FACTORS THAT INFLUENCE THE USE OF CLIMATE FORECASTS

Evidence from the 1997/98 El Niño Event in Peru

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The use of forecasts in coastal Peru during the1997/98 El Niño differed from patterns described in the literature, particularly in the influence of user education and the time of hearing the forecasts on levels of forecast use.

APPROACHES TO THE STUDY OF CLIMATE FORECASTS. The promotion of the use of seasonal to interannual climate information by U.S. government and international agencies has increased the number of studies that address the use of forecasts. This work has largely been applications oriented. These studies seek to identify the current and potential patterns of forecast use, the integration of forecasts into decision making, and the most appropriate ways to communicate information to various groups. Much of this work has rested on models that calculate the influence of forecasts on different socioeconomic activities in various societal contexts (Stern and Easterling 1999). In addition, empirical research has complemented these modeling studies by examining concrete patterns of forecast perception and communication and, in some cases, of forecast use as well. Numerous factors have been identified that influence perception, communication, interpretation, and use of forecasts [see Stern and Easterling (1999) for a recent review of climate forecast applications studies]. Our study of the fishery sector in five Peruvian ports during the 1997/98 El Niño concurs with earlier studies that indicate that subpopulations differ significantly in their use of this information; it also supports the long-established claim that perceived accuracy influences forecast use. However, our study suggests that the timing of forecast dissemination, sectoral sensitivity, and socioeconomic variables influence forecast use in ways different from those commonly presented in modeling studies and in

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some other empirical studies. This result implies that there is a need for field-based studies to determine the effectiveness of dissemination strategies for particular populations in particular circumstances.

Several modeling and empirical studies identified perceived and actual accuracy as important factors affecting the use of climate forecasts (e.g., Sonka et al. 1992; Mjelde and Dixon 1993; Changnon et al. 1995; Brown et al. 1986; Sherrick et al. 2000). Katz and Murphy (1997) propose minimum forecast quality thresholds for forecasts to be used in different settings. Our study supports this claim, since respondents in locations where local impacts followed the national-level forecasts of El Niño events more frequently in previous years were more likely to respond to the 1997 national forecast than those in other locations with less frequent impacts.

The timing of a forecast is often cited as a characteristic that affects forecast use (see Stuart 1982; Weiss 1982; Vining et al. 1984; Easterling 1986; Easterling and Mjelde 1987; and Mjelde et al. 1988, cited in Mjelde and Dixon 1993; Bohn 2000). The intuitive assumption is that the farther in advance information gets into the hands of a decision maker, that is, the longer the "lead time," the better (Cash et al. 2003, manuscript submitted to *Sci. Technol. Human Values*). The most realistic scenarios constructed are those in which accuracy decreases as lead time increases (Mjelde and Dixon 1993), revealing the trade-offs between these two forecast characteristics. Such trade-offs have clear implications for forecasters, who face choices in the lead time for their products. Put simply, a good forecast at the wrong time (e.g., after a decision to plant has been made) is of little use. This has led some researchers to construct decision calendars identifying crucial decision periods for specific sectors (e.g., Pulwarty and Melis 2001). In the Peruvian case described here, there was not a clear relationship between the time of hearing a forecast and the actions that were taken, suggesting that these decision makers had more flexibility in response to forecasts than is often assumed.

Other studies have recommended that forecasters direct their products to specific sectors. Some research has stressed the importance of targeting forecasts to particular sectors, since decision makers in some sectors (e.g., insurance companies, reservoir managers, industrial farming operations) can make use of the relatively low-resolution climate forecasts, while other groups (e.g., subsistence farmers) need much finer-scale information for their decisions. Some research has argued that sector-specific scenario building can overcome obstacles of perceived accuracy or usefulness that have limited the adoption of forecast use (Hammer et al. 2001; Hearn et al. 2002; Hayman and Easdown 2002). Our findings indicate that forecasts influenced decisions outside of the decision makers' occupational specialization, suggesting that attention to behavior outside the principal income-generating economic activity may reveal decisions that affect the levels of potential use of forecasts.

