen's Kappa is generally interpreted with the following framework: less than zero=no agreement; 0 to 0.20=slight agreement; 0.21 to 0.40=fair agreement; 0.41 to 0.60=moderate agreement; 0.61 to 0.80=substantial agreement; and 0.81 to 1.0=almost perfect agreement. A t value can be calculated for kappa by dividing the kappa value by the asymptotic standard error when the null hypothesis is true (the true value is 0). This t value has an associated statistical probability that is often reported. While both percentages and correlation techniques tend to be liberal and over-assess levels of agreement, Cohen's kappa is considered a very conservative measure and underestimates the strength of agreement. This is because it only includes exact matches as agreement, when often misses are only a category off and the raters are actually in relative agreement. It is possible to use a weighted kappa statistic to account for close misses but it is not commonly done and the statistic is not included in any major software packages.

2.7. Coding issues for the secondary data indicators

To ensure content validity with the constructs of vulnerability and resiliency, multiple indicators were developed (1) population composition, (2) poverty, (3) housing characteristics, (4) labor force, (5) natural and technological disasters, (6) housing disruptions, and (7) personal disruptions. To evaluate the agreement of the social indicators with the ethnographic research, it was necessary to code the indices into the same categories employed in the qualitative analysis. These categories were: (1) low, (2) medium, and (3) high. These categories were assigned on the basis of factor scores. The index score for each variable was arrayed for all 122 communities into thirds based on frequency. As such it is possible for all of the community study sites to be in the low, medium, or high category for any given index. Each separate community (N=122) was coded into one of the thirds (low, medium, or high) based on the index factor score, so the response categories within the nine communities are not evenly distributed (e.g., 3 lows, 3 mediums, and 3 highs).

To evaluate rater agreement it was necessary to condense the multiple indices for vulnerability/resiliency (seven indicators) into single assessments so as to be comparable to the ethnographic analysis. Ideally a single index measuring vulnerability/resiliency could be constructed to cover all the dimensions of the concept and still remain unidimensional. However, this could not be achieved with a satisfactory level of reliability and unidimensionality within the principal components analysis. The next effort involved summing the factor scores into a single score and then placing the scores into thirds to match the ethnographic categories. This was done and produced highly consistent results with the ethnographic data. However, such a summing of factor scores is inadvisable since each index is assumed to be of equal importance in the analysis, which is not likely to be the case. Several weighting schemes were also attempted via factor and canonical correlation analysis. All produced highly similar results, varying very little from the simple summation of the factor scores but adding a layer of complexity that was hard to analyze and discuss. Ultimately all efforts at summing the factor scores were abandoned due to methodological problems.

To produce a single score comparable with the ethnographic analysis, a simple modal response coding scheme was employed. In this case the number of high, medium, or low categories were added up and the category that occurred most frequently within a community was assigned to that community. In several cases there was a tie between the low and high categories, when that occurred the medium response was assigned. Since the categories were treated at the nominal level there were no issues with the weighting of indices. Additionally, the interpretation of the results is simple and straightforward. Last, such an approach has obvious face validity and produces results consistent with much more complicated procedures but with methodological flaws (see [15],[19]).

3. Indices and indexes

Below are the principal components analyses of the clusters of indicators presented in Table 1. For each index the frequencies of the variables, factor scores, and ranking for each community are presented. In addition for the analysis the Eigenvalue, percent explained variation, and theta reliability are also presented. In all cases the indices are unidimensional and have a strong underlying structure in relation to the concept that is being measured.

3.1. Population composition vulnerability/resiliency index

The population composition vulnerability/resiliency index (Table 2) consisted of seven variables: (1) percentage of whites in the community (range 57.1 to 90.4%), (2) percentage of female singled headed households (range 7.7 to 16.9%), (3) all parents in the household are in workforce with children under six years old (range 23.3 to 55.7%), (4) percentage that speak a language other than English in the home (range 14.6 to 49.9%), (5) percentage population less than 18 and greater than 65 (range 29.6 to 46.5%), (6) the percentage of high school graduates (range 58.2 to 92.7%), and (7) the percentage of college graduates (6.7 to 41.2%).

