Demographic and environmental conditions are uncoupled in the social–ecological system of the Pribilof Islands

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Abstract

Since the end of the commercial fur seal hunt in 1984, the economy of the Pribilof Islands, Alaska, has lacked a stable, lasting basis. As a contribution to the effort to understand and promote the effective management of the Pribilof Islands as a social–ecological system, we examined current and recent conditions on the islands to assess local perceptions of, and prospects for, economic, social and environmental well-being. We found few correlations between environmental conditions and socio-economic indicators. The lack of apparent connection between population levels and economic or environmental stimuli is likely attributable to one or more of several factors: (a) modest economic dependence on the environment; (b) predominance of other economic inputs to the economies of the islands; (c) islanders basing residence choices largely on non-economic factors; and (d) the islanders' tolerance for economic fluctuations and uncertainty. These results suggest economic analysis alone is insufficient to explain the dynamics of this social–ecological system, contrary to many other case studies and an expectation of tight coupling and clear connections between society and ecology in the Pribilofs.

The islands of St. Paul and St. George in the Pribilof Islands of Alaska, in the south-eastern Bering Sea (Fig. 1), have been inhabited by Aleuts since the late 18th century, when Russian traders brought them there to hunt northern fur seals (*Callorhinus ursinus*) for their pelts. The islanders have established a strong sense of identity and place, as demonstrated by their unwillingness to relocate when this was proposed in the 1960s (Jones 1980). Until commercial seal hunting ended on St. Paul in 1984 (having ceased earlier on St. George), it was the dominant economic activity on the islands. Since then, the people of the Pribilof Islands have engaged in commercial fishing, fish processing, fisheries support services, capital improvement projects, ecotourism and other activities, none of which has yet provided a lasting economic basis for the communities.

We recently conducted a study to compile existing data and gather new data on recent economic, social, demographic and ecological trends on the islands and the surrounding waters. The purpose of the study was to establish a social and economic baseline, against which further changes could be measured, in response to needs identified by the Pribilof Islands Collaborative, a consortium of organizations from the islands themselves, from the fishing industry and from the environmental community. This consortium seeks to develop cooperative solutions to common problems, and requires information on current social, environmental and regulatory conditions and systems. Although the study was not focused on resilience and vulnerability per se (see B.L. Turner et al. 2003; Walker et al. 2004; Ford & Smit 2004; Chapin et al. 2006), the data provide an opportunity to explore connections (or a lack thereof) between demographic trends and potential economic and environmental drivers.

Social–ecological systems have been assessed in light of resilience and vulnerability (e.g., Folke et al. 2003), drawing on concepts originally developed in ecology (e.g., Holling 1973). The term "resilience" has been used in a variety of ways (see Brand & Jax 2007 for further discussion), most typically meaning the ability of a system to experience change without losing the ability to return to its original state. By this definition, resilience is an internal property of the system in question. By contrast, "vulnerability" is often defined as a function of the sensitivity of a system to change, its exposure to change and its ability to adapt to change (e.g., McCarthy et al. 2001).

