Climate Information and Conflicting Goals:
El Niño 1997-98 and the Peruvian Fishery

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Abstract

The development of seasonal-to-interannual climate predictions has spurred widespread claims that distributing forecasts will yield benefits for society. Based on the use and non-use of forecasts in the Peruvian fishery sector during the current El Niño event, the authors identify significant potential constraints on the realization of such benefits. Further, they argue that understanding such constraints is only one of the elements necessary for guiding optimal forecast-dissemination choices. Forecast providers also require an appropriately detailed definition of societal benefit. That is, forecast providers must consider explicitly whose welfare counts as a benefit among groups such as labor, industry, consumers, future generations, and different regions. Both a definition of societal benefit and an understanding of socioeconomic structures in the region of interest should be brought to bear on forecast dissemination choices. The authors conclude with hypothetical examples of dissemination choices made using this process.

1. Introduction

Many have claimed that an ability to predict seasonal-to-interannual climate variability will result in benefits for society:

> The provision of forecast information in a form that countries can use to benefit their societies is a welcome and exciting way that the wealthier countries of the world can help the poorer countries to help themselves. (World Climate Research Programme 1997, 6-1).

> The ability to anticipate how climate will change from one year to the next will lead to better management of agriculture, water supplies, fisheries, and other resources. By incorporating climate predictions into management decisions, humankind is becoming better adapted to the irregular rhythms of climate. (NOAA 1994, 23).

Glantz (1979) questioned the common assumption that a “reliable” forecast of an El Niño event would necessarily yield significant societal benefit. In particular, he hypothesized that various constraints might limit the usefulness of such a forecast for fisheries management. Such constraints include: the variability of El Niño intensity and duration; difficulties translating predictions of air-sea interaction in the Pacific Ocean into reliable forecasts of fish stocks; difficulties understanding probabilistic forecasts; insufficient lead time to undertake mitigating action; and socioeconomic and political pressures on regulators to appease the fisheries industry.

Twenty years later, the strong 1997-98 El Niño event offers an opportunity to compare these claims with real-time observations of forecast use. Dissemination of seasonal-to-interannual forecasts is now routine, and with operational forecasts comes pressure to apply this knowledge to capture the societal benefits assumed to exist. In light of these recent developments, this article focuses on two main issues: first, by observing the use and impact of climate information during the 1997-98 El Niño event,[1] we identify actual constraints on generating societal benefits; second, we argue that an understanding of constraints is only one necessary element of optimal forecast dissemination choices - an appropriately detailed definition of societal benefit is necessary as well. That is, forecast providers must base decisions on determination of what counts as contributing to benefits among, for example, the interests of labor, industry, consumers, different regions, and present and future generations.[2] Thus we suggest that those agencies concerned with generating benefits and facing the challenges of dissemination bring both an explicit definition of societal benefit and an understanding of the socioeconomic context (within which political constraints arise) to bear on all climate forecast dissemination choices.

This article draws on observations of actual uses and impacts of climate forecasts (El Niño-related) in the Peruvian fisheries sector during 1997-98. In terms of constraints on the usefulness of climate information, these Peruvian examples indicate that depending on socioeconomic context, forecast dissemination may often have unintended and even what might be viewed as “perverse” consequences. These Peruvian examples also reveal a range of actors in society with different views of what constitutes societal benefit. These views may arise from personal taste, greed, moral or ethical positions, political ideologies, perceptions of the resilience of nature, or other factors.

Forecast providers face the following issues. First, certain constraints may block a forecast from reaching some who would benefit from their information. Thus the challenge of effective dissemination can be to reach more people. Second, forecasts of low value may be generated and disseminated at some cost, and forecasts that could even be harmful, in the sense of lowering societal welfare, may reach people when perhaps they should not.[3] In a growing literature on forecast value (see, for example, Katz and Murphy (1997)), one models an agent making a specific decision in two types of situations: first, without the forecast in question, for instance in what are considered to be average or normal conditions; and second, with the forecast. In principle, the forecast information could permit “better” decisions, i.e. ones that produce greater expected utility for the agent who decided to use the updated information. It is precisely this gain in the expected utility for the agent that is defined as the forecast’s value.

It is important to note that this does not mean that a decision made using the forecast information will always provide higher actual utility in the future. Rather, updating the agent’s information using the forecast will raise the agent’s expected future utility, or utility averaged over all the possible states of the world given their probabilities. An agent may rationally (or "correctly") update her view of the probabilities of those states of the world using a forecast, and as a result make a decision with higher expected utility (than that which would have appeared best in light of the non-updated probabilities), but then end up worse off in the future than she would have been without the forecast. This occurs when the particular state of the world that actually occurs in the future favors a particular decision.

Note that such an occurrence would not indicate that the forecast itself was "harmful", even though in this specific instance the agent would end up with lower actual utility in the future. The forecast information is an aid to decision-making, and thus its value is calculated at the time the decision is made, while there is uncertainty about the future state of the world (e.g., about the climate next year). In other words, the forecast value must be judged in terms of the usefulness of the updated set of probabilities for making decisions, not in terms of the stochastic actual outcome. For this reason, the quality of a forecast can really only be judged over time or, more precisely, in light of many instances of probabilistic predictions and actual occurrences, so that whether the forecast probabilities are close to correct can be determined.

Within this framework, though, it is quite possible that a forecast may be of low or zero value to the agent. The literature suggests a "forecast quality threshold", i.e. a minimal level of accuracy below which forecasts should rationally be ignored (see, e.g., Katz et al. (1982) and below Section 3B4). This is simply the level of accuracy below which information does not permit agents to improve their decisions, i.e. to raise their expected utility. Thus, as suggested in the Introduction, only some forecasts (those of relatively high accuracy) may be worth any costly efforts to disseminate.

The Introduction also stated, though, that forecasts which could be "harmful" should not reach forecast users. This statement appears to be at odds with the forecast value literature, as just discussed. However, when the term "harmful" is seen in societal (not individual) terms, the apparent conflict vanishes. Consider a situation where the expected-utility-raising action of the agent who uses the forecast indeed helps that agent, but harms another agent. For instance, as in the Introduction, large firms' reactions to forecasts could hurt artisanal fishermen. Without even considering the many details of aggregating benefits and harms, it is clear that in such a situation it would be possible to conclude that on net the reactions to the forecast had harmed the society.

This is an important point, as the many ways to aggregate benefits and harms are a major reason that “societal benefit” could mean infinitely many things. One distinction is between the aggregate level of benefits for a whole society and the distribution of those benefits among its members. This paper assumes the possibility that the aggregate potential benefit from a forecast could be sufficient to make efforts to realize those benefits through forecast dissemination worthwhile. One of its foci, however, is the need for attention to which members or groups within society receive those benefits, or are harmed. This distributional issue can not be avoided by reference to a common measure such as GNP, as this measure, like all measures, assumes a particular way of measuring benefit or harm and a particular implicit set of “weights” assigned to each person or group in society. Standard cost-benefit-analysis texts allow that a society's or policy maker's view concerning equity may be explicitly incorporated within aggregate measures of benefits. Practically speaking, if the forecast user benefits from the forecast, but a group that is politically favored is harmed by the changed decision of the forecast user, the provision of the forecast may be seen as negative. In general, a combination of benefits to agents using forecasts and harms to others from those uses certainly could result in net harm.