The principal components analysis produced a single factor solution with an eigenvalue of 2.698 with an explained variation of 44.974%. The Armor's Theta Reliability coefficient for this index was 0.755, which represents adequate levels of internal consistency. The factor loadings ranged from −0.408 to 0.944. The strongest loadings were for the variables percentage high school graduates (0.944), percentage college graduates (0.733), and percentage whites (0.715). All the factor loadings were above 0.350 and so were included in the index.

3.2. Poverty index

Poverty in the U.S. is defined by the Federal government using an absolute threshold. Individuals or families at or below the poverty threshold (line) are considered to be living in poverty. The threshold varies by time, location, and family size but in most areas of the U.S. in 2007 the line for a single individual was $10,590 and was $21,203 for a family of four. The poverty index (Table 3) incorporated five items into an index: (1) the percentage population in poverty in 2007 (range 5.5 to 25.1%), (2) the percentage population 50% below the poverty threshold in 2007 (range 3 to 13.5%), (3) the percentage of population over 65 in poverty in 2000 (range 2.3 to 16.3%), (4) the percentage under 18 in poverty in 2000 (range 6.1 to 33.5%), and (5) the cost of living index for 2008 (range 73.8 to 89.4).

The principal components analysis produced a single factor solution with an eigenvalue of 3.581. The explained variation for the model was 71.625%. The Armor's Theta Reliability coefficient

Table 2
The population composition vulnerability/resiliency index.

Community	Percent whites 2000	Percent female single headed HH	Both parents in work force w/ kids > 6 years	Percent speak other language 2000	Percent > 18 and < 65 2000	Percent high school 2000	Percent college	Population composition score	Ranking
Port Lavaca	71.9	13.7	55.4	40.3	42.4	68.1	17.7	−1.066	7
Seadrift	77.7	9.2	46.7	32.4	36.3	58.2	6.7	−1.238	8
Port O'Connor	90.4	7.7	45.2	22.4	45.5	70.6	11.8	−0.455	4
Palacios	57.1	13.4	23.3	49.9	46.5	57.2	12.6	−1.923	9
Seabrook	88.9	8.1	56.2	14.6	29.6	92.7	41.2	1.211	1
San Leon	80.4	7.3	32.1	22.4	33.3	76	11.9	−0.048	2
Galveston	58.7	16.9	55.7	26.5	37.1	74.4	23.7	−0.505	6
Texas City	60.3	7.4	41.2	15.4	42.2	77.1	11.2	−0.487	5
Bacliff	82.6	12	47.8	20.6	37.2	69.9	8.6	−0.322	3
PC components									
Factor loading	0.715	−0.408	0.661	−0.728	−0.486	0.944	0.733		
Theta reliability 0.755									
Eigenvalue 2.698									
Percentage explained variation 44.974		Single factor solution					High ranking = More resilient Low ranking = More vulnerable		

Table 3
The poverty index.

Community	Percentage population in poverty 2007	Percentage population 50% under line 2007	Percentage over 65 in poverty 2000	Percentage under 18 in poverty 2000	Cost of living index 2008 USA Avg = 100	Poverty index score	Ranking
Port Lavaca	20.1	8.6	14.7	25	75.6	1.221	5
Sea Drift	25.1	13.5	11.7	33.1	73.8	1.929	1
Port O'Connor	6.8	4.6	11.1	19.7	82.1	0.147	8
Palacios	24.2	9.9	14.3	28.9	75.4	1.563	2
Seabrook	5.5	3	5.1	6.1	88.8	−0.680	9
San Leon	19.7	11.9	2.3	33.5	86.8	1.090	6
Galveston	22.3	10.5	14.2	32.1	89.4	1.347	3
Texas City	15.2	4.2	11.3	19.3	85.5	0.324	7
Bacliff	21.7	8.9	16.3	30.6	84.8	1.322	4
PC components							
Factor loading	0.974	0.808	0.746	0.945	−0.601		
Theta reliability 0.900							
Eigenvalue 3.581							
Percentage explained variation 71.625			Single factor solution		High ranking = More vulnerable Low ranking = More resilient		

for the index was 0.900 which represents high levels of internal consistency for this index. The factor loadings from the principal component analysis ranged from −0.601 to 0.974. The strongest loadings in the analysis were for the percentage population in poverty in 2007 (0.974), the percentage under 18 in poverty in 2000 (0.945), and the percentage population 50% below the poverty line in 2007 (0.808).