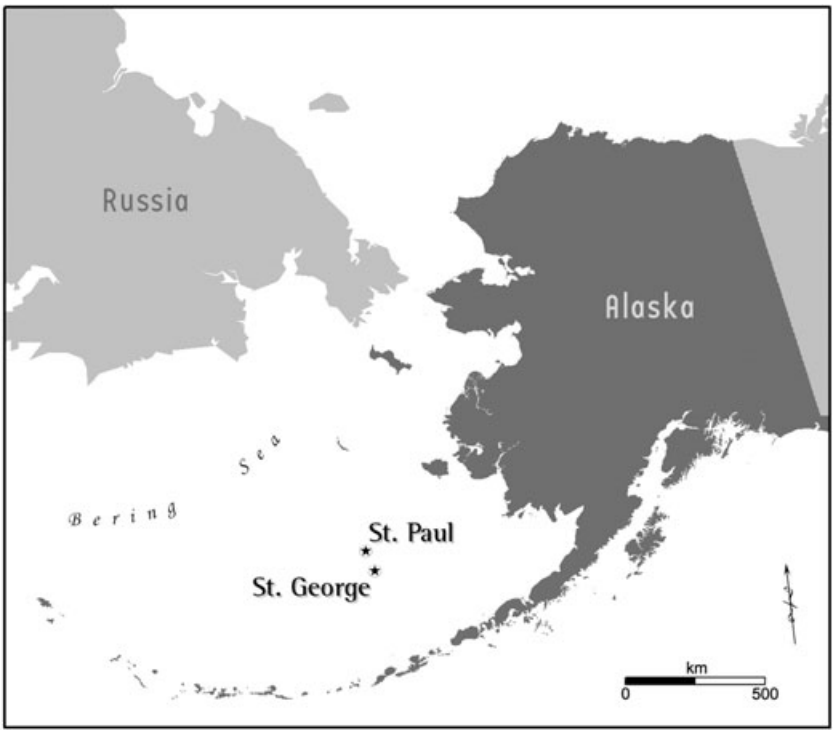

Fig. 1 Map of the south-eastern Bering Sea and the Pribilof Islands, showing the communities of St. George and St. Paul.

In this sense, vulnerability defines the relationship between a given system and the external factors that affect it (see, e.g., Ford et al. 2006: fig. 1).

Huntington et al. (2007), drawing on studies in the North Atlantic (e.g., Hamilton & Haedrich 1999; Hamilton et al. 2003; Hamilton, Colocousis et al. 2004; Hamilton, Jónsson et al. 2004) and the Kola Peninsula in north-western Russia (Voinov et al. 2004), suggest that population dynamics can provide quantitative indicators of social impacts and well-being. With this in mind, we use the data from St. Paul and St. George to identify population trends or patterns, and then to see if there are correlations between population dynamics and ecological or economic indicators for the islands. To put it another way, we use population levels as an indicator of resilience to a variety of economic and ecological stimuli—i.e., can the system resist change by retaining the same population level?—and as a basis for considering the implications for assessing the vulnerability of St. George and St. Paul to external shocks—i.e., is the system likely to be exposed to greater changes than it can cope with?

The results were less than clear-cut, perhaps reflecting insufficient data, but more likely indicating a greater range of drivers of population dynamics than we had anticipated, both in terms of the factors influencing resilience and vulnerability (e.g., N.J. Turner et al. 2003), and in terms of the degree to which those concepts are subjective for the individuals concerned. The two communities, despite shared sociocultural history and geographical proximity, displayed different responses to the various changes they faced, indicating the importance of specific individual and community characteristics in determining the actual course of events. Additionally, the concept of a social–ecological system assumes connections between society and ecology (e.g., Berkes & Folke 1998). Our findings do not refute such connections, but suggest that in the case of the Pribilof Islands those connections are not primarily economic in nature. We return to these ideas in the Discussion.

Social and economic history of the communities studied

A review of historical and contemporary information on social and economic indicators in the Pribilof Islands shows three major phases of development in the past quarter of a century. The first phase was dominated by commercial seal hunting, which persisted for two centuries, but ended in 1984. There appear to have been several motivations for that decision: namely, the withdrawal of the United States from the Fur Seal Treaty, a large public anti-sealing campaign and the decreasing demand for seal fur (O'Harra 2005).

To help make up for the loss of this economic mainstay, several initiatives, mainly around commercial fishing opportunities, were started. First, residents of the Pribilof

Table 1 Phases and transitions in the economy of the Pribilof Islands since 1980.

Phase/*Transition*	Period	Characteristics
Commercial seal hunting	From the late 1700s to 1984	Stable economy, strong social–ecological connection, no major environmental or other shifts
Switch to commercial fisheries	1980s	Abrupt change, reorganization of community activity, 20 million USD in grants to aid transition
Commercial fisheries	From the 1980s to the present	Variable economy, including: snow-crab crash; decline in halibut fishery; important infrastructure and fisheries support (processing, port facilities); social–ecological connection still strong, but mediated by regulatory regime
Declining commercial fisheries, expansion of other activities	From the 1990s to the present	Gradual change (except for snow-crab crash on St. Paul), shift in community activity, loss of revenues and jobs
Various economic activities	1990s to present	Weaker overall social–ecological connection, variable economy based on various activities, with none being dominant, poor perception of economic conditions and outlook

Islands petitioned the International Pacific Halibut Commission (IPHC) to create a regulatory area around St. Paul and St. George with its own quota. The rationale for this was that the area would be able to remain open, even when other regions of the Bering Sea had reached their quota. In 1986, the IPCH created a separate regulatory region, Area 4C, around the Pribilof Islands, "to facilitate special fishing privileges granted to the local residents of the Pribilof Islands" (NOAA 2005).