An understanding of forecast value is crucial for considering forecast dissemination policy. This paper, however, focuses on other issues. In particular, this paper considers why even if forecast information in principle has great value, potential benefits of this sort may in fact not come about. Of course, it may not be the case that today’s forecasts could help Peruvian artisanal fishermen, for example, because their accuracy for coastal areas may be below the threshold where some value exists. However, as many have asserted that such potential value or benefits of El Niño forecasts do exist, we allow for this possibility but then focus on how socioeconomic context and the existence of different societal groups may thwart the generation of actual value. Thus the dissemination challenge could be to reach fewer people, or to know when not to disseminate.

Below, we give conditions regarding differential access to climate information which suggests the need to put effort into information dissemination strategies and also conditions when forecast quality and multiplicity of conflicting forecasts which could make withholding or controlling information a useful option.[4] We conclude with hypothetical examples of dissemination decisions made using this approach. Each scenario maps a pairing of a definition of societal benefit and a level of understanding of social context of constraints to the dissemination choices that appear most likely to maximize the defined societal benefit.

Currently, their is dialogue among the major meteorological agencies concerning a common policy for climate forecasts, suggesting both a need for some form of agreement on standards of forecast quality (or validation), and that meteorological policy makers believe that forecast distribution can be "managed" (or limited) to some extent. It is recognized that providers of technical information, such as individual climate scientists, may not feel it their role to study forecast "users," and may hesitate to make any determination of which groups or goals contribute to societal benefit. While such hesitancy is understandable for individual scientists, an approach of the sort suggested above seems imperative for public agencies funding such research and for those who promote the dissemination of these scientific findings to address societal needs. While dissemination choices could be made without any information on constraints, they would not then be likely to achieve any given goal. Also, while disseminating choices can be made without any thought as to what constitutes a societal benefit, a disseminator will be implicitly endorsing the view of societal benefit that favors whatever groups (if any) happen to benefit, quite likely at the expense of others. When the dissemination options available differentially impact upon groups in a society, forecast distribution is *de facto* a political endeavor.

2. Background

a. El Niño and El Niño forecasts

The El Niño-Southern Oscillation (ENSO) is a coupled atmospheric-oceanic phenomenon that has global manifestations and occurs approximately every four to seven years. The atmospheric component of ENSO refers to the Southern Oscillation, an inter-annual seesawing of sea-level atmospheric pressure anomalies between a region near northern Australia and one in the southeast Pacific (near Tahiti). The oceanographic component of ENSO has been commonly called El Niño. The warm phase of ENSO involves an extensive warming of the upper ocean and a depression of the thermocline in the eastern tropical Pacific, while the cold phase involves an analogous cooling of the upper ocean and a rise of the thermocline in the eastern tropical Pacific. During an El Niño, a consequence of the deepened thermocline is that the wind-driven coastal upwelling off the coast of South America carries warmer water than usual to the surface. Coastal temperatures anomalies as high as 10 C have been recorded off the coast of Peru (Sharp and McLain 1993). Dramatic shifts of flora and fauna in waters off southern Colombia and Ecuador to Peru and northern Chile are linked to El Niño events (Barber and Chavez 1983; Arntz et al. 1985). In severe events, the increased ocean temperatures and reduced concentrations of phytoplankton negatively impact some pelagic (surface-dwelling) species, such as the commercially important anchovy and sardines. In addition, tropical species of fish may extend their ranges to the south as warmer waters appear along the Peruvian coast.

In the early 1970s, at least in part due to a crash of the Peruvian anchovy fishery, interest in forecasting El Niño rose dramatically because forecasting came to be seen as more than an academic exercise.[5] Knowledge gained about the coastal upwelling and how it is affected by various natural factors was seen as applicable to national economic development issues.[6] The extraordinary 1982-83 El Niño, which influenced inter-annual climate variation around the globe, catalyzed government and scientific interest in developing an El Niño forecast capability. This highlighted the relevance and accelerated the planning of the multinational Tropical Ocean and Global Atmosphere (TOGA) program which was in operation from 1985-1994 and resulted in a greatly improved understanding of short-term climatic fluctuations.[7] In any event, momentum toward operationalized climate forecasts has palpably increased. Further, all forecast groups, to differing degrees, employ the concept of "societal benefit" within the rationale behind their efforts.[8]

The most recent El Niño event of 1997-98 has served to heighten interest in the phenomenon. Thanks to large-scale media coverage, numerous workshops and conferences, and the evolution of global communications technologies such as the internet, societies around the world have become further aware both of the El Niño phenomenon and of the existence and potential value of El Niño forecasts. We can now begin to test the common assumption that if a “reliable” El Niño forecast existed, its dissemination would necessarily yield significant societal benefit. This article, which examines the case of the Peruvian fisheries during the

1997-98 event, suggests reconsideration of this assumption. Furthermore, it attempts to draw general lessons from this case that may be relevant to seasonal-to-interannual climate forecast dissemination issues in other locations and sectors.

b. The Peruvian fishery

Fueled by the increased post-World War II demand for fishmeal and the collapse of the California sardine fishery in the 1950s, which made boats and machinery cheaply available, the Peruvian industrial fishing boom began in the mid-1950s and lasted until the early 1970s. In the context of weak regulations and technological advances, its catch increased to more than 12 million metric tons (primarily anchovy) by 1972, when overfishing combined with the 1972-73 El Niño led to a collapse of the fishery. It was not until the early 1990s that the anchovy fishery recuperated to pre-1973 levels. Throughout much of the 1990s the Peruvian fishing sector accounted for over 10 percent of the world's catch (consistently ranking second to China), with over 90 percent of that going to fishmeal production. Second only to mineral products, fishmeal is of appreciable importance in Peru’s economy, representing more than 4 percent of the gross domestic product, and generating over $1 billion in foreign exchange earnings in 1996.

The fishing sector can be roughly divided into artisanal (small-scale) and industrial groups. These two groups fish different species using different methods of capture and are subject to different regulations. Interannual climate variations, generally related to El Niño events, shift the spatial availability and relative abundance of the variety of harvested species. As different groups and sub-groups specialize in extraction of different species, a given event may benefit one group, or set of sub-groups, while harming others.

The artisanal subsector is comprised of approximately 50,000 small-scale producers who fish (and dive) for sale to an internal fresh-food market, for export, and for subsistence. Historically, they have occupied the lower socioeconomic strata of the society, are generally self-employed, and have limited political influence due to poor organization.

The industrial sub-sector directly employs approximately 26,000 persons. The majority of non-management laborers are fishing fleet workers and fishmeal plant and cannery workers. A significant number also work in associated industries such as net making and repair, engine repair, and ship building and repair. At present, labor union power has significantly diminished in the fishing sector due to the large fraction of short-term contract workers and the removal in 1996 of regulations which protected worker security during non-fishing periods called *vedas* (closed seasons). In the mid-1990s, the largest fishing firms began diversifying into canned fish products, agriculture, mining, and other industries. Finally, the industrial sub-sector has throughout the period of commercial fishing wielded strong political influence (Thorp and Bertram 1978; Baltazar 1979; Zapata 1998).

The financial sector is linked to the fishing sector through banks, many of which have invested heavily in the industrial fleets and plants. Banks are also potential users of forecasts, as they must make new loans, refinance debts, and foreclose based on their perceptions of the upcoming fishing season. As important economic entities, they may also wield political power.

