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The Documented Historical Record of El Niño Events in Peru: An Update of the Quinn Record (Sixteenth through Nineteenth Centuries)

LUC ORTLIEB

ORSTOM, Institut Français de Recherche Scientifique pour le Développement en Coopération, Programme Paléoclimatologie et Variabilité Climatique Tropicale (UR 1), Centre Ile de France, 32 Avenue Henri-Varagnat, F-93143 Bondy-Cedex, France

Abstract

The áclassical chronology of El Niño events for the past four and a half centuries proposed by Quinn et al. (1987) was primarily based upon indications of anomalous meteorological and hydrological phenomena observed in Peru and neighboring areas, as described by various authors and anonymous sources. This sequence of reconstructed El Niño events, later improved and modified by Quinn (1992, 1993; Quinn and Neal 1992), became the major reference for proxy calibrations and for most studies on climate variability related to El Niño/Southern Oscillation (ENSO) during historical, pre-instrumental, times. Precisely because global and regional records of interannual climate variability are becoming more diversified and accurate, there is an urgent need to reevaluate and consolidate the documentary record of El Niño manifestations, particularly in southwestern South America, a key area for ENSO studies.

A preliminary revision of some of the sources used by Quinn et al. (1987) to elaborate on their record (Hocquenghem and Ortlieb 1992b) showed that some of the El Niño events were actually poorly documented and simply may not have occurred. For instance, some events had been reconstructed exclusively from evidence of Rímac River floods at Lima, while no clear relationship has been established between these floods and ENSO manifestations. Another question concerns the significance of anomalous rains in southern Peru: Do they correspond to El Niño situations, as inferred by Quinn et al., or rather to conditions associated with the opposite phase of the Southern Oscillation (La Niña)? Furthermore, a previous analysis of documentary sources on rainfall excess in central Chile during the sixteenth through nineteenth centuries (Ortlieb 1994) revealed many discrepancies with respect to the regional El Niño record of Quinn. The lack of coincidence (especially in the sixteenth and seventeenth centuries) may reflect

inaccuracies in the Chilean and Peruvian records, but it may also indicate a different regime, during the Little Ice Age (LIA), of the teleconnection pattern as observed nowadays in the precipitation excess anomalies in northwestern Peru and central Chile.

This study thus focuses on the sources provided by Quinn et al. and involves a detailed critical analysis of the source reliability, the interpretations of the strength of the events, and the significance of the data with regard to the reconstruction of past El Niño events. For each event, the nature, location, and sometimes the date of the meteorological anomalies that support Quinn interpretations (information not given in the 1987 paper) are included. Additional data on historical rainfall excess (or drought) provided by recent studies are also integrated into the overview covering the 1525–1900 period. For some particular (so-called) El Niño events, the reliability of the references, some transcription problems, and internal contradictions within the sources are reviewed. A major case is made for the need for evidence of rainfall in the coastal region of northern Peru in the assessment of El Niño event reconstruction. Conversely, it is assumed that drought episodes in northern Peru should be coeval with non–El Niño situations.

With respect to the Quinn et al. (1987) and Quinn and Neal (1992) sequences, the resulting compilation of El Niño manifestations in Peru and southernmost Ecuador puts into question the occurrence of some 42 events and suggests the exclusion of 25 previously identified El Niño years. New sources support the inclusion of 7 previously unrecognized El Niño years. The new revised chronological sequence of historical Peruvian El Niños is then compared with other compiled documentary records from the western Pacific region (Whetton and Rutherfurd 1994) and with the coral reef proxy record from the Galapagos Islands (Dunbar et al. 1994). These comparisons lead to the conclusion that a more reliable, consolidated, El Niño record for the past few centuries is still needed. More precise reconstructions of the historical climatology of some key areas of South America, a better assessment of the teleconnections through time, and multiproxy studies that associate documentary records should help researchers to reach this objective.

Introduction

The Quinn Record(s) of Historical El Niño Events

Without question, the late William Quinn was a true pioneer in the study of variability of El Niño manifestations through time. After his work on historical reconstructions of Peruvian river floods and anomalous rainy events, Quinn is rightfully considered as the "father" of the past few centuries' record of the El Niño/Southern Oscillation (ENSO) phenomenon. Quinn et al. (1987; henceforth "QNA") established the strength scale of the El Niño events that has been generally adopted by the large community of scientists working on ENSO and climate variability. Quinn's list of past El Niño events recorded in the eastern Pacific during the past four and a half centuries has been viewed as the major reference for any long-term analysis of the ENSO mode. Practically all the centennial/decadal studies within the past decade that used dendroclimatology, coral reef sequences, annually layered tropical ice cores, or other proxy sequences were compared to, if not calibrated with, Quinn's El Niño chronologies (Quinn and Neal 1983a, b, 1992; QNA; Quinn 1992, 1993).