The Community Development Quota (CDQ) Program began in 1992. Sixty-five communities, all located in the Bering Sea or within 50 nautical miles of the Bering Sea, are currently eligible to participate (Dept. of Commerce/NOAA 2005). Six non-profit corporations were formed by the eligible communities, and are known as the CDQ groups. St. Paul is the only community with its own CDQ group, the Central Bering Sea Fishermen's Association (CBSFA). The community of St. George joined up with five other communities to form the Aleutian Pribilof Island Community Development Association (APICDA). The intention was that the program would help Bering Sea communities to create a more diversified local economy, provide new opportunities for employment for local residents and allow entry into a fishery where high capital investment had previously prevented access (NOAA 2005).

In addition to the creation of the 4C management area and the development of CDQ groups on both islands, the federal government provided 20 million USD in grants to help St. Paul and St. George develop the infrastructure and capacity to engage in commercial fisheries in the region, including protected harbours on the islands, where none had existed naturally (Scholz & Klain 2005). Halibut and crab were the main target species.

This second phase of economic activity peaked in the 1990s, but has since declined because of changes in crab and fish stocks, as well as regulatory and other changes affecting the viability of St. George and St. Paul as locations for ports and processing. Rebuilding commercial fishing activities on the islands remains a goal, but has not yet been achieved. The third and current phase can be considered a mixture of various activities, including fisheries, ecotourism and tribal government services, such as health and housing provision, environmental remediation activities on properties previously owned by the federal government, and a suite of information technology businesses financed by the tribal corporations.

Although the end of commercial seal hunting was an abrupt change, the transition between the second and third phases has been more gradual. There has been considerable overlap in the types of activities, but nonetheless they have resulted in a distinctly different social and economic system today than was the case 20 years ago (see Table 1). Gradual change does not, however, imply painless change. A 1989 report by the city of St. George noted that the city was on the brink of collapse. Nearly two decades later, the city appears to be in the same position, perhaps reflecting the chronic uncertainties facing a small, remote community.

Methods

This study used two means of gathering data: one for compiling existing data and another for generating new data. Existing data were obtained from key information sources regarding commercial and subsistence fisheries in the Bering Sea around the Pribilof Islands, the socioeconomic aspects of these activities involving St. Paul and St. George (Table 2), and the history of economic activities on the islands.

New data were gathered through on-island surveys focused primarily on: (a) the role of subsistence activities in relation to environmental, economic and social health, (b) the perceived social and economic impacts of changes

Table 2 Sources of data compiled during the project.

Source	Type of data/information	Form of data/information
Alaska Department of Fish and Game	Fisheries and subsistence	Online
Aleut Community of St. Paul Island–Tribal Government–Ecosystem Conservation Office	Subsistence	Published reports
Aleutian Pribilof Island Community Development Association	Community development quota	Interviews with authors
Central Bering Sea Fishermen's Association	Community development quota	Various
City of St. George	Various	Various
City of St. Paul	Various	Various
Commercial Fisheries Entry Commission	Fisheries	Online
Institute for Circumpolar Health Studies	Subsistence	Published report
International Pacific Halibut Commission	Fisheries	Online
National Marine Fisheries Service	Observer	Online
National Oceanic and Atmospheric Administration	Various	Various
Southwest Alaska Municipal Conference	Population	Online
St. George Traditional Council Kayumixtax Environmental Conservation Office	Environmental	Various
US Census Bureau	Census data	Online

in fisheries or fishery management, (c) the potential for local economic development and (d) the value of commercial fisheries to the islands and the region.

In September and October 2005, Ecotrust developed Memoranda of Understanding (MOUs) with on-island partners, specifically, the Aleut Community of St. Paul Island–Tribal Government and St. George Traditional Council. Local partners then assisted Ecotrust in determining the appropriate timing for the surveys, interview protocols and data-handling modalities.