The El Niño influenced anchovy collapse in 1973, coupled with political change in the country, led to a temporary nationalization of the fishery, resulting in massive layoffs and restructuring of the industry. Currently, regulations are made by the Ministry of Fisheries. Its decisions are, in theory, informed by the recommendations of the board of directors of the governmental scientific agency in charge of fisheries and oceanographic studies, as well as the advice of experts from the United Nations Food and Agriculture Organization (FAO). This board of directors is made up of representatives from the navy, the industrial fishing sector, a scientific agency, and the Ministry of Fisheries. The board members are in turn informed by the agency's scientists. Regulatory mechanisms include species as well as minimum size restrictions, *vedas* (closed seasons or bans), spatial and gear restrictions, and statistical reporting. Regulations are inconsistently enforced.

c. El Niño 1997-98 and the Peruvian fishery

Reluctance by a range of decision-makers to act upon early forecasts of the 1997-98 El Niño was influenced by their memory of the characteristics of prior El Niño events, and the existence of multiple conflicting forecasts of the event. For example, the 1997-98 event manifested early in the year compared to the last big event of 1982-83, contributing to the debate over how the event would develop. Similarly, some fishermen, firms, and bankers recalled the "false starts and finishes" of the El Niños of 1991-95 and were also hesitant to take significant proactive measures (e.g., cancel plans to build new boats and plants, buy new nets, divestment, etc.) well in advance. Finally, biological indicators which accompanied the 1982-83 event, such as the arrival of massive numbers of jellyfish to the coastal areas, did not occur in 1997-98, discouraging procurement of different equipment in anticipation of the arrival of other commercially valuable tropical species. The uncertainty surrounding the development of the event was further compounded by conflicting forecasts. The first official announcement of an impending event came from the Peruvian meteorological service in June of 1997, though it was heavily disputed by other local agencies, leading to numerous conflicting forecasts in the media. The first government measures, which included forming a multisectoral task force led by the head of the national oceanographic agency, took place shortly afterwards, in July 1997.

1) BIOLOGICAL IMPACTS AND GOVERNMENT REACTIONS

Of the approximately U.S. $162 million spent by the government on preventive actions, only U.S. $4.1 million was spent on the fishing sector (primarily on infrastructure reinforcement in port areas). Relatively limited proactive measures aimed at minimizing the negative and enhancing the positive impacts on the fisheries sector were implemented, which many attribute to the governments' economic policy of minimal intervention in private sector activities. Towards the start of the event (April 1997), the small pelagic fish stocks composed primarily of anchovy (*Engraulis ringens*) moved closer to shore in search of cooler, nutrient rich waters.[9] These conditions led to a spike in catch which the Peruvian oceanographic agency realized was related to the anomalous warming and changing biological conditions of the waters (see Fig. 1). Based on the recommendations of the oceanographic agency, the Ministry of Fisheries implemented a fishing ban (*veda*) in the central-north sections of the coast in April, but it was retracted just a few days later due to industrial pressure. The Minister himself was forced to resign due health problems brought on by the stressful nature of the situation. The high catches declined rapidly as fish began to migrate both vertically below the range of the nets (>70 meters), and southward into northern Chile. The oceanographic agency increased their monitoring of biological indicators and began efforts at coordinating this monitoring with their Chilean counterparts.

Despite industry pressure to continue fishing, the Peruvian oceanographic agency recommended a *veda* in the south (from 16 S to the Chilean border), a virtually unprecedented measure. Again, due to political pressure, the *veda* period was cut short, but in reality fishing had already dropped to very low levels, imposing what fishermen called a "*veda natural*". Pending the results of monitoring cruises the Ministry of Fisheries set a low preliminary quota on anchovy for the upcoming period (September - March) and enacted special decrees which allowed the extraction of non-traditional species, as well as the use of smaller size net mesh to fish traditional species (despite protests from some local scientists and some international agencies).

By mid-1998, oceanic conditions very slowly began returning to "normal", and the fish that "survived" the extreme conditions were now concentrated in the few pockets of water which supported the nutrient base for them to feed. Despite the fact that stocks were comprised of mixed species with few juveniles (indicating possible failure of recruitment of an age-class) which makes selective harvest of fish by size and species nearly impossible, and biological indicators of a stressed stock (e.g., low fat content, underdeveloped reproductive organs), many days of "experimental" or "exploratory" fishing were permitted, leading to an increase in landings.

In keeping with recent market-oriented reforms of President Fujimori, and in contrast to government reaction following the 1973 collapse, there was no nationalization of the industry or government subsidization. Nor did the government take advantage of the situation to buy out vessels and retire them as recommended by FAO advisors in late 1997 as an option for reducing the capacity of the overcapitalized fleet prior to the return of the diminished stock.

The artisanal sector experienced a boom in the availability of tropical species such as mahi-mahi (*Coryphaena hippurus*) and shark (*Isurus oxyrinchus*), the growth rate of octopus (*Octopus spp.*), scallops (*Agropecten purpuratus*), and other species. However, there was virtually no government aid to these fishermen for switching to appropriate gear and finding new markets for potentially valuable species. The majority of government aid arrived in the form of repairing port infrastructure damage and foodstuffs.

2) INFORMATION SOURCES

Widespread coverage of the developing El Niño event took place in newspapers, television, and the radio, with special sections and shows devoted to the topic. There were complaints, however, of an overabundance of conflicting information, attribution of any weather anomaly to El Niño, and sensationalistic reporting. Some valid information was undermined by the perception that there were individual, institutional, or private incentives influencing the content. Other formal information sources were widely publicized meetings. The first, an emergency meeting, was held by the *Comisión Permanente Pacífico del Sur* in early July in Lima. The consensus at this meeting was that it was too early to tell the severity of the event and it would not be until October that its magnitude would be known. It was also acknowledged at the time that the predictive model that seemed to best capture the evolution of the event at the time was the NOAA/National Center for Environmental Prediction coupled model, although it seemed to underestimate the severity of the event.[10] It is noteworthy that there was virtually no artisanal sector representation at this meeting while the industrial representatives played central roles in shaping the focus of the fisheries working group and general sessions.

A second major regional conference with attendance by international experts and in part supported by U.S, national, and international organizations took place in Lima in late October of 1997. Entitled, "Is this the El Niño of the Century?", it was intended to produce a consensus forecast of the event. There was a difference in opinion regarding the potential impacts of the event among the three major Peruvian scientific agencies. The national meteorological service was predicting an extreme event on par with that of 1982-83; the geophysical institute which had previously been considered the leader in climate prediction was insistent that the impacts of this event (referring primarily to precipitation) would be much less severe than 1982-83; and the oceanographic agency was predicting a weakening of the event with only a moderate impact on marine species of primary economic interest. The difficulty arriving at consensus of both the event itself as well as of its impact on the different sectors was compounded by institutional and individual competition which will be discussed in the following sections. Based on interviews and observations following this event, most decision-makers in the fishing sector were left confused by the mixed opinions that resulted from this event and discrepancies in the forecasts allowed the alternative constructions of uncertain information in self-serving manners. Again, there were no artisanal representatives at this conference (there was an exorbitant entrance fee for the public presentation of the information). Many scientists and policy makers claim that there was pressure by central governmental officials and the private sector to play down the severity of the event in their public statements for fear that it would lead the banks to stop lending (which in fact, they did) and discourage foreign investment in the country.