Constraints identified from case studies of climate forecast use are increasing in prominence in the literature (e.g., Stern and Easterling 1999; Roncoli and Magistro 2000; Letson et al. 2001; Jochec et al. 2001; Broad et al. 2002; Ziervogel and Downing 2004). This expansion is due in part to the increased production and dissemination of climate forecasts and to the great prominence of the 1997/98 ENSO event. These studies emphasize contextual constraints and incentives for adopting forecasts. Some suggest that potential users may be unable to interpret probability (Barnston et al. 1999; Fischoff 1994; Patt 2001; Phillips et al. 2001; Wilks 2000), suggesting that ignorance and, by extension, lack of education limit forecast use. Others point to socioeconomic constraints on decision options (Barrett 1998; Finan and Nelson 2001; Patt and Gwata 2002; Phillips et al. 2001), showing that poorer individuals and groups may lack the ability to redirect their resources to make use of forecasts. Our findings indicate significant variability among groups with different socioeconomic characteristics (e.g., age, education, income level) in the use of climate forecasts, precluding sweeping assumptions about the ability, or lack thereof, of subpopulations to use the forecasts. We note that some of the people deemed less likely to make use of forecasts, particularly the poor and less educated, responded at higher rates than others.

BACKGROUND. El Niño events are familiar to Peruvians. Evidence of El Niño impacts and local adaptation to its effects can be traced back several millennia. The effects of El Niño, the warm phase of the ENSO cycle, in Peru are most evident in the austral summer, with local warming of the coastal waters due to changes in wind patterns and in upwelling characteristics. Air temperatures and precipitation also increase along much of the coast. These effects, which vary in intensity and duration from event to event, can have dramatic impacts on the marine and terrestrial ecosystems, turning vast desert areas into lakes surrounded by a blooming landscape (Arntz et al. 1985). Dramatic flooding associated with heavy rainfall, coastal damage due to higher sea level, and temperature increases can strongly affect local populations, especially on the north coast. Impacts on agricultural production and associated industries occur throughout the nation, often due to widespread damage to the roads and bridges. Southern and interior parts of the country are also impacted by ENSO events, although these effects are not as consistent from event to event as along the coast (Zapata Velasco and Suiero 1999).

The 1997/98 El Niño proved to be one of the strongest of the twentieth century, comparable to the 1982–83 event that brought El Niño to the world's attention. Unlike the 1982–83 event, this event was forecasted and observed prior to the arrival of the most dramatic impacts. Rumors of a pending El Niño started in Peru as early as March 1997. The government officially announced in early June that an event was possible. These Peruvian forecasts were based on various sources: statistical models developed by local scientific agencies, information from groups such as the National Oceanic and Atmospheric Administration (NOAA) and the World Meteorological Organization (WMO), and observational data gleaned from scientific cruises. Despite the growing awareness that something was occurring, there was no consensus about the anticipated magnitude and duration of the event. In mid-1997, various Peruvian agencies made conflicting predictions. A burst of highly publicized stories appeared in newspapers, on television, and the radio in June (Broad et al. 2002). By September 1997, the government, cognizant of the risk because of the country's experience with the 1982–83 event, in which many lives were lost and millions of dollars in damage occurred, had begun a massive public works campaign to reinforce bridges, to clean drainage areas, and to adopt other proactive measures. Nonetheless, some uncertainty about the scale of the event continued. In late October 1997, NOAA, in conjunction with the Peruvian Marine Institute, other national and regional organizations, and representatives of the financial and industrial fisheries sectors, convened an international Climate Outlook Forum meeting in Lima to bring together experts to answer the question: "Is this the El Niño of the Century?," resulting in a mix of opinions regarding the coming climate conditions. The government public works campaign continued through early 1998. The private sector, for the most part, was left to its own to take action (Zapata, Velasco and Suiero 1999). In December 1997, the heavy rains began. Despite the extensive prevention works, these rains destroyed sections of the major coastal highway and disrupted transportation nationwide. Flooding occurred not only on the north coast, the region most often affected by El Niño events, but, in an entirely unanticipated fashion, in the south-central department of Ica as well. The major commercial fisheries were heavily impacted, though unusual tropical species appeared in coastal waters. The highland areas received a mix of drought and flood, leading to massive mudslides, damage to crops, and disruption of transport.