During the late autumn of 2005 and the early spring of 2006, the survey was distributed to all individuals over the age of 18 currently living on St. George and St. Paul. The survey was four pages long, printed on both sides of ledger (A3 or 11 × 17-inch) paper, and was folded for a booklet appearance. It was composed of five subsections: subsistence, environment, fisheries, demographics and technical skills. The majority of the survey questions were closed-ended (i.e., were multiple choice), although a number of questions left space for respondents to write in additional information. Three seven-point Likert scale questions were used to assess the respondents' perceptions of how the local environment, local economy and commercial fisheries are trending over time. For these questions we used three label points: "getting worse" (point 1), "staying the same" (point 4) and "getting better" (point 7).

Approximately 75 and 235 surveys were distributed to residents of St. George and St. Paul, respectively, in the autumn of 2005. A poor response rate from St. Paul prompted us to issue a second distribution of the survey in the early spring of 2006 to St. Paul. In total, 141 surveys were returned (51 from St. George and 90 from St. Paul). After codifying the survey results, existing and new data were combined and analysed. More specifically, we ran linear least-square regressions to test for correlations between a variety of dependent and independent variables.

The first analysis attempted to identify variables that influenced population size on St. Paul and St. George. Annual data from the period 1990–2004 was used (we could not locate annual population data sets prior to 1990), and two regressions were run: one with St. George's population and the other with St. Paul's population as the dependent variable.

The second set of analyses tested for correlations between survey respondents' perceptions of how the (1) environment, (2) economy and (3) local commercial fisheries were changing over time. Dependent variables for all three regressions were the same, and included basic demographic variables (i.e., age, gender and education level), and two dummy variables (1 = individual had at some point in his or her life lived off-island; 1 = individual had been, or was currently, a commercial fisherman).

The final set of analyses started with the 1980, 1990 and 2000 US census data for all Alaskan communities, and analysed various relationships between population, income and employment.

Results

Population dynamics

Annual population data from the period 1990–2004 are shown in Fig. 2. Our first set of regressions tested for statistically significant correlations between population size and other trends on both St. Paul and St. George. Independent variables were mainly fisheries related:

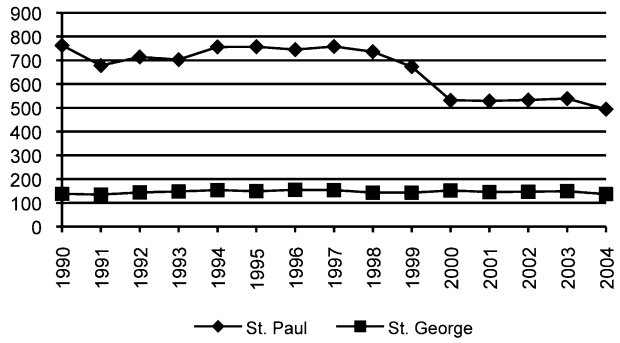

Fig. 2 Population levels in St. George and St. Paul, for the period 1990–2004.

Table 3 Selected census data for St. Paul.

US Census data for St. Paul	1990	2000
Males (% of total)	62.6%	55.3%
Native Alaskans (% of total)	66.1%	85.9%
Age: 25–44 years (% of total)	40.6%	32.6%

walleye pollock biomass, fur seal-pup population, annual commercial harvest of halibut and annual harvest of snow crab (*Chionoecetes opilio*), and included a dummy variable for snow crab (1 = after the snow-crab crash).

For St. George, at the 0.05 level of significance, no independent variable was found to be statistically significant. For St. Paul, however, two variables were found to be statistically positively correlated with population: the dummy variable representing the year of the snow-crab crash, and the total annual harvest of snow crab, with *P* values of 0.001 and 0.046, respectively.

It is tempting to speculate that the population increase, and decrease, was primarily the result of individuals with no prior connection to the Pribilof Islands moving to the islands in response to new opportunities, and then leaving when those opportunities disappeared. The population figures in question, however, do not include annual data on ethnicity, so such a conjecture cannot be completely resolved with the available data. Decadal census statistics for the years 1990 and 2000 are available, however, and do provide some, albeit limited, evidence in support of this theory. As shown in Table 3, the percentage of non-natives, males and individuals aged 25–44 are all higher in 1990 compared with 2000 (the year after the snow-crab crash), which is consistent with the idea that workers migrated to St. Paul when snow-crab harvests supported additional employment, and left when those opportunities ceased.