The key paper for the historical chronology of El Niño events, which included the sources of the data on which Quinn based his interpretations, was the one published in 1987 (QNA). In the early 1990s, Quinn extended his reconstructions of past El Niño (ENSO) events, both geographically and chronologically. With the purpose of strengthening the historical ENSO chronology, he began to correlate the documentary record from South America with data from India, China, and Nile floods (Quinn 1992, 1993). In this process, he was thus led to distinguish two chronological records of climatic anomalies: one considered to be of global meaning, based on all the available data from East Africa, and the Indian and Pacific Oceans, and referred to as the "ENSO chronology," and another one called the "regional El Niño chronology," which was established from eastern Pacific and western South American data. With respect to the original 1987 work, the regional El Niño chronology differed in the extension to several years of some events, a shift to the following (or preceding) year, or modifications in the evaluated strength of some events. Some moderate events that had not been qualified for the sixteenth through eighteenth centuries in QNA were included in Quinn (1992, 1993) and Quinn and Neal (1992; henceforth referred to as "Q&N") records. To obtain his latest regional El Niño chronologies, Quinn reinterpreted some data and/or revised some previous interpretations. However, he did not plainly discuss the old or new sources of information that led him to the 1992 and 1993 papers. The list of documentary sources published by QNA in 1987 was modified and completed by Q&N: These two lists constitute the basic reference for Quinn's reconstruction of El Niño events in South America.

Previous Work

After a short note on the most improbable occurrence of an El Niño event in 1531–32, during the conquest of Peru by Pizarro, Hocquenghem and Ortlieb, in 1991, took advantage of a relatively easy access in Peru to most of the original sources of information cited by QNA to critically reexamine the historical documents and references used by QNA (Hocquenghem and Ortlieb 1992a,b). They located the proper information in many of the references cited by QNA (the 1987 work did not mention page references) and considered it useful to quote the significant sentences of the relevant data that had led to the interpretation of El Niño occurrences (Hocquenghem and Ortlieb 1992b; hereafter noted as "H&O"). Naturally, in almost all the cases, the original information had been written in Spanish, as was the H&O paper. As a result of their critical analysis, H&O questioned the occurrence of some of the events and cast some doubts on the intensities of others.

Among a body of references that mainly concerned evidence from Peru, QNA included a source (Taulis 1934) that deals with the variation of annual precipitation in central Chile during the past few centuries. Later, Q&N added two other sources from Chile (Vicuña Mackenna 1877; Vidal Gormaz 1901). The inclusion of rainfall data from 30°S in the QNA record posed a problem of teleconnection within the South

American region. As was shown by Quinn and Neal (1983a,b), Deser and Wallace (1987), Aceituno (1987, 1988), and Ruttlant and Fuenzalida (1991), there is a very close relationship between the negative phase of the Southern Oscillation (warm El Niño events) and precipitation excess in central Chile. Ortlieb (1994) thus tried to consolidate the historical sequence of rainy years in central Chile through an analysis of Taulis's (1934) work, by comparing it to two other records (Vicuña Mackenna 1877; Urrutia de Hazbún and Lanza Lazcano 1993). This study showed that aside from the fact that Taulis's work was not fully reliable, there is no satisfactory correlation with the QNA and Quinn (1993) records, specifically for the sixteenth through eighteenth centuries. The lack of coincidence between El Niño manifestations in Peru and Chile could mean that the documentary records were still substantially inaccurate and incomplete, but it might also imply that during the Little Ice Age (LIA) a different teleconnection pattern may have existed between northern Peru and central Chile. This interesting conclusion regarding a possible variation of the ENSO mode during the larger scale climatic variations of the past few centuries calls for a more precise study of the historical climate variability in southwestern South America.