The marine ecosystem experienced some of the most dramatic shifts due to El Niño. Massive migration of pelagic species southward and deeper, out of the range of nets, had major negative effects on the industrial fleet and the fishmeal-processing sector. Reduced reproduction and recruitment of these species led to low catches following the event, exacerbating problems for this heavily overcapitalized industry. The small-scale, or artisanal, fleets experienced other changes: the arrival of tropical species in massive quantities provided alternatives to their normal catch. However, due to the strength of the event, the abundance of these normally valuable species from Ecuador to central Chile led to a sharp decline in prices. Additionally, damage to ports and roads impeded the marketing of the catch in many cases, the high air temperatures increased spoilage and health problems.

DATA COLLECTION. In 1998, 596 individuals associated with the Peruvian fishing sector were surveyed in five port towns: Paita, Chimbote, Callao, Pisco, and Ilo (see Fig. 1). The survey was part of a larger project studying actual and potential uses of climate information in the fisheries sector and included ethnographic, archival, and statistical analysis of fisheries–climate re-

Fig. 1. Map of South America, showing field sites in Peru.

lationships (see http://iri.columbia.edu/application/sector/fishery/Peru/ for details on the components of the project). A team of interviewers from a major Peruvian social science research institute traveled to five ports to provide consistency in interview techniques. They used contacts with local universities, agencies, and organizations involved in survey research to conduct the interviews. Survey sites include the major industrial and artisanal fishing and processing centers. The north–south spread of sites covered most of the country's coast, allowing an exploration of geographic differences in responses to El Niño. Among land-based private sector activities, firm owners, managers, and cannery and fishmeal-processing workers were surveyed. Vessel owners, crews, and those in associated service industries (e.g., net repair, mechanical support), both in small-scale and industrial fishing subsectors, as well as divers, were included in the survey. Our statistical methods are described in appendix A.

FINDINGS. Our first set of findings concerns media access in our sample. Since forecasts are usually disseminated through the mass media, it is possible that media access would influence the time of hearing the forecast and the nature of response to the forecast. However, these towns have high rates of media saturation, even among the poor and less educated segments of the population, similar to rates throughout Peru (Fowks 2000). In our sample population, 95.5% listen to radios regularly, while 70.0% mention that they tune in to news and public affairs programs, the ones most likely to cover forecasts. Television ownership is also high: 96.8% of the entire population has at least some access to television, since they were all able to name programs that they watch regularly; 82.0% watch news and public affairs programs. The level of newspaper readership is 97.5%. Even the individuals who do not purchase newspapers see newspapers displayed prominently in kiosks in public squares, markets, and along principal streets; bold headlines and color photographs on front pages convey elements of stories to those with little or no education. Though some studies have emphasized the uneven nature of access to forecasts, we found relatively homogenous access to the media that delivered forecasts in our case. The only example of limited media access was to the Internet: 3.2% of the population have a computer at home, and only 1.6% have access to the Internet, whether at home, at work, or through cybercafes.