In the survey, we asked individuals whether they had ever lived somewhere other than the community in which they currently live. The majority of respondents had lived elsewhere: 70% of St. Paul residents and 73% of St. George residents stated that they had lived off-island at some time. A follow-up question asked individuals why they had lived elsewhere. The most common reasons cited for living off-island were, in order of frequency: education, employment and being born/growing-up elsewhere.

Economic trends

The population analysis of St. Paul and St. George rests on a few data points for two small communities. To broaden the analysis, we also examined the US census data from 1980, 1990 and 2000 for all Alaskan communities. After excluding communities located on the road system, regional hubs and communities for which data were lacking for one or more census years, we analysed various relationships between population, income and employment for the remaining 177 communities. These communities were further broken down into fishing and non-fishing communities, which resulted in an additional analysis to test for: (1) differences between these two groups and (2) similarities between the Pribilof Island communities and the other 70 fishing communities of Alaska (as identified by Sepez et al. 2005).

Regressions tested for the following correlations: (1) population and employment, (2) population and median household income, and (3) median household income and employment, where in each pairing the latter variable was assumed to be independent. Results showed that neither St. Paul nor St. George stands out in a statistically significant way from these other communities around the state. Likewise, narrowing the analysis to 72 fishing communities, St. Paul and St. George did not appear to show statistically significant differences, or trends, from other communities. Nor do the two communities qualitatively show similar patterns to one another (see Table 4).

This analysis of the existing data was also complemented by the data gathered during the on-island survey. More specifically, we asked survey participants to rate the current economic stability of the Pribilof Islands, to rate, on a seven-point Likert scale, how the economic stability of the Pribilof Islands is changing over time, and to provide basic employment information. In the case of two questions seeking information on the economic stability of the islands, we did not define the term "economic stability", but rather, left it to the interpretation of the respondents.

In response to the question regarding the current stability of the economy, perceptions on St. George were less positive than those on St. Paul, with one-third of St. George's respondents giving the economy a rating of "not stable at all". In contrast, only 6% of St. Paul respondents

Table 4 Demographic indicators for St. George and St. Paul, taken from the US census.

	Population		
	1980	1990	2000
St. George	156	143	152
St. Paul	648	752	532
	Median household income (USD)		
	1980	1990	2000
St. George	24 583	25 250	57 083
St. Paul	22 813	39 922	50 750
	Employment rate		
	1980	1990	2000
St. George	41%	47%	78%
St. Paul	26%	57%	51%

gave the economy this rating. We used a proportional two-tailed Student's *t*-test to test the null hypothesis (H_0 = no difference in proportions) at the 0.05 level of significance for responses rating the economy "not stable at all". The null hypothesis was rejected ($P = 0.002$), which demonstrates a statistically significant difference in perceptions between the two islands on this particular question.

Responses to the question of how economic stability is changing over time were again less positive on St. George than on St. Paul, with 31 and 9% of respondents from each island, respectively, marking the "1" box. We again used a proportional two-tailed Student's *t*-test to test the null hypothesis (H_0 = no difference in proportions) at the 0.05 level of significance for this question: the null hypothesis was once again rejected ($P = 0.004$). Overall, the median response of St. George respondents was "2", whereas for St. Paul respondents it was "3".

With regard to employment, less than half of the survey respondents from St. George (43%) had full-time employment, and another 20% worked part-time. On St. Paul, 65% of respondents had full-time employment, with an additional 7% working part-time. Although 31% of all respondents stated that they were not currently employed, it should be noted that many of those individuals were either retired (12%) or work seasonally and were surveyed in the off-season (6%). Personal communication confirms that, at least on St. George, job vacancies currently exist. Evidence suggests that this is in part because of the low wages offered, and in part because people who want jobs already have them. Perceptions of local employment were reflected in the words of one respondent: "You need to have a variety of jobs to make it here".

Another component of the Pribilof Island economy is subsistence harvests. Generally defined, subsistence is the taking of fish, wildlife or other wild resources for the sustenance of families, communities and cultures. Subsistence is a recognized way of life for both Alaska Natives and non-Natives, and as such is recognized by both the federal and State of Alaska governments as the highest priority consumptive use of fish and wildlife.