3.3. Housing characteristics vulnerability/resiliency index

The housing characteristics vulnerability/resiliency index (Table 4) consisted of five items: (1) median rent in dollars in 2000 (range $430 to $635), (2) median mortgage in dollars in 2000 (range $546 to $1302), (3) median number of rooms in houses (range 4.1 to 5.1 rooms), (4) the percentage of houses with inadequate plumbing (range.2 to 1.7%), and (5)) house age in years 2008 (range 24 to 54 years).

The principal component analysis produced a single factor solution with an eigenvalue of 2.592 and an explained variation of 51.937%. The Armor's Theta Reliability coefficient for this index was 0.768 reflecting adequate levels of internal consistency. The factor loadings ranged from −0.361 to 0.884. The strongest loadings were for the variables median mortgage costs in dollars (0.884), median number of rooms per house (0.880), and median rent costs in dollars (0.841).

3.4. Labor force structure index

The labor force structure index (Table 5) consists of five variables (1) median household income in 2007 (range $31,623 to $63,507), (2) percent unemployed in 2007 (range 2.3 to 11.4%), (3) percent population in the labor force in 2000 (range 48.3 to 75.9%), (4) worker classification percent self employed in 2000 (5.6 to 26%), and (5) percent of population receiving supplemental security income (disability) (range 1.6 to 8.7%).

The principal component analysis produced a single factor solution with an eigenvalue of 2.392 and an explained variation of 47.834%. The Armor's Theta Reliability coefficient for this index was 0.727 reflecting adequate levels of internal consistency. The factor loadings for this analysis ranged from 0.351 to 0.883. The

Table 4
The housing characteristics vulnerability/resiliency index.

Community	Median rent in dollars 2000	Median mortgage in dollars 2000	Median number of rooms 2000	Houses with inadequate plumbing	House age in years 2008	Housing index score	Ranking
Port Lavaca	$430	$765	4.5	0.6	30	−0.705	5
Sea Drift	$455	$546	4.4	1.2	43	−1.511	1
Port O'Connor	$490	$596	4.4	1.5	36	−0.767	8
Palacios	$385	$863	4.7	0.5	39	−0.917	2
Seabrook	$635	$1302	4.8	0.2	24	−0.024	9
San Leon	$546	$877	4.1	0.4	33	−0.959	6
Galveston	$531	$929	4.4	0.6	54	−0.709	3
Texas City	$544	$867	5.1	0.9	41	−0.446	7
Bacliff	$576	$794	4.7	1.7	34	−0.918	4
PC components							
Factor loading	0.841	0.884	0.88	−0.599	−0.361		
Theta reliability 0.768							
Eigenvalue 2.592							
Percentage explained variation 51.937			Single factor solution		High ranking = More vulnerable Low ranking = More resilient		

Table 5
The labor force structure index.

Community	Median household income 2007	Percent unemployed 2007	Percent population in the labor force 2000	Class of worker self employed 2000	Percent people receiving SSI 2000	Economic structure Score	Ranking
Port Lavaca	$39,199	4.2	58.8	6.7	5.7	−0.925	7
Sea Drift	$36,742	5.8	48.3	8.5	5.4	−0.871	6
Port O'Connor	$47,854	5	51	26	6.4	−0.833	5
Palacios	$31,623	11.4	50.7	8.8	8.7	−1.618	9
Seabrook	$63,507	3	75.9	6.6	1.8	0.628	1
San Leon	$39,051	11.4	62.5	11.5	4	−0.671	3
Galveston	$35,610	10.1	59.7	5.6	5.3	−1.001	8
Texas City	$38,924	8.1	58.4	9.2	5.3	−0.802	4
Bacliff	$39,668	5.3	66.5	8.5	3.8	−0.513	2
PC components							
Factor loading	0.883	−0.672	0.351	0.741	−0.702		
Theta reliability 0.727							
Eigenvalue 2.392							
Percentage explained variation 47.834			Single factor solution		High ranking = More resilient Low ranking = More vulnerable		

strongest loading in the analysis were for the variables median household income (0.883), percentage of self employed workers (0.741), and percent people receiving supplemental security income (disability) (−0.702).