3) Industrial and artisanal impacts

There was a dramatic rise in catch during the start of the event, as industrial fishermen were able to minimize the distance traveled and could quickly fill their seine nets and make multiple trips per day, even though they were often fishing within the space legally designated for the artisanal fleet (0 - 5 nautical miles from shore). Following the short *veda* in April, industrial sector landings continued to decline steadily and there were widespread reports of fishing illegal species with illegal gear, including dynamite. These accusations are supported by the reduced quality of the fishmeal produced, indicative of the use of non-traditional species for fishmeal and fish oil. Most of the industrial fleet, following the displaced pelagic stocks, had migrated to the southern port towns, spurring complaints by local citizens of an increase in drunken revelry and delinquency. The implementation of a southern veda in August was met with extreme resistance by the fishing industry as well as the mayors of the southern towns. In letters to President Alberto Fujimori, published in the major newspapers, they argued primarily on nationalistic grounds, that the fish should not be protected if they are going to migrate south and be caught by competing Chilean fishermen. Again the veda was lifted prematurely. By the end of 1997, massive unemployment had spread through the industrial fishing sector, including the northern Chile region. Despite the anomalous conditions during most of 1997, however, extremely high fishmeal prices and the massive landings at the start of the event resulted in a high profit margin for the fishing industry as a whole.

The year 1998 saw continued decline in both catch and profits, with production reduced to half that of 1997 (Gestión 1999). The economic impact on the industry and the incentive to downplay the severity of the impacts was accentuated by the fact that two of the largest fishing firms, one of which had opened the highest production cannery in the world in early 1997, had recently begun issuing bonds and did not want to scare away potential investors. Eventually, the social disruption characterized by high unemployment was undeniable, as exemplified by the front-page headlines of the countries' major newspaper (referring to the largest fishing port of Chimbote): "Chimbote is a beggar with an ocean view" (Villanueva Chang 1998, A8).

It was not until mid-1998 that the government provided aid in the form of food relief to some of the industrial fishermen in the hardest hit areas. Individual fishing firms re-negotiated debts, and due to virtually non-existent labor laws, workers were left with little recourse. This second condition was exacerbated because revenue for the industrial fishermen's recently privatized social security and health organization is drawn from a percentage of the catch. This agency's coffers quickly ran dry. A similar funding system exists for the semi-privatized enforcement of fishing regulations, also limiting regulatory capacity at the time it was needed most. In short, pressure to allow fishing of the recovering stock, from a heavily indebted industry (over U.S. $1 billion) and a disgruntled labor force, was immense.

The arrival of tropical species was initially profitable for a large subset of the artisanal sector, but as the event increased in strength, there was such an abundance in supply all the way into Chile, that the market price dropped to below U.S. $1 per pound for mahi mahi, in which case landings did not cover the cost of basic expenses such as fuel, ice, and food for a fishing trip. Other factors undermined the potential benefits of additional species. For instance, stricter European health regulations prevented the rapid transition into new available overseas markets, the opening of a lengthy closed season on octopus in Mexico drove the international prices down, and the "Asian crisis" reduced export demand. In other instances, fishermen, although aware in advance of the likelihood of the possibility of catching alternative species, simply did not have the accumulated capital to invest in new gear and the government provided virtually no aid for such proactive measures.

The typically massive migration of the lucrative ocean shrimp (*Penaeus spp.*) from Ecuador southward into Peru was much less than expected, leading some experts to speculate that the overfishing in Ecuador over the past few years undermined a key positive biological impact of El Niño. The increased sea-level (over 28cm in some ports) exacerbated the severity of the storm damage and the number of days the small vessels were prevented from fishing. Many of the rural fishing villages were also the most susceptible to damage from the heavy rains of the event, and were unable to get their products to market due to washed out roads and bridges. They received governmental aid that was intended primarily for reconstruction of infrastructure damage and some foodstuffs.

4) POLICY IMPACTS

While it is still premature to quantify many of the impacts of the 1997-98 El Niño and of policies based on forecasts, some speculative statements can be made. Proactive measures based on advanced warning of the event certainly appear to have prevented some loss of life and property damage. Considering the case of fisheries, however, the provision of forecasts did not prevent: (1) massive labor disruption; (2) an increase in illegal fishing activity; (3) an apparent (at least short-term) biological and economic collapse of the fishery. Also, forecasts did not lead to the exploitation of the opportunities brought by El Niño, such as capitalizing on the export of tropical species.

To speculate further, the relative success of disaster prevention measures, although subject to issues of corruption, political favoritism, and failed measures, might be attributable to common shared values which facilitate coordinated collective action in this arena. In contrast, the fisheries sector is composed of antagonistic, competitive social groups and subject to the formal and informal influence of the private sector over regulatory mechanisms. In addition, it may be that the engineering and technological fixes associated with civil defense are relatively straightforward (albeit resource limited) compared to fisheries management. The complexity of environmental-biological interactions and fishing pressure influencing reproduction, recruitment, and predation is daunting. In the following sections we analyze in further detail some of the obstacles which may have impeded groups from better preparing for the event.

3. Forecast uses and impacts

In this section, using selected examples from the Peruvian fisheries' responses to the recent El Niño 1997-1998 event, factors which may limit the societal benefits of forecast provision are identified. These are of two types. The first set is (a) the limitations of forecasts themselves. The second set is (b) societal constraints. The latter include: i) lack of access to forecast information; ii) difficulties making productive use of probabilistic information; iii) the stifling of information dissemination and distortion of informational content; and iv) producers' and other actors' individual reactions to forecasts (e.g., layoffs or increased resource extraction), which may be inconsistent with what the provider has defined as societal benefit.

a. Limitations of forecasts

For actors such as fisheries regulators and firms to be able to take even relatively secure steps to integrate forecasts into their planning and operations, those forecasts must contain appropriate spatial resolution for regions that are of central interest to the fishing sector. However, forecasts of the oceanographic aspects (primarily sea-surface temperatures) of El Niño events have the greatest skill for two regions in the central Pacific known as the Niño 3.0 region (5 N - 5 S, 90 -150 W) and the Niño 3.4 region (5 N - 5 S, 120 - 170 W). Further, it is acknowledged that models have limited skill for coastal areas, such as off Peru, which feature steep gradients in oceanographic characteristics as well as coastal bathymetry. Accordingly, current model-based forecasts can be of only limited relevance for this region's fisheries decisions.[11] Further, the collection of observational data for the Peruvian coast, which might permit the development of forecasts with greater skill for coastal areas, is limited by a lack of fixed buoys to monitor current conditions or provide data for models.

In order to inform adequately regulators' and firms' decisions, forecasts should predict not only the onset of an event but also its intensity and duration. Although knowing about the onset of an event can help in planning, many important fisheries decisions are made after an event has already begun and as a function of its expected intensity and duration. Public sector decisions of this sort include readjusting catch quotas and revoking or increasing subsidies, while private decisions include stockpiling fishmeal or whether or not to refinance loans.

Even perfect climate forecasts would not be totally sufficient for fisheries management, in which the decision makers focus is not climate *per se* but rather the implications of climate for both current and future generations of fish. However, translating climate predictions into accurate fish-stock prediction (directly or through ecosystem/nutrient models) raises additional modeling challenges (Masood 1997; Parsons 1996). Most current models of fish population dynamics do not use climate information.[12]

Finally, although this is not a limitation but rather an inherent characteristic, it is worth emphasizing that forecasts are probabililistic. Thus, potential forecast users may be presented with a relatively complex set of information, such as a normal probability distribution across a range of temperature anomalies. This becomes even more complex, in a very particular way, when this underlying uncertainty is masked within an apparently simple set of information. For instance, a graph of monthly temperature anomalies over the next year may be presented as a "experimental forecast". The term "experimental" may imply a lack of certainty to a sophisticated forecast user, but if the graph lacks error bars then even that user lacks the information that the probability distribution provides.[13] Further, many potential users may interpret the experimental forecast as a deterministic one.

b. Societal constraints

1) ACCESS

Assuming that forecast information is of some potential value, forecast providers should be concerned with delivering that information in the appropriate form to target audiences. Even for perfect forecasts, some audiences may have problems of access and/or understanding. In addition to the point that not all groups understand the provider's native language, it is clear from the 1997-98 event that audiences (e.g., artisanal, industrial, bankers, and scientists) had different levels of access to communication technologies such as the internet, fax machines, or short-wave radios, and that this led to varying degrees of access to forecasts.