Our second set of findings indicates that informants first heard forecasts of the 1997/98 El Niño event at different times. The pretests of our survey instrument showed that at the time of the interview, late in 1998, many of the interviewees could not state the precise month when they first heard the forecast. However, most could recall the relation of their time of hearing and the month of June 1997, when the first newspaper headlines and television announcers discussed the news that a major El Niño event was impending, and when the national congress started debates on the most appropriate response to this event. We use the term "early hearers" for the 38.9% of the total who received the forecasts before June, "middle hearers" for the 20.1% who received them during that month, and "late hearers" for the 25.8% who did not receive them until afterward. An additional 15.2% could not recall the date when they heard the forecast. Figure 2 gives the age categories for the early hearers. The early hearers were distinctive in several ways. They tended

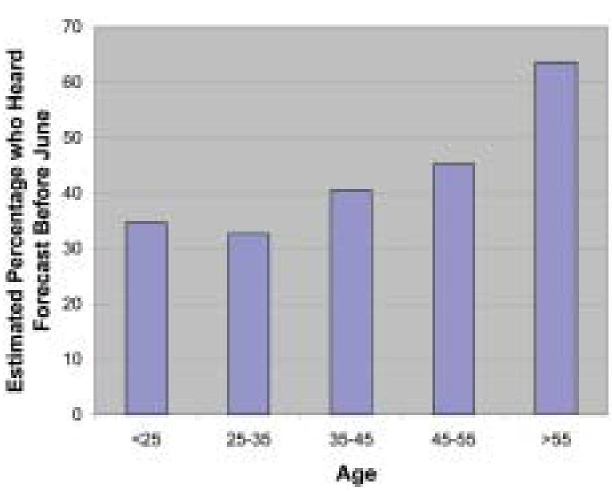

Fig. 2. Percentage of early hearers of the El Niño forecast by age groups.

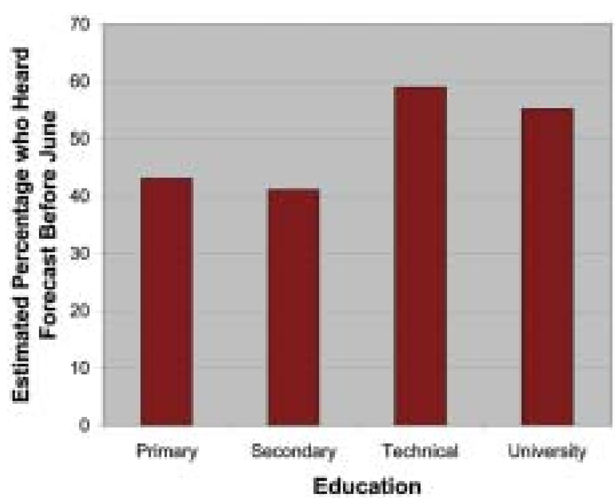

Fig. 3. Percentage of early hearers of the El Niño forecast by education.

to be older than the middle and late hearers (not shown) and more educated (see Fig. 3). The individuals in this group tended to have more organizational ties; that is, they were more likely to belong to unions or neighborhood associations, or to be affiliated with nongovernmental organizations (see Fig. 4). Since all people in the sample have good access to the media, it seems possible that people with stronger social ties process information more fully, perhaps through discussions at meetings of organizations or through conversations with fellow members. The differences between the middle and late hearers were less striking than the ones that separate these two groups from the early hearers. Though the middle hearers tended to be younger than the late hearers, this effect is not significant at the $P = 0.05$ level.

Our third set of findings concerns the topic of response, defined as concrete actions that individuals took in response to the forecasts. Figures 5, 6, and 7 give the probability of responding to the forecasts for the towns studied by age group, and by education, respectively. Our preliminary questionnaire reflected our expectation that the people in our sample would take actions that would reduce the negative impact of the El Niño event on their livelihoods in the fisheries sector. We thought that they would react to an expected decline in fish populations and catch by increasing the proportion of their income that they saved, or by seeking employment in other sectors. Our pretest revealed that many more took action to protect their houses, which they thought might be damaged by the unusual heavy rains that fall in El Niño years in this otherwise arid region. This is a form of economic action as well. Houses are a form of savings, since they hold their value, and often appreciate as urban growth advances. They also serve as income-generating investments. Fishermen