3.5. Natural and technological disaster risk index

The natural and technological disaster risk index (Table 6) consists of five variables: (1) standardized (U.S. average = 100) damaging hail risk (range 57 to 154), (2) standardized (U.S. average = 100) damaging hurricanes risk (range 355 to 499), (3) standardized (U.S. average = 100) damaging tornadoes (range 45 to 473), (4) standardized (U.S. average = 100) damaging winds (range 13 to 127), and (5) Environmental Protection Agency Registered Facilities (range 2 to 212).

The principal components analysis produced a single factor solution with an eigenvalue of 3.232 and an explained variation of 64.632%. The Armor's Theta coefficient for this index was 0.869 reflecting high levels of internal consistency. The factor loadings for this analysis ranged from 0.368 to 0.868. The strongest loadings were for the variables damaging hurricanes (0.868), damaging hail (0.867), and damaging winds (0.727).

3.6. Housing disruptions index

The housing disruptions index (Table 7) consists of six variables: (1) percentage change in median rent 1990 to 2000 (range −6.1 to 47.7%), (2) percentage change in median mortgage costs 1990 to 2000 (range 24 to 92.3%), (3) percentage change in home values 2000 to 2007(range 42.7 to 80.4%), (4) percentage change in number of renters 1990 to 2000 (−41.2 to 48%), (5) percentage of residents who moved into their current house in 1999–2000 (range 15.5 to 33.6%), and (6) percentage of residents who moved into their current house in 1995–1998 (range 24.3 to 35.3%).

Table 6
The natural and technological disaster risk index.

Community	Damaging hail risk average USA AVG=100	Damaging hurricanes risk average USA AVG=100	Damaging tornadoes risk average USA AVG=100	Damaging winds risk average USA AVG=100	EPA registered facilities	Potential disaster score	Ranking
Port Lavaca	77	355	110	15	20	−1.237	7
Sea Drift	57	371	45	13	2	−1.561	9
Port O'Connor	57	371	45	13	2	−1.581	8
Palacios	76	398	104	33	5	−0.894	6
Seabrook	130	442	468	92	8	1.241	4
San Leon	132	465	429	92	6	1.549	3
Galveston	100	499	265	69	189	0.982	5
Texas City	140	488	349	127	212	1.824	1
Bacliff	154	458	473	105	8	1.666	2
PC components							
Factor loading	0.867	0.868	0.579	0.727	0.368		
Theta reliability 0.869							
Eigenvalue 3.232							
Percentage explained variation 64.632			Single factor solution		High ranking=More vulnerable Low ranking=Less vulnerable		

Table 7
The housing disruptions index.

Community	Percentage change median rent 2000	Percentage change median mortgage 2000	Percentage change in property values 2007	Percent change in no of renters 2000	Percentage moved into house 1999–2000	Percentage moved into house 1995–1998	Housing disruptions score	Ranking
Port Lavaca	29.1%	53.0%	52.3%	−5.7%	19.8	29.4	−0.495	5
Sea Drift	47.7%	32.2%	80.4%	−22.9%	19.7	30.3	0.326	2
Port O'Connor	−6.1%	92.3%	42.7%	−31.5%	15.5	29.9	−1.746	9
Palacios	19.2%	74.3%	49.4%	−6.7%	20.5	32	−0.866	7
Seabrook	46.7%	64.2%	56.4%	−41.2%	33.6	35.3	0.895	1
San Leon	30.3%	41.0%	66.4%	48.0%	21.1	29.8	−0.920	8
Galveston	39.4%	24.0%	66.4%	−2.8%	27.6	29.2	0.136	4
Texas City	32.2%	48.9%	66.2%	−7.1%	19.4	24.3	−0.764	6
Bacliff	34.0%	31.2%	66.4%	−2.7%	27.5	29.2	0.173	3
PC components								
Factor loading	0.865	−0.543	0.792	−0.486	0.728	0.67		
Theta reliability 0.789								
Eigenvalue 3.088								
Percentage explained variation 44.108			Single factor solution		Low ranking=More vulnerable High ranking=More resilient			

The principal components analysis produced a single factor solution with an eigenvalue of 3.088 and an explained variation of 44.108%. The Armor's Theta Reliability coefficient for this index was 0.789 reflecting adequate levels of internal consistency. The factor loadings for the analysis ranged from −0.486 to 0.865. The strongest loadings in the analysis were percentage change in median rent (0.865), percentage change in home values (0.792), and percentage moved into house from 1999 to 2000 (0.728).