2) UNDERSTANDING

Yet another limitation may arise from a lack of ability to interpret the information that arrives as intended by the provider. A real-time satellite image that is misinterpreted by local scientists is as ineffective as a bulletin which arrives to a rural village by surface mail two months late. Misinterpretation of forecast information has been a serious problem, in particular because most forecasts contain probabilistic statements which often necessitate subjective interpretation. This has been exacerbated by local agents, especially the media, who attempt to turn probabilistic statements into sensationalist, deterministic headlines.3) DISTORTION

Another constraint on forecast value observed during this event involves the stifling and/or distortion of information and the generation of competing forecasts based on misinformation or misinterpretation. For instance, as Peruvian public-sector scientists, who are often relatively poorly paid, consult for private industry, the desire to be valued for private information may create incentives for them to withhold at least temporarily their latest or highest-quality information from public release. Further, the desire to be well-liked by potential private employers may generate pressure on scientists to distort information, possibly by injecting certainty into scant information.

There are also incentives at the firm level which encourage alternative interpretations of uncertain climate data. As witnessed during the 1997-98 event, some fishing firms were awaiting large bank loans and did not wish to highlight the possible severity of an upcoming El Niño event and the increased risk to the bank. Alternatively, others wanted to play down the severity of an event in order to benefit from competitors' bankruptcy. Finally, firms deep in debt were seeking to have a state of emergency declared to avoid foreclosure. A common perception among government employees and regulators is that scientists may be fired if their recommendations are inconvenient for those elites linked to the fishing industry. Thus the media and government scientist were pressured by different politically powerful groups to favor certain interpretations of probabilistic forecasts.

Furthermore, competition among public (or non-profit) institutions for limited national and international funds may generate incentives to “manipulate” information. Peruvian scientific institutions (such as meteorological and oceanographic agencies) clearly compete to be viewed as the definitive source of information on "El Niño".[14] This competition may result in sensationalist statements and counter statements to the public (especially via the media) that are based less on scientific certainty than on the desire to appear authoritative. Further, it raises an extremely important point for “external” (foreign) forecast providers. Given the lack of perfect certainty and the issues raised above, a provider may be tempted to step away from formal public provision programs altogether. However, these examples make it clear that if any information at all is available (even on a “purely scientific” website) some “popular forecast” is likely to be generated by local institutions which have an incentive to show expertise.

4) REACTIONS

Additional constraints arise if rational choices by individuals run counter to the outcomes anticipated or desired by forecast providers. One important possibility is the rejection of a forecast. For instance, during the 1997-98 El Niño event, Peruvian decision-makers were exposed to numerous conflicting estimates (e.g., competing different forecasts by two agencies in the same newspaper). Individuals may lose confidence in all forecast information, and ultimately, quite rationally, reject its use.[15] Such rejection may become even more frequent if decision makers are already skeptical of a source of forecasts. For example, they may reject valid information based on preconceptions regarding either the credibility of an institution's representative (perhaps suspected of injecting personal biases) and/or its capacity for producing reliable information. One basis observed for such preconceptions is a previous "bad" forecast by the institution. This occurred during this El Niño event when one of Peru's most prestigious scientific institutions lost credibility by making several high visibility forecasts that there would be only moderate rains in the north of the country instead of the torrential rains actually experienced.[16]

Reactions other than rejection may also run counter to the outcomes that are either anticipated or desired by forecast providers. For instance, if resource sustainability were a provider goal, at least two types of potentially unanticipated reactions might be seen as negative. First, if upwelling forecasts (developed from climate forecasts) were of sufficient spatial resolution and lead time to estimate accurately the future location of fish stocks, industrial fleets might have time to switch locations and increase their extractive capabilities, with potentially drastic adverse implications for the future standing stocks. Second, observations of this El Niño event suggest that the news alone that a strong El Niño event will diminish available stocks may likely lead some groups to increase current extraction efforts (when a conservationist might advocate reduced efforts in the face of upcoming environmental stress). This effort could be increased by an expectation that regulations would further restrict future catch.

An alternative definition of societal benefit might focus on the welfare of labor. In this case, it may matter that, given weak labor laws and unions in Peru (for example, no minimum wage during closed seasons), management may fire its workers in response to a prediction of an El Niño event. If such responses are not considered, such an outcome may not be anticipated. Even if anticipated, however, this outcome of forecasts and rational choice may be viewed negatively depending on providers' interests and goals.

4. Defining societal benefit

As a result of changes in funding resulting from the end of the Cold War, it is becoming an increasingly common trend to justify scientific work on its societal relevance (Pielke Jr. and Glantz 1995). As noted, historically, “external” forecast providers (in the case of Peru, institutions such as the U.S. government or U.N. agencies) have stated their mandates in terms no more specific than “to increase societal benefit”. However, such broad mandates fail to distinguish among competing conceptions of benefit, some of which would be served by one dissemination strategy and some by others. Table 1 summarizes variable conceptions of benefit within the Peruvian fishery. Of course, each one of the groups identified could be broken down into numerous subcategories which may have competing goals on a more localized scale.

Without further specification along the lines of Table 1, a broad mandate such as “increase societal benefit” provides inadequate guidance for choosing between different dissemination strategies.[17] Unless it is determined whose welfare contributes to societal benefit (and unless what contributes to their welfare is understood), a provider can not decide whether a given impact of forecast provision is a benefit, or whether the aggregate of all impacts represents an increase in societal "net" benefits.[18]

For example, providers need some basis for choosing between providing forecasts solely on the internet versus also providing them over radio. Observations of the 1997-98 El Niño event suggest that the former strategy would primarily inform fishmeal plant owners and managers, while the latter would inform union leaders as well. Should an extreme event potentially lead to layoffs, the latter strategy might enable labor to prepare for and mitigate the impacts of such managerial decisions. However, radio distribution increases costs, a factor to be considered in the choice between strategies, and the definition of societal benefit becomes crucial. If labor’s welfare is deemed insignificant in the computation of societal welfare or benefit, the higher cost radio distribution would not be justified. Conversely, if labor’s welfare is given significant weight in such calculations, then radio distribution would be indicated. A provider without the guidance of a sufficiently detailed definition of societal benefit, however, may choose a dissemination strategy without regard to its effects. This, as previously noted, exposes the provider to the risk that it will be seen as "endorsing" the actual outcomes of dissemination such that, de facto, the provider has defined which societal benefits count.

5. Dissemination choices

This section aims to demonstrate that bringing both a detailed provider definition of societal benefit and an understanding of socioeconomic context and possible constraints on forecast value to bear on forecast dissemination choices are crucial for making appropriate policy choices. This is done with hypothetical examples of dissemination decisions made using this approach. Each scenario maps a pairing of a definition of societal benefit and a level of understanding of social context/constraints to the dissemination choices which appear most likely to maximize the defined societal benefit. As should be expected in actual policy situations, what is best differs across scenarios.