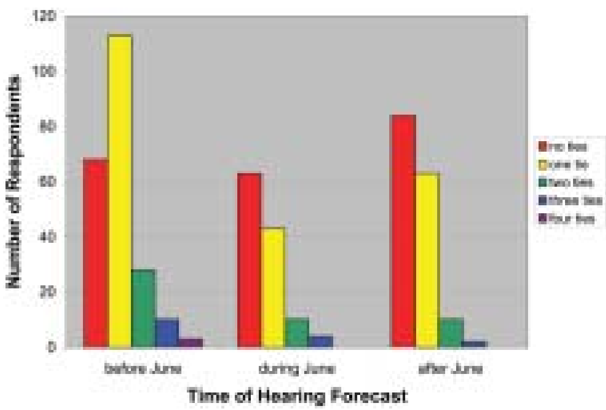

Fig. 4. Number of respondents vs. time of hearing stratified by organizational ties.

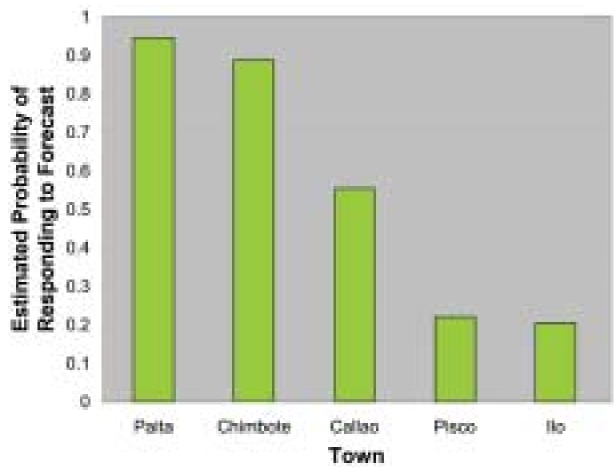

Fig. 5. Probability of response to forecast for each town in the study.

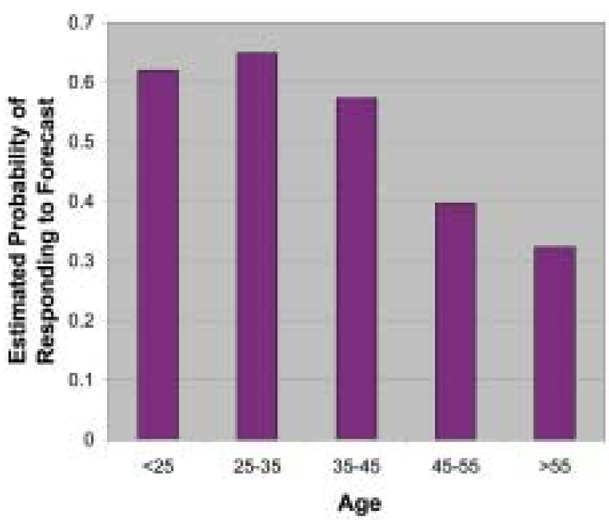

Fig. 6. Probability of response to forecast by age category.

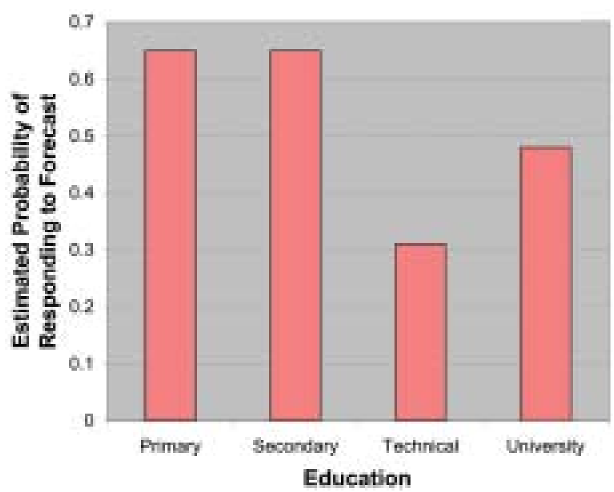

Fig. 7. Probability of response to forecast by education.