3.7. Personal disruption index

The personal disruption index (Table 8) consists of five variables: (1) percentage change in unemployment 1990 to 2000 (range −0.31 to 1.78), (2) percentage change in travel time to work 1990 to 2000 (range −0.31 to 1.22%), (3) number of registered sex offenders per 1000 population (range 1.27 to 6.87 per 1000 population), (4) percentage of population separated (range 1.7 to 4.4%), and (5) percentage of population that is divorced (range 8.5 to 17.7%).

The principal components analysis produced a single factor solution with an eigenvalue of 2.44 and an explained variation of 48.873%. The Armor's Theta Reliability coefficient for this index was 0.739 reflecting adequate levels of internal consistency. The factor loadings for this analysis ranged from −0.382 to 0.928. The strongest loading in the analysis were for number of registered sex offenders per 1000 population (0.928), percentage population separated (0.871), and percentage change in unemployment 1990–2000 (0.715).

4. Results

4.1. Ethnographic assessment

Community socioeconomic vulnerability was assessed by using historical and contextual information, including over 120 personal interviews. Each interview was coded and scored on a master sheet to record the rate and incidence of topics for all

Table 8
Personal disruption index.

Community	Percentage change in unemployment 1990–2000	Percentage change travel time to work 1990–2000	Number of registered sex offenders per thousand pop	Percentage separated population	Percentage divorced population	Personal disruptions score	Ranking
Port Lavaca	−0.31	0.22	3.24	3	11.2	−0.220	5
Sea Drift	0.38	1.22	2.22	2.7	13.4	−0.468	2
Port O'Connor	0.67	0.70	2.78	1.7	17.7	−0.172	9
Palacios	0.50	0.27	2.52	2.6	8.5	−0.309	7
Seabrook	−0.25	0.53	1.27	2	15.7	−0.849	1
San Leon	1.78	0.01	6.87	4.4	16.1	2.406	8
Galveston	0.80	0.19	2.67	3.6	12.6	0.508	4
Texas City	−0.28	0.15	3.16	3.2	13.1	−0.184	6
Bacliff	0.00	−0.31	4.45	3	15.1	0.591	3
PC components							
Factor loading	0.715	−0.381	0.928	0.871	0.409		
Theta reliability 0.739							
Eigenvalue 2.444							
Percentage explained variation 48.873			Single factor solution		High ranking = More vulnerable Low ranking = More resilient		

Table 9
Summary of ethnographic results.