Before working through these scenarios, consider an illustrative partial list of dissemination options from which a forecast provider might choose: whether to disseminate at all; which model to base a forecast on; forecast spatial resolution; forecast/dissemination lead time; forecast/dissemination frequency; dissemination medium (e.g., the internet versus the radio, and whether to train users); dissemination location(s), including the choice of through which “local” institutions to provide information; target population; whether (or whom) to charge and how much; and finally, whether (or whom) to train in interpretation of observations, predictions, and probabilistic forecasts.

Twelve scenarios are presented in Tables 2-4; six comparisons of scenarios are the focus. Within each table, the two types of comparisons are made between adjacent scenarios: the first, across a row, involves a shift in the definition of societal benefit; and the second, down a column, involves a shift in the relevant constraints on forecast value. In each case, the shift considered also indicates a shift in the “best” dissemination choice.

The shifts in definition of societal benefit are of three different sorts: from a goal of maximizing current GNP to one of resource sustainability, from interest to lack of interest in the welfare of labor, and from interest in artisanal to interest in industrial fishermen. These scenarios are offered merely for the purposes of illustration, and it is anticipated that providers' definitions of societal benefit will be considerably more complex. The shifts in constraints on forecast value are also along three dimensions: regulatory strength, access to information and understanding of probabilities, and distortion of forecast information. In both cases, the three dimensions chosen of course represent only a tiny fraction of the set of all such issues. Finally, in no case are the authors arguing that the particular choice indicated is in fact the benefit-maximizing choice; it would take significant additional assumptions and information to determine that. Further, the authors do not endorse a particular definition of societal benefit. Reasonable indications of “best” choices are provided in order to illustrate the main point that both the definition of societal benefit and an understanding of constraints are crucial for making policy choices.

Consider the upper row in Table 2, which assumes that regulatory power is low. In the scenario to the left, with a goal of maximizing current GNP, since forecasts may enable or provide incentive for increased extraction, to maximize societal benefit the provider may wish to make sure everyone has the best forecasts possible, as increased extraction means increased sales and increased current GNP. However, shifting the definition of benefit may modify the best choice. With a goal of resource sustainability, to maximize societal benefit, a provider might choose, if possible, to give forecasts only to regulators. Given low regulatory power, if the fishing firms had forecasts, they might seriously threaten future fish stocks. On the other hand, even though they are weak, it may be worth getting the regulators the information, as they may achieve some marginal gains in protecting resources.

Next consider a shift in the constraints on forecast value within the right column, which assumes a societal goal of resource sustainability. As noted, if regulatory power is low, then forecast information should not go to the fishing firms. However, if regulatory power is high, then as long as the regulators get the information, resource sustainability will be enforced (as this was assumed above to be the domestic regulators’ goal). In that case, forecast information may as well go to everyone in order to promote other gains. For example, firms might better plan fleet maintenance or avoid costly investment mistakes.

Consider the lower row of Table 3. Here it is assumed that labor's (e.g., union) access to and understanding of probabilistic forecasts is low and, implicitly, that others have high access and understanding. To the right, since what happens to labor is inconsequential, there is no reason for a provider to do anything more than what seems reasonable and convenient, such as putting forecasts on the internet. However, shifting the view of benefit may affect the best dissemination choice. If labor's welfare does matter to the provider, or, in the extreme, if it is the only thing that matters to the provider, then a much different dissemination strategy may appear best (i.e., may appear to maximize societal benefit). Greater dissemination efforts, such as translating forecasts and broadcasting via the radio, and even training, may be in order.

Next, consider a shift in the constraints on forecast value within the left column, where it is assumed that labor's interests are valued by the provider. As noted, if labor does not easily receive and/or is not trained in the interpretation of forecasts, then significant dissemination efforts may be in order. If, however, a well-organized union not only has good internet access but also clearly disseminates the information to its members, then the provider may prefer to rely on lower cost dissemination via the internet (assuming both that dissemination is costly and that providers' budgets are quite limited).

Finally, consider the upper row in Table 4, which assumes that the only forecasts that anyone ever takes into account are those of the provider in question. Since legal access to near-shore areas can be traded by artisanals to industrials, differing artisanal and industrial expectations regarding future fish stock locations may lead to such trades (which have in fact been observed). Further, assuming that industrials better understand probabilistic forecast information, trades based on forecasts will tend to benefit the industrials at the expense of the artisanals. Thus, in the scenario to the right, where the provider cares most about industry, to maximize societal benefit forecasts should be disseminated in order to foster trades which will benefit industrials. In the scenario where the provider cares about artisanals, however, there is a case for withholding forecasts, as their provision would lead only to what the provider perceives as a bad outcome.

However, the left column addresses an issue relevant to such a choice, one which arose during the 1997-98 El Niño event, for which myriad forms of forecast information were advanced by a wide range of agents.   Withholding a forecast may not be an option. Although a provider may withhold its forecast, that is unlikely to leave decision makers (either firms or regulators) in a "forecast-less" state. In this case (i.e., in the lower cell of the left column), despite the shortcomings of its forecast and its problematic uses, the provider may wish to make its information “heard above the din”. Further, in order to make its probabilistic statements understood (and to enhance its credibility), it may wish to offer some training in interpretation.

6. Conclusions

We have argued that both a clear, appropriately detailed definition of societal benefit and some understanding of the existing constraints on forecast value are crucial elements in a process which leads to the best choices regarding the dissemination of climate forecasts. We should, however, place the points we have made in some perspective. First, it is recognized that the sketches of the social structures and individual decisions which could constrain forecast value were just that, sketches. While it is beyond the scope of this paper to present more detailed evidence, our arguments and examples are based on observation of reactions within the Peruvian fishery to the 1997-98 El Niño event.

In addition, the term “forecast provision” has been used to mean just about any provision by any individual or institution of just about any form of climate information. This relatively loose use of terms avoided an important discussion regarding which, among a set of more precisely defined approaches, might generate the greatest societal benefit. For instance, the provision of forecasts based on an enhanced ocean monitoring program versus the provision of forecasts based solely on coupled ocean-atmosphere models may be appropriate for some decision-makers in the fishery.

A related issue is the overabundance of accessible climate forecast information. As was evident during 1997-97 El Niño, someone surfing the Web, may be as likely to find an experimental prediction from an unvalidated model as a forecast which takes into account several models and other more local climatic conditions besides El Niño. This raises the question as to whether there should be some sort of quality control (validation) for publicly distributed information. Results that are intended for sharing with colleagues, for instance, could be password protected, while forecast products which have been approved by the community through a consensus process could be distributed more widely in the proper forms by a limited number of specialized organizations. This approach could minimize the burden of media relations and difficulties relaying probabilistic information. Such a "clearinghouse" approach could allow the information to be tailored to the needs of end-users to minimize misinterpretation and distortion of the information.

As dissemination efforts increase, providers may also need to choose where to focus among sectors. In this case, it is possible that fisheries would be given a low priority, particularly if it turns out to be relatively difficult to use forecast information to achieve societal benefits. For instance, in fisheries, the necessary forecast information involves fish stock modeling, versus more reliable stream flow modeling needed for water management. Further, in fisheries, understanding of private decisions is necessary for making dissemination decisions, which is not the case in sectors where most of the relevant decisions are public.