store equipment in their homes, and their wives often run small stores out of a room in the house.[1]

The ethnographic research that accompanied the surveys generated information that allows us to consider the reasons that might have limited the responses taken by actors in the fisheries sector [this topic is covered more extensively in Broad et al. (2002)]. During interviews and participant observation, we found that most groups tended to wait until the target stocks dropped almost to zero before considering changes in equipment or grounds. This response is not illogical, nor is it driven by an inability or unwillingness to recognize problems. Fisheries constantly fluctuate at inter- and intraseasonal time scales, a feature that fishers have come to expect. Moreover, many actors had limited capital and were unable to purchase equipment that would only be used during extreme events. They recognized as well that the disruption of transportation networks linked to ENSO-related flooding would make it difficult to market catch before it spoiled. Some workers did switch to other occupations (or reallocated their effort to secondary employment), but the opportunities in the labor market were extremely limited, due to the economic downturn that accompanied this El Niño and a generally weak economy. Though not the focus of this paper, we note that the fishery managers did take some proactive measures including increasing sampling and monitoring cruises and restricting fishing even while local abundance was high. This last action was an unprecedented measure.

In our sample population, 48.4% took some form of action to protect their houses: 33.7% fixed or strengthened their roofs, 11.8% cleaned pipes that connected the houses to storm drains or sewers, and 5.2% covered the interior patios of their houses, an important action in this area, since many houses, especially the ones in poorer neighborhoods, have patios of bare earth that can become badly waterlogged. In addition, 10.2% reported protecting their houses in other ways, by reinforcing walls, building dikes, replacing broken windows, and the like. (These percentages for specific actions total more than 48.4% because some people adopted more than one form of action.) We note that these actions demonstrate that a sizeable portion of our study population found forecasts to be useful. Moreover, we note that these responses were of low risk, since housing is a safe investment in this region. These responses had a nonzero, though low, cost. Households had to reallocate capital and labor from other categories of production, expenditure, or savings to fix up their houses, at a time when they were at risk of reductions in income.

Several factors are positively correlated with the likelihood of an individual to protect their houses. The strongest effect was that of latitude (see Fig. 5). People who lived in the northern towns of Paita and Chimbote were more likely to take action than those in Callao, in central Peru, who in turn took action more often than those in the southern towns of Pisco and Ilo. This difference probably reflects the historical experience of these towns. The frequency of El Niño-related rainstorms and floods decreases from north to south. It seems likely that the individuals in the northern towns placed greater credence on the forecasts than those farther south. It bears noting that this latitudinal variability in response is associated with variable perception of risk rather than with relative ability to respond.

Other factors also influence the likelihood of taking action. Less educated and younger people responded more frequently than those who had more education or were older (see Figs. 6 and 7). This greater responsiveness may be a consequence of their higher levels of vulnerability. We think that it is likely that their levels of income and wealth were lower, so that their houses were more flimsy. We did not directly collect quantitative data on economic variables such as household income, wealth, and housing values, about which individuals are less likely to respond honestly than on demographic variables such as age and education. However, our data provide at least indirect confirmation of this association of taking action and vulnerability. A higher proportion of the people who reinforced their houses suffered some damage than the proportion of those who did not take such action. Figure 8 shows the proportion of individuals who responded and did not respond to the forecast, and who did and did not suffer damage by location. It was more frequent for responders' houses to collapse entirely, or for a wall to fall down, or part of the roof to be destroyed. It is plausible that the individuals who did take action would have likely suffered even greater damage had they not taken action, since their houses may have been more poorly built, or located in areas more prone to flooding and landslides.

Equally interesting are the variables that do not influence the likelihood of taking action. The time of hearing does not have a direct influence; though both

[1] Of the workers in the commercial fishing fleet, 97.2% are men; the few women who fish participate occasionally in the small-scale artisanal and diving sectors. In addition, 20.8% of the married fishermen report that their wives work, chiefly as petty traders and vendors. Other occupations also involve income-generating activities that take place at home, such as washing clothes and tailoring. Unmarried fishermen may have coresident female relatives such as mothers or sisters who also work at home.