Bacliff	Vulnerability: moderate. Bacliff is primarily composed of older homes and is a residential community with no large industry. It is near to the petrochemical facilities in Texas City, thus potentially exposed to a technological disaster. Given that Bacliff is not very dependent on fisheries, new or expanded regulations would not have a significant impact on the well-being of the community as a whole.
Galveston	Vulnerability: high. Galveston has a high proportion of people living in poverty. Its housing stock is old, and as a barrier island, it is prone to natural disasters. Galveston also depends on a few key resources economically, and it is very vulnerable to economic perturbations. Galveston is not very dependent on fisheries, and thus regulations would not have a big impact on the well-being of the community. However, due to Galveston's other vulnerabilities, displaced fishermen would have a difficult time.
Kemah/ Seabrook	Vulnerability: low. Kemah and Seabrook are primarily residential areas with the usual complement of shops, small businesses, superstores, and hotels that serve residents and visitors. There is no major industry in either city. The towns are primarily bedroom communities for commuters who work in nearby industry, the university, NASA or myriad businesses in downtown Houston. These communities are not very dependent on fisheries, and regulatory changes would have only a moderate impact on the communities as a whole. A diversified economy surrounds these communities. There are several industrial parks, a major port, and numerous government contractors within a 30 min drive.
San Leon	Vulnerability: high. San Leon is unincorporated. It has a large Vietnamese community, many of which are not fluent in English. The housing stock is mixed. There are large substantial houses along the bay, trailers and older recreational houses that are now permanent homes. The fishing industry is an important part of the economy to San Leon, and the decline of shrimp and crab has impacted the town. A majority of its housing stock was severely damaged during Ike and the town is still struggling.
Texas City	Vulnerability: medium. Texas City has a seawall that mitigates the impact of storm surges from hurricanes. It has a mixed stock of houses ranging from the early 1900s to very modern, and it is a diverse community with a range of ethnic and income groups. It is home to one of the oldest petrochemical complexes on the coast and was the site of a major disaster in the 1940s, and there have been several explosions since. Its proximity to these plants makes it vulnerable to technological disaster.
Port Lavaca	Vulnerability: low. Port Lavaca has a diversified economy that is a mix of mercantile, heavy industry, tourism, shipping and agriculture. Although its infrastructure is vulnerable to storms, as a community it has a diversified economy and population and could most likely rebound from a hurricane. It is not dependent on the fishery for a significant portion of its revenue and hence regulation would not severely harm the community as a whole. There are several chemical facilities close to Port Lavaca and thus the potential for exposure to technological disaster exists.
Seadrift	Vulnerability: high. Seadrift is unincorporated. It has a large Vietnamese community, many of which are not fluent in English. Seadrift has a legacy of conflict between Vietnamese and Anglo fishermen. The commercial fishery is in economic trouble, and a recreational fishery is not well established. There is one industrial facility across the bay from Seadrift and several more within an hour's drive.
Palacios	Vulnerability: high. Several families own most of the commercial fleet and employ both local and migrant labor. Dense social ties bind the members of the fishing community together. There is a large Vietnamese community in Palacios that is not fluent in English and unable to find employment outside of the fishery. There are some industrial opportunities within driving distance, but outside of the town. Many fishermen interviewed stated a reluctance to work in these plants, however, for fear of exposure to pollutants. Because Palacios is still dependent on fishing, it is vulnerable to regulatory changes and storms.
Port O'Connor	Vulnerability: high. Port O'Connor has few remaining commercial fishers, due to the combination of imports and gentrification. It has always been primarily a sport-fishery oriented community, but with gentrification, even the bait shrimpers are finding it difficult to find dock space or sell their catch. The recreational fishery is the economic driver of the community; hence, regulations aimed at the recreational sector would harm the community.

interviews and for each of the nine study communities. On the basis of all sources of data in the ethnography, three anthropologists individually ranked each community's vulnerability as low, medium or high. Their rankings matched in all nine cases. The summary results are given in Table 9. Community socioeconomic vulnerability depended fundamentally on economic diversification according to respondents. The communities with the greatest amount of economic diversification were ranked with the lowest

Table 10
Vulnerability/resilience indices.

Community	Pop Comp	Poverty	Housing	Labor force	Nat/tech disast	Housing disrupt	Personal disrupt	Quantitative modal response	Qualitative ethnographic assessment	Differing classification
Port Lavaca	High	High	Low	High	Low	Low	Low	Low	Low	
Sea Drift	High	High	Low	High	Low	High	Low	High	High	
Port O'Connor	High	Med	Low	High	Low	Low	Med	Low	High	*
Palacios	High	High	Low	High	Low	Low	High	High	High	
Seabrook	Low	Low	Med	Low	High	High	Low	Low	Low	
San Leon	Med	High	Low	High	High	Low	High	High	High	
Galveston	High	High	Low	High	High	Med	High	High	High	
Texas City	High	Med	Med	High	High	Low	Med	Med	Med	
Bacliff	Med	High	Low	High	High	Med	High	High	Med	*

Matched on 7 0 f 9 Communities, 77.8%
Spearman's rho=.608, P=.082
Kappa =.625, P=.005

vulnerability, and the communities dependent primarily on commercial fishing, recreational fishing, or heavy industry show high vulnerability according to respondents.