Allowing for these caveats, the arguments advanced in this paper still appear to be rather generally applicable. First, retaining a focus on Peruvian fisheries, dissemination is not the only choice that should be affected by considerations of societal benefit and constraints on forecast value. Research and development choices might also be considered in this way. For example, those who generate forecasts choose whether to focus their research on a long time scale or on increased temporal and spatial resolution for a relatively short time scale. If short-term fishing-firm profits were the definition of benefit, then the latter might be preferred, whereas if sustainability were the goal, an improved forecast of long-run stock dynamics (which would aid in regulatory management decisions) might appear to be the best choice for allocation of research resources.

For both research and dissemination, our points should apply to other regions as well as to other sectors. That other South American countries are concerned with the effects of El Niño (for fishing or other reasons) is demonstrated by the membership of Chile, Ecuador, and Colombia in a regional organization called Comisión Permanente del Pacífico Sur (CPPS), which has a branch dedicated to the study of El Niño. For fishing, spatial shifts in some tuna populations have been linked to large zonal displacements of the Pacific warm pool (Lehodey et al. 1997). For other sectors, similar considerations seem likely to arise in applications of forecasts to agriculture, disaster prevention, water resource management, and health. For instance, it may be necessary in agriculture to consider the conflicting interests of subsistence farmers and agro-business companies. As in the case of artisanal fishers, if small-scale is the provider's focus, more widespread dissemination and training in interpretation may be the appropriate policy choices.

In sum, the last two decades of intensive research have yielded increases in the ability to forecast aspects of El Niño events. These efforts on the physical science side stand in marked contrast to the paucity of studies of the socioeconomic effects of climate variability and climate forecasts. The relevant gaps in understanding include not only the identification of affected categories of people and how they are affected, but also whether in responding to such variability such groups are likely to use forecast information beneficially, if at all. In focusing on how providers' dissemination and research choices might lead to societal gain, the following points should be emphasized:

1. Actual forecast use and the impacts of any given forecast-dissemination choice are difficult to predict absent of an appreciation of the socioeconomic context in a forecast's target area;

2. A forecast provider's actions inevitably "endorse" a view of societal benefit, as any dissemination choices will have different effects for different social categories;

3. From (1) and (2) above, it follows that in order to maximize the value of forecasts through dissemination policies, a forecast provider must not only define in an appropriately detailed fashion the societal benefit it wishes to confer, but must also acquire some understanding of socioeconomic context in a forecast's target area;

4. From (1) through (3), above, it follows that retrospective studies of how forecasts were used in real-world decisions would permit more informed choices by forecast providers in the future.

REFERENCES

Anderson, D. L. T., E. S. Sarachik, et al., 1998: The TOGA Decade: Reviewing the Progress of El Niño Research and Prediction. *J. Geophys. Res.* 103, 14167-14510.

Arntz, W .E., A. Landa, and J. Tarazona, 1985: El Niño: Su Impacto en la Fauna Marina. *Bol. Inst. Mar.*, vol. ext**.**, Perú-Callao, 222 pp.

Bakun, A., 1996: *Patterns in the Ocean: ocean processes and marine population dynamics*. California Sea Grant College System, 323 pp.

Baltazar, C. M., 1979: *Estado, Pesca y Burguesía: 1939-1973*. Lima: Realidad y Teoría.

Barber, R.T. and F.P. Chavez, 1983: Biological Consequences of El Niño. *Science*, 222, 1203-1210.

Barnston, A. G., M. H. Glantz, and Y. He, 1999: Predictive Skill of Statistical and Dynamical Climate Models in Forecasts of SST during the 1997-98 El Niño Episode and the 1988 La Niña Onset. *Bull. Amer. Meteor. Soc.*, in press.

Bjerknes, J., 1966: A possible response of the atmospheric Hadley Circulation to equatorial anomalies of ocean temperature. *Tellus*, 8, 820-829.

Broad, K., 1999: Climate, Culture, and Values: El Niño 1997-98 and Peruvian Fisheries. Ph.D. diss., Columbia University.

Carson, D. J., 1998: Seasonal Forecasting. *Quart. J. Roy. Meteor. Soc.*, 124, 1-26.

Chavez, F. P., P.G. Strutton, and M. J. McPhaden, 1998: Biological-physical coupling in the central equatorial Pacific during the onset of the 1997-98 El Niño. *Geophys. Res. Lett.*, 25, 3543-3546.

Dreser, C., and J. M. Wallace, 1987: El Niño events and their relation to the Southern Oscillation: 1925-1986. *J. Geophys. Res.*, 92, 14189-14196.

Glantz, M.H., 1979: Science, politics, and economics of the Peruvian anchovy fishery. *Marine Policy*, July**,** 201-210 .

_____, Ed., 1995: *Usable Science II: The Potential Use and Misuse of El Niño Information in North America.* NCAR, 260 pp.

_____, 1996: *Currents of Change: El Niño's impact on climate and society*. Cambridge University Press, 194 pp.

Gestión, 1999: *Producción pesquera cayó 50.8% en 1998*. 10 January 1999, 17.

Katz, R. W., A. H. Murphy, and R.L. Winkler, 1982: Assessing the value of frost forecasts to orchardists: a dynamic decision-making approach. *J. Appl. Meteor.*, 21, 518-531.

_____, and A. Murphy, 1997: *Economic Value of Weather and Climate Forecasts*. Cambridge University Press, 222 pp.

Kawasaki, T., S. Tanaka, Y. Toba, and Taiguchi, 1991: *Long-Term Variability of Pelagic Fish Populations and Their Environment : Proceedings of the International Symposium*, Sendai/Japan, 14-18 November, Pergamon Press, 402 pp.

Lehodey, P., M. Bertignac, et al., 1997: El Niño Southern Oscillation and tuna in the western Pacific. *Nature*, 389, 715-718.

Lluch-Belda, D., R. A. Schwartzlose, et al., 1992: Sardine and anchovy regime fluctuations of abundance in four regions of the world oceans: a workshop report. *Fisheries Oceanography*, 1, 339-347.

Masood, E., 1997: Fisheries science: All at sea when it comes to politics? *Nature*, 386, 105-106.

Mittaine, J. F., Ed., 1998: *Proc. from Fishmeal Exporters Organization Annual Conference*, Puerto Rico, 16-17 Nov, Fishemeal Exporters Organization, 69 pp.

NOAA, 1994 El Niño and Climate Prediction. *Reports to the Nation on Our Changing Planet*. Spring 1994, 1-24.

Orlove, B.S. and J. Tosteson, 1998: *The use of forecasts of the 1997-98 ENSO event in five nations (Australia, Brazil, Ethiopia, Peru and Zimbabwe)*. Presented at the *Trans. AGU EOS* 79, pF42. [Available from Benjamin Orlove, University of California at Davis, 1 Shields Avenue, Davis, CA 95616.]

Parsons, T. R., 1996: Taking stock of fisheries management. *Fisheries Oceanography*, 5, 3/4, 224-226.

Pauly, D., and V. Christensen, 1995: Primary production required to sustain global fisheries. *Nature*, 374: 255-257.

Pfaff, A., K. Broad, and M. H. Glantz, 1999: Who benefits from climate forecasts? *Nature*, 397: 645-646.

Philander, S. G., 1990: *El Niño, La Niña, and the Southern Oscillation.* Academic Press, 293 pp.

Pielke Jr., R.A., and M.H. Glantz, 1995: Serving Science and Society: Lessons from Large-

Scale Atmospheric Science Programs. *Bull. Amer. Meteor. Soc.*, 76, 2445-58.