In the combined responses from the two islands regarding the consumption of subsistence foods, 3% of individuals stated that they never consume subsistence foods, and another 17% rarely consume subsistence foods. The most popular response to this question (43% of respondents) was an "occasional" consumption of subsistence foods. Individuals were also asked what percentage of their overall food consumption came from subsistence foods. Responses were again similar between the islands, with the majority of all respondents (65%) stating that subsistence foods account for 20% or more of their diet. Responses also suggested that subsistence foods may account for a slightly higher percentage of overall food consumption on St. George than on St. Paul.

The sharing of subsistence foods is widespread on both islands, indicating its role in supporting social relationships. Several reasons were given for participating in subsistence activities, and results differed between the two islands. For St. George respondents, the most popular response related to "cost", namely that subsistence foods cost less than food bought in the store. On the other hand, St. Paul respondents most frequently listed "taste" as a primary reason for consuming subsistence food. The two other most popular categories were culture/tradition and health. More specifically, respondents stated that subsistence foods are: (1) a part of their culture and that they grew up eating them, and (2) good for their health and more healthful than store-bought food.

Ecological trends

To improve our understanding of how residents on both islands view their local environment, the survey asked individuals to rate the environmental quality of the local environment. We defined the "local environment" as the island and the region around it, particularly the marine environment, and not the villages themselves. In regard to current environmental quality, the most popular response on both St. George (33%) and St. Paul (39%) was "somewhat good". St. Paul respondents generally felt more positive about the quality of the local environment. On St. Paul, 44% of respondents felt the environmental quality was "very good" or "extremely good", whereas only 31% of St. George respondents felt the same.

In an effort to gain a more dynamic perspective of the local environment, we also asked individuals to rate how the environmental quality of the Pribilof Islands is

changing over time. Although the most popular response on both St. George (46%) and St. Paul (20%) was that environmental quality was rated as a "3", the overall distribution of responses looks quite different between the two islands. The majority of St. George respondents (81%) felt that, at least to some degree, the environmental quality of the islands is getting worse. This is also true for St. Paul, although not to the same degree: only 63% of respondents indicated similar feelings. On the other hand, 19% of St. Paul respondents felt that the environmental quality is improving, but only 6% of St. George respondents felt that way.

Correlations

The connections found between demography and economics were tenuous. In two regression analyses with perceptions of environmental change and economic change as the dependent variables, the only independent variable found to be significant was place of residence, i.e., whether the respondent lived on St. Paul or on St. George. Other variables tested included income (which yielded a significant correlation, but was rejected because a large number of respondents misunderstood whether the question concerned individual or household income), years of residence on the island, whether the individual had ever lived off-island, level of participation in environmental activities, gender, education, age, Aleut heritage and participation in commercial fisheries.

Even though we were not able to find a direct connection between them, both marine mammal populations (i.e., fur seals and Steller sea lions) and the subsistence harvests of these animals have decreased in recent years. There is relatively little evidence, however, that the availability of subsistence resources has changed sufficiently to be responsible for harvest declines, or to cause changes in the human population or other community measures on either island.

There is a hypothesis that as prices increase individuals are more likely to participate in subsistence harvests and/or consume subsistence foods, because they are less costly. To further test this hypothesis, we performed a price comparison between St. George, St. Paul and Anchorage, similar to one conducted during a 1981 subsistence study by the Alaska Department of Fish and Game (Veltre & Veltre 1981). In 1981, the St. George prices for a set basket of goods were 44% higher than those in Anchorage, and St. Paul prices were 30% higher than those in Anchorage. St. George prices were also 11% higher than prices on St. Paul. Before making a comparison with 2005 prices, it should be noted that although every effort was made to price an identical basket of goods, some items were no longer available in the stores, or were only available in a different size. Wherever possible, substitutions were made using similar products.

In 2005, the difference in prices had increased between stores in the Pribilof Islands and in Anchorage, relative to the 1981 findings. For the chosen basket of goods, prices on St. George were 66% higher than those in Anchorage, and prices on St. Paul were 46% higher than those in Anchorage. This finding, combined with steadily declining subsistence harvests, suggests that the expected correlation between grocery store prices and subsistence harvests does not hold true in the case of the Pribilof Islandss.