Among other recent studies worth mentioning on the relationship between the El Niño system and climate variability of the past centuries are several papers presented at the 1992 international symposium on "Former ENSO phenomenon in western South America: Records of El Niño events" (Hisard 1992; Huertas 1993; Macharé and Ortlieb 1993; Mabres et al. 1993). For northern Peru, a doctoral dissertation in history brought out previously unpublished material from national and regional archives, some of which is of major interest for the reconstruction of climate variability in Piura province (Schlüpmann 1994). A dissertation (Minaya 1994) was focused on the correlation between the precipitation regime in southwestern Peru and El Niño occurrences during the past forty years. Conclusions of this work were examined in relation to the QNA record (Ortlieb et al. 1995) and with regard to the link between the El Niño phenomenon and the exceptional rainfalls in the extremely arid Atacama Desert of northern Chile (Ortlieb 1995).

It is timely to synthesize the data accumulated during the past few years and to verify how they combine with the published Quinn records (QNA; Q&N; Quinn 1993). It might also be useful to recapitulate and revisit the reservations regarding the reconstruction of some El Niño events previously expressed by H&O in the light of newly available information.

A Need for Reevaluation of Quinn's Records

In the recent studies dealing with climatic variability of the past few centuries, particularly those referring to the ENSO mode, it is striking to note how the El Niño chronologies proposed by Quinn are accepted without discussion. In particular, it is seldom mentioned that QNA, Q&N, and Quinn (1993) had ranked the confidence in their reconstruction of past El Niño events. As it commonly happens in such cases, Quinn himself was more cautious with his own ENSO chronological sequence than authors who used his records to compare or calibrate their data. Actually, there has been a general tendency to lean upon Quinn's work – to consider his records as a "black box" that need not be opened and scrutinized. No one (to my knowledge) questioned the fact that QNA, Q&N, or Quinn (1992, 1993) mixed documentary data for Peru, Chile, Bolivia, and Brazil, while much remains to be understood regarding the El Niño teleconnection pattern within southwestern South America and its possible evolution in the course of the past few centuries.

Another justification for this overview is provided by the recent publication of ENSO chronologies for the Indo-Pacific region (Whetton and Rutherfurd 1994; Whetton et al. 1996; Allan et al. 1996), which also reveal some discrepancies with the QNA chronology of El Niño events and with the records of larger scale, global ENSO records of Quinn (1992, 1993) and Q&N. Some of these discrepancies should vanish through a closer look into the original sources used by QNA, Q&N, and Quinn and through a critical reevaluation of some of the criteria used over a decade ago in the reconstruction of former El Niño events.

Methodological Problems

As may be expected, the elaboration of a historical sequence of El Niño events from documentary sources is not an easy task and faces problems of various kinds. Some of these problems, as for any historical work, concern the availability and diversity of written reports and other sources, the appropriate selection of original observations, the evaluation of their reliability, the detection and elimination of distorted or spurious information, etc. Another kind of difficulty, more specific to paleo-ENSO studies, involves the link between the detectable effects of a meteorological anomaly (flood, drought, destruction) and the El Niño phenomenon. Because earthquakes and anomalous rainfall have been considered as closely associated during colonial times in Peru, it can be expected that some reports on natural disasters may have led observers to erroneously attribute building destruction to unusual meteorological conditions rather than to seismic activity or other causes.

The determination of the intensity of former ENSO events is particularly difficult to assess. This task is hampered by the extreme heterogeneity of the written sources, the variable degree of exaggeration of the chronicles, the intrinsic difficulty of quantifying an atmospheric phenomenon through its effects on the environment (which may itself have changed significantly in the course of the past centuries), and finally by the known fact that "normal weather" is not news.

Historical Data Analysis

The sources of information used and cited by QNA and Q&N consist of documents of varied origin: published books and articles, newspaper articles, review studies, and a few unpublished archives. Obviously, the role of Antunez de Mayolo, distinguished Peruvian geographer and third coauthor of the QNA chronology, was essential in the data selection and analysis of the sources. The compilation made by QNA can be considered as rather complete, as far as published material is concerned. Not many important new sources have been found since the QNA work. Any improvement of the El Niño chronology, be it for data consolidation or for inclusion of new evidence, should come from time-consuming research into unpublished (regional or national) archives in Lima and other Peruvian towns, especially in Trujillo, Lambayeque, Piura, and Tumbes. A clear example of such fruitful research is the doctoral study of Schlüpmann (1994), which dealt with agrarian socioeconomic structures in Piura (northern Peru) in the sixteenth through eighteenth centuries.

One of the fundamental criticisms that may be raised about the tables published by QNA is that the sources are presented as of equivalent value. Hocquenghem and Ortlieb (1992