Pulwarty, R.S., and K.T. Redmond, 1997: Climate and Salmon Restoration in the Columbia River Basin: The Role and Usability of Seasonal Forecasts. *Bull. Amer. Meteor. Soc.*, 78, 381-397.

Rayner, S., and E.L. Malone, 1998: *Human Choice and Climate Change, vol. 1*. Battelle Press, 491 pp.

Sharp, G. D., and J. Csirke, 1983: *Proceedings of the Expert Consultation to examine changes in abundance and species composition of neritic fish resources*. San Jose, Costa Rica, Food and Agriculture Administration.

_____, and D. R. McLain, 1993: Fisheries, El Niño-Southern Oscillation and Upper-Ocean Temperature Records: An Eastern Pacific Example. *Oceanography*, 6, 13-22.

Siekevitz, P., 1972: *The Social Responsibility of Scientists*. NY Academy of Science, 112 pp.

Stern, P.C., and W.E. Easterling, 1999: *Making Climate Forecasts Matter*. National Academy Press, 175 pp.

Thorp, R., and G. Bertram, 1978: *Peru 1890-1977: Growth and policy in an open economy*. Columbia University Press, 475 pp.

Trenberth, K.E., 1997: The Definition of El Niño. *Bull. Amer. Meteor. Soc.*, 78, 2771-2777.

Villanueva Chang, J., 1998: Chimbote es un mendigo con vista al mar. *El Comercio*, 7 Sep A8.

Walters, C.J., 1989: Value of short-term forecasts of recruitment for harvest management. *Can. J. Fish. Aquat. Sci.*, 46, 1969-1976.

World Climate Research Programme, 1997: *Climate Variability and Predictability: Initial Implementation Plan* (DRAFT). International CLIVAR Project.

World Meteorological Organization, 1998: Commision for Basic Systems. Extraordinary Session (ITEM 4.3): Global data processing system-infrastructure needs for Seasonal to Interannual Climate Prediction. Karlsruhe.

Zapata, A., 1998: *Los actores de la pesca industrial Peruana, 1955-97*. Instituto Estudios Peruanos.

1996: Learning to Predict Climate Variations Associated with the El Niño and the Southern Oscillation: Accomplishments and Legacies of the TOGA Program. National Academy Press, 171 pp.

Endnotes

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[1] Certain terms used in this paper may appear to imply a precise definition where no such consensus exists. One example is “El Niño”. Trenberth (1997) argues that exactly what “an El Niño event” involves is not well defined. For instance, it is clear that rather different meteorological events have been described by the term “El Niño”. Another example is the term “forecast”. Some would distinguish among forecasts, predictions, and observations, although our observations in Peru indicate that those receiving these different types of information may not always perceive such distinctions. Thus our use of the term "forecast" includes primary prediction products produced by atmospheric scientists, customized forecasts for specific areas and sectors, as well forecasts of El Niño’s evolution based on real-time observations of the climate system. We use the terms forecast and prediction interchangeably.

[2] Potential providers of seasonal-to-interannual climate forecasts include, for example, U.S. governmental agencies such as NOAA and NASA-JPL, some of whom have chosen to proactively promote the use of their information overseas, and university groups and individual scientists whose information was circulated (non-purposefully) in Peru; international organizations such as the World Meteorological Organization (WMO) and the International Research Institute for Climate Prediction (IRI); U.S. and Peruvian universities and individual scientists who distributed forecasts on the web or contributed to bulletins which present numerous; Peruvian governmental meteorological, geophysical, and oceanographic agencies as well as several non-governmental organizations (NGOs) and regional scientific organizations. In this article, the term “forecast provider” could refer to any of those agents. Examples of the types of information disseminated include computer generated forecasts intended for distribution, experimental forecasts produced for research purposes, and real-time satellite observations that were accessible to the public both in the U.S. and in Peru.

[3] The Introduction considered climate forecast dissemination policy issues, assuming the possibility of a useful or valuable climate forecast. Such discussion presumed some common understanding of what it means for a forecast to provide benefits, or to have value. Below we briefly sketch some basic concepts related to forecast value.

[4] It is noteworthy that during the 1997-98 El Niño event, information seemingly not intended for widespread distribution (e.g., labeled as experimental forecasts) found its way into the Peruvian public sector via the internet or via one of the three major El Niño-related conferences held in Peru.

[5] There was considerable scientific interest in understanding and forecasting coastal upwelling processes, exemplified by the international experiment known as Coastal Upwelling Ecosystems Analysis (CUEA), which was being carried out off the Peruvian coast when the 1972 El Niño event took place. The North Pacific Experiment (NORPAX) was also being conducted in the early 1970s, with the objective of improving prediction of climate and weather for the Pacific Ocean and North America.

[6] Coastal upwelling regions associated with the Eastern Boundary Current account for 0.1% of the world ocean, yet account for 5% of global primary production and 17% of global fish catch (Pauly and Christensen 1995).

[7] For a thorough overview of recent development in seasonal forecasting and the international perspective on the provision and use of such forecasts, see Carson (1998) and for a review of the TOGA Program, see Anderson et al. (1998) .

[8] While there are already claims of having achieved societal benefit from forecasts, there is a dearth of reliable empirical evidence supporting such claims, and there is ample published evidence revealing the variety of difficulties in utilizing climate-related forecast information (Glantz 1995, 1996; Pulwarty and Redmond 1997; Rayner & Malone 1998; Broad 1999; Orlove and Tosteson 1998; Pfaff et al. 1999; Stern and Easterling 1999).

[9] For an overview of the effects of the 1997-98 El Niño on biogeochemical cycles, see Chavez et al. (1998).

[10] For a comprehensive overview and analysis of the performance of a range of statistical and dynamical models, see Barnston et. al (1999).

[11] Recall, the forecast value literature firmly endorses the idea that a forecast may have no value. In particular, if a forecast's accuracy is lower than the relevant 'quality threshold', it should be ignored (see, e.g., Walters (1989)).

[12] There are management implications raised by the increasing evidence that anchovy (genus Engraulins) and sardine (genus Sardinops) populations fluctuate on multi-year or decadal scales as well as interranual timescales, as well as evidence of basin wide synchrony in fluctuations of small pelagics (Bakun 1996); (Sharp and Csirke 1983); (Sharp and McLain 1993); (Kawasaki et al. 1991); (Lluch-Belda et al. 1992) .

[13] Such a graphical forecast could then lead users to misunderstand the information it intended to present. Even if the information intended were of value, the information conveyed could worsen decisions.

[14] Competition among external forecast providers was also evident during the 1997-98 event.

[15] It is interesting here to once again make reference to the forecast value literature. Murphy discusses forecast verification in Chapter 2 of Katz and Murphy (1997), suggesting that it should take the form of a distributions-oriented approach to assessing forecast quality. From this perspective, a surfeit of public forecasts with varying predictions, which jointly cause potential users to perceive the set of forecasts as "no more than noise", could be modeled as having caused potential users to calculate a personal distribution over events that has extremely high variance, e.g. positive weight on a great number of widely varied outcomes. This diffuse distribution, intuitively judged to be unhelpful, would in Murphy's terms lack 'sharpness', i.e. one of the elements of forecast quality (as the highest quality forecasts would be perfectly sharp and unbiased, i.e. have probability one on the truth).

[16] See http://www.igp.gob.pe/enero.htm for the forecast and discussion of the methodology used.

[17] This and other related points are raised in a more general context in Siekovitz (1972).

[18] That is, whether such an aggregate calculation were a simple or weighted.