Discussion

Our results suggest that there is no simple story connecting population levels on the Pribilof Islands with environmental or economic drivers. Although a common perception on and off the islands is that of intimate connection between people and environment, the evidence suggests a loose coupling, at least in material terms. One possibility is that the social–ecological connection is highly resilient, and has simply not been pushed far enough to demonstrate a major response, demonstrating low vulnerability to the extent that exposure to change is low, relative to sensitivity or adaptability to change. For example, subsistence production systems and related indigenous ways of utilizing local resources are typically flexible and adaptable by necessity, in a variable environment (e.g., Krupnik 1993; Nuttall 2005).

It is also possible that the lack of sensitivity to change indicates that economics are not the primary determinant for the islanders' choice of where to live. Attachment to place, and the associated culture and society, may be more important than income levels or career opportunities for those residing on the islands, as suggested by some of the responses to the open-ended questions in our survey. Alternatively, it could indicate that the system, again, has greater resilience than was anticipated. One explanation for why major economic changes have produced minor population responses is the degree to which the communities and individuals benefit from transfer payments, such as government grants or support programmes. The presence of such payments would be largely independent from local economic performance and environmental conditions, and may serve as an insulator against local fluctuations (but in turn may be a source of additional vulnerability if those payments are not reliable, a topic that is outside the scope of our study).

Other studies have found that remittances play an important role in island economies, particularly in the South Pacific (see Connell & Brown 1995, 2004; Browne & Mineshima 2007; among others). However, the

parallels between these studies and the Pribilof Islands, based on preliminary evidence, do not appear to be strong. As noted earlier, the majority of individuals on both islands have lived off-island at some point during their lives and have subsequently returned. Additionally, the primary reason for leaving was for education, demonstrating that although they left to receive education, they also chose to return to the islands rather than finding jobs elsewhere. This finding seems counter that of Browne & Mineshima (2007), who noted that individuals with higher skill levels tend to be the ones that migrate from Pacific islands, leaving a shortage of skills on-island. Browne & Mineshima (2007) also note the potentially large social costs of migration, in particular, the breakdown of families as a result of long separations. Again, this does not appear to be an issue on the Pribilof Islands, at least anecdotally, as conversations with residents indicate that they move to and from the islands for reasons other than just education or employment (e.g., to visit family, to shop or to take a vacation). A future, more in-depth, line of inquiry around what role, if any, remittances and population circulation play within the Pribilof Island economy would be useful in understanding how and why these islands might differ from other islands around the world.

The one exception to the apparent lack of social–ecological coupling is the snow-crab crash and the attendant population decline on St. Paul. Here, more data would be valuable in determining who comprised the population increase during the boom years, and who left during the decline. A plausible explanation, although entirely speculative without the relevant data, is that the boom years attracted workers with no cultural or other ties to the islands, who were then quick to leave when employment opportunities disappeared.

Through the changes of the past quarter of a century, population levels on the islands have demonstrated varying degrees of resilience and vulnerability. The differences in trends between St. George and St. Paul, despite the islands sharing the same sociocultural history and environment, support the idea that responses to environmental stimuli in the Pribilof Islands do not follow simple trajectories, but are at least strongly mediated by the specific circumstances of the place and the time. Some thresholds affecting the community as a whole undoubtedly exist, such as the minimum number of children required to keep a school open. Short of such major turning points, however, are numerous individual decisions, thresholds and responses (for example, Kelly & Adger [2000] point to the difficulty of generalizing vulnerability, even in a small community). One person leaves to find work or to go to university, but another finds a way to earn a livelihood and stays. Others return after having worked off-island for a period of time. Sensitivity to a given stimulus depends in part on the beholder. More research on these personal decision processes would be helpful to illuminate the relationship between individual resilience and vulnerability, and their manifestation for the community as a whole.

It is possible that our inability to find clear connections among environment, economics and demographics reflects a lack of appropriate data. However, results from studies in the North Atlantic (e.g., Hamilton & Haedrich 1999; Hamilton et al. 2003: Hamilton, Colocousis et al. 2004; Hamilton, Jónsson et al. 2004) indicate that such clear connections do exist in some cases, and that our data should have been sufficient to at least suggest such correlations for the Pribilof Islands, should they exist.