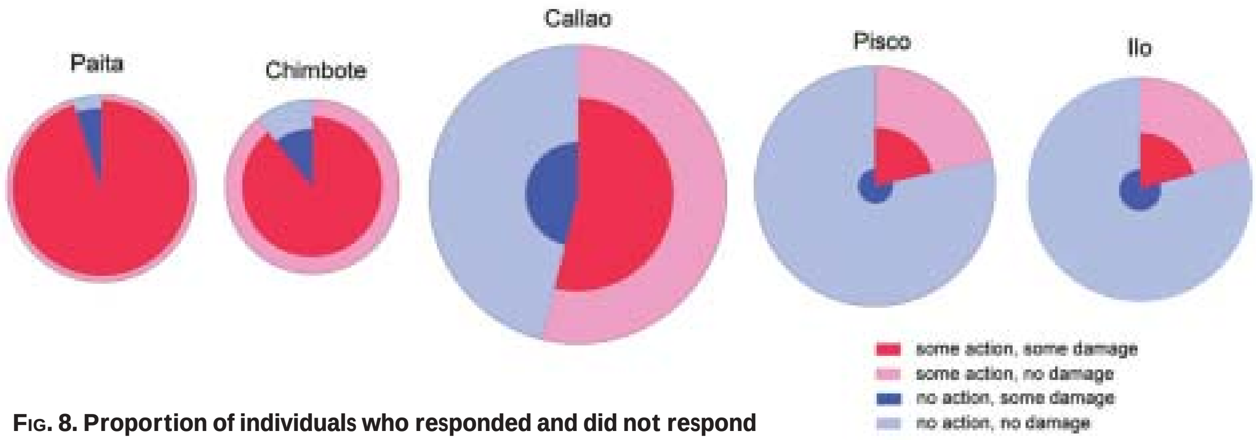

Fig. 8. Proportion of individuals who responded and did not respond to forecast, and who did and did not suffer damage, by location.

time of hearing and likelihood to respond are correlated with age and education, the logit models show that there is no independent effect of time of hearing on likelihood to respond. Nor is there any influence of media access on the likelihood to respond.[2]

DISCUSSION. We believe that our findings have implications beyond Peru for future studies of climate impacts, forecast use, and information dissemination strategies. Peru's high sensitivity to climate variability and high public awareness of the effects of ENSO suggest that it is a useful case to examine, since other countries that are also affected by climate variability are likely to increase in their awareness of this factor. Moreover, Peru is representative among emerging nations in terms of general indicators (per capita annual income is around $2500; the population is around 70% urban and 95% literate). To be sure, Peru is unusual in many ways, especially for its history of strong El Niño impacts.

Most generally, we note that responses occur outside of formal public and private sector institutions. Actions were triggered by relatively general information, such as newspaper headlines and radio announcements that claimed that an "El Niño" was coming. We found that reactions to such information went beyond fishing activities, our focus of study; such cross-sectoral responses suggest that the sectorally limited studies that dominate the literature may overlook a range of decisions, whether the household level, as in our study population, or at other levels as well.

Our study has significant implications for information dissemination channels. First, media saturation facilitated an equitable flow of information through print and broadcast media across all social strata in the study region, in contrast to the provision of information on the Internet that reached a very restricted group. This flow of information was facilitated by preexisting social networks, identifying another sociological characteristic for information providers to consider when designing dissemination strategies. In general, our case contrasts with the other cases, described in the literature, in which access to information is very uneven.