In spite of this emphasis on economic dependency relayed by informants, each community site also had residents that discussed other forms of vulnerability and resiliency in the open-ended interviews. These discussions were remarkably similar in each community but varied a great deal across research sites [see [19] for a detailed analysis]. For example, in Texas City many residents identified the primary vulnerability as the location of numerous petrochemical plants and refineries that have had disastrous explosions, spills, and releases in the past. This is quite different than the general theme of discussion in Port O'Connor where respondents saw vulnerability in the form of changing recreational fishing regulations that could have a large impact on that sector of their economy. Across all the nine ethnographic study communities there was broad evidence for the set of indices identified in the review of literature and operationalized in the social indicators utilized in this study.

4.2. Establishing external validity of the vulnerability/resiliency indicators with the ethnographic data

Table 10 presents the inter-rater agreement analysis for vulnerability/resiliency. The qualitative ethnographic approach produced an assessment that was very current and grounded in the perspective of community residents. The quantitative social indicators approach was dependent on information that is necessarily time lagged through data collection processing by agencies and organizations. Nonetheless the two techniques produced similar assessments. Seven of nine communities (77.78%) matched in their rankings of vulnerability/resiliency. Spearman's rho (a nonparametric measure of correlation) for vulnerability/resilience was 0.608 but was not statistically significant due to the small sample size (n=9). Cohen's kappa, a very conservative measure of association, was 0.625 and was statistically significant. This reflected a substantial agreement between the techniques even after removing the possibility of random matching that can occur among variables with relatively few categories.

5. Discussion and conclusions

In our nine study communities, the conditions that lead to resiliency and vulnerability varied. Both the ethnographic and quantitative approaches were sensitive enough to detect this variation and, in addition, there was a high level of correlation between the two differing approaches in describing community conditions. In the two communities where the assessments differ (Port O' Connor and Bacliff), one community classification missed by only one category (Bacliff — Medium and High assessments), and one was off by two categories (Port O' Connor — Low and High Assessments). The one category difference in Bacliff is less troubling than in Port O'Connor. Through the ethnography it was determined that conditions in Port O'Connor changed rapidly and the quantitative data was too insensitive to catch this rapid shift. However, in general it was found that the quantitative data was most useful in a comparative framework to identify places that over a period of time have risks associated with deficits of assets in the seven quantitative domains identified. This identification can be used to identify communities that would be disproportionately impacted by changes in the fishery, including allocations, regulatory changes, and closures. This approach lessons the impact of time obsolescence in the quantitative approach. The necessity of further ethnographic research when vulnerable communities are identified is a key finding of this work. The combination of quantitative and qualitative research offers the best use of resources to do effective social impact assessments in the communities that are most likely to experience the greatest impact. This can save considerable time and effort in the social impact assessment.

This approach has also proven useful for fisheries regulators. In the National Oceanic and Atmospheric Administration (NOAA) Fisheries Service Southeastern Regional Office (SERO) and Northeastern Regional Office (NERO) a project to duplicate the study indicators was undertaken. In this project social indicators of vulnerability and resilience were developed for coastal communities in the North Atlantic, South Atlantic, and Gulf of Mexico. The index development process relied upon updated data and produced indicators that were nearly identical to this study and often with similar levels of reliability. Further, a similar triangulation strategy is being utilized and may show similar levels of external validity. These results have encouraged further development of social indicators on a national level which will begin as a pilot study in the immediate future. The ultimate application of this social indicators approach will be to incorporate the social indicators into a social impact process and the indices in the SERO and NERO offices have already been used for this purpose. This approach has shown substantial promise for informing programmatic efforts and influencing regulatory policy to minimize negative impacts and maximize benefits.

In the near future it is very likely that fisheries management in the U.S. will move to a more ecosystems based framework. Without a doubt, the integration of socioeconomic factors into these models can be more readily achieved through quantitative indicators as presented here. In the past the reliance on

ethnographic profiles of fishing communities has limited the inclusion of socioeconomic information into the heavily quantitative ecosystem models that are based primarily on biological and economic data. The incorporation of social indicators will enhance the human dimension of this ecosystem approach.

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