Instead, our results lead us to two related interpretations. First, the local economy is not closely linked to the environment at present. Environmental changes have undoubtedly had an effect, and in the case of the snow-crab crash have had a major (if short-term?) demographic effect. In other cases, however, the economic system has been able to adjust or cushion the effects of the loss of the commercial seal hunt or the decline in halibut catches. In part, this reflects the ability of the islanders to draw on other sources of support, such as state and federal support for capital improvement projects or for making the transition from seal hunting to fishing. In part, it may also reflect a lack of sensitivity to ecological inputs, at least to the extent that other economic activities can replace fisheries and the like as sources of income. Again, we do not suggest that the local economy is independent from the local environment, merely that the connection is not particularly strong.

Second, individual choices about whether to live on- or off-island are similarly insensitive to economic considerations. More research is needed into the factors that influence such decisions, for example, by interviewing people who have left the islands as well as those who have stayed. For those who have stayed, however, the economic conditions and outlook do not appear to explain their choice. Instead, other factors such as social conditions, family ties and connection to place are likely to be more influential than income and economic opportunity. Furthermore, the individuals who stay are likely to have a high tolerance for uncertainty, which is to say a high personal resilience in the face of actual or anticipated changes.

For those interested in using the social–ecological system of the Pribilof Islands as a management unit, as implied in the goals and practices of the Pribilof Islands Collaborative, it is therefore essential to understand exactly what the system consists of, and how its components relate to one another. Our results suggest that an

economic analysis alone is insufficient to explain the functioning of the system, at least with respect to population dynamics. For students of social–ecological systems in general, our results appear to contradict most case studies, and are in opposition to the expectations of tight coupling and clear connections between society and ecology (for example, see the case studies and analysis in Berkes & Folke [1998]). Effective management is not possible when the system is not yet understood.

It appears, therefore, that in the case of the Pribilof Islands at least, resilience and vulnerability are the products of multiple factors, producing a variety of responses among individuals, and at times divergent responses between the inhabitants of St. George and St. Paul. This is evidenced in our survey results by the differences in responses both among individuals and between the two islands to questions about economic and environmental trends and stability. Vulnerability at the community level may therefore be better understood as ranges of individual distribution rather than single, aggregate points (Fig. 3). Individual circumstances and personalities will determine where within those ranges each person finds him- or herself. The sudden snow-crab crash reflects a tighter clustering of vulnerability on St. Paul (or perhaps the arrival of a group whose social and economic position on the island was compact and vulnerable), with the result that many people left the island in response to a single shock to the system. The more gradual halibut decline has occurred within a wider range of vulnerability, and has allowed more time for adaptation or transformation, producing a less marked demographic response. A narrow range of vulnerability may thus indicate a system threshold, the presence of which is determined by specific individual circumstances, in combination with the underlying properties of the system in question.

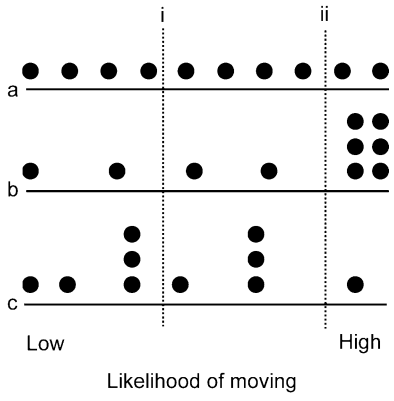

Fig. 3 Conceptual diagram of resilience and vulnerability to moving off-island. The horizontal lines a, b, and c show different distributions of the likelihood to move, reflecting the varying degrees of resilience. The vertical lines i and ii show changes of different magnitudes. Vulnerability is a function of sensitivity (a, b, c) and change (i, ii). The combination of b and ii illustrates the situation on St. Paul during the snow-crab crash, whereas a and c suffer far lower impacts. All three systems are vulnerable to change of the magnitude shown for i, indicating a general vulnerability to major change.

Further research is required to test this conceptual model as a means of evaluating and understanding resilience and vulnerability in a multi-dimensional system. In particular, structured institutional analysis would help elucidate the rules and practices that influence individual behaviour, in the context of both social and ecological systems (Young 2002; Young et al. 2006; Janssen et al. 2007). Given the roots of individual behaviour in cultural values, such an analysis would further benefit from in-depth ethnographic methods to assess individual choices, and their relationship to community patterns.

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