Finally, our findings challenge some commonly held belief about the use of forecasts. In contrast to the studies that emphasize the need for longer lead times to increase the value of forecasts, we found that the people who heard the forecast early were no more likely to respond than those who heard it later; in this case, at least, there was no advantage in providing early forecasts.[3] Moreover, we found that use of forecast information decreased, rather than increased, among individuals with higher levels of education, presumably because their higher incomes and wealth buffered them against some El Niño impacts. Our work also suggests that poorer people may be as able to use forecasts as well as wealthier people. In sum, the groups that used forecasts most frequently are not the ones whom have

[2] The time of forecast reception was not a factor that influenced the actions taken at the household level, although it did play a role in other components of the fishing sector. Major changes, especially by industrial fishers and plant owners, would require arranging for financing, ordering new equipment, and finding markets for new products. Such business actions operate on a time horizon of well over a year, outside the time window of our current forecast capabilities (and of El Niño events themselves). Thus major actions involving changes in infrastructure were not taken, but changes in fishing behavior, such as moving fleets to the south in expectation of changes in small pelagic migratory patterns, some anticipatory layoffs, and reinforcing of coastal structures, did take place.

[3] We note that both fishing and house construction are relatively unconstrained by seasonal cycles in this area of rich fish stocks and dry weather, so these findings do not seem to be influenced by the particular month in which the cutoff date fell.

often been described as the populations most able to act upon advance climate information, whose greater education would make them more able to comprehend forecasts, and whose greater resources would allow them to act in response to the forecasts. The relative novelty of these findings suggests the importance of concrete field-based studies of use of forecasts to complement the model- and theory-based accounts that have tended to predominate the literature.

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APPENDIX A: STATISTICAL METHODOLOGY. The survey data collected in this study was largely categorical. Even variables that might be considered continuous were grouped into categories, because greater precision was unrealistic. Respondents' ages, for example, were grouped into one of five categories of roughly one decade in length. Because of the categorical nature of the data, we chose to model the outcomes as binary, using logistic regression analysis. In logistic regression analysis, the probability of an event occurring is estimated by

$$P\,(\text{event}) = 1/(1+e^{-(B_0 + B_1x_1 + B_2x_2 + \ldots)}),$$

where B_n represent coefficients assigned to each variable (x_i) in the model. Because most of the variables are categorical in this dataset, each is assigned a set of "dummy variables" that can take on a value of one or zero, indicating membership or nonmembership in each category. Thus for each category in each variable in the model, a positive coefficient indicates that membership in that category makes the event more likely. Each coefficient is estimated using maximum likelihood estimation [see Agresti (1990, 112–117) for a complete discussion]. The probability that each coefficient equals zero is tested using Wald statistic (the square of the ratio of the estimate to its standard error), which has a chi-square distribution.

Place was consistently the key predictor variable in the logistic model. Further, there were a limited number of other potential variables that were likely to be useful. Therefore it was deemed appropriate to select model variables using backward stepwise selection (Neter 1990). All potentially useful variables were entered into the model. Single variables were then removed and tested against the null hypothesis that model partial deviance equaled zero. If rejected, the variable was retained. If accepted, the variable was removed.

The odds ratio estimate indicates whether membership in a certain category is more or less likely than membership in another category to increase the probability of the event occurring. For comparison of category *m* versus category *n*, the estimate is given by

$$\text{ORE} = [(P_m/(1 - P_m)]/[P_n/(1 - P_n)],$$

where ORE > 1 indicates that membership in category *m* makes the event more likely than membership in category *n* and ORE < 1 indicates that membership in category *m* makes the event less likely than membership in category *n*. For example, if we are modeling the outcome "respond to El Niño," the ORE of living in the northernmost port of Paita versus living in the southernmost port of Ilo is 123.0, or living in Paita as compared to Ilo increases the odds of responding by two orders of magnitude. By contrast, the ORE for responding to El Niño for those with a technical education, versus those with a college education, is 0.477. In other words, the odds of those with a technical education were half of those with a college education.

As for the maximum likelihood estimates, the ORE is tested for significance using the Wald chi-square test. In the case of the ORE, the model is tested against the null hypothesis of ORE = 1.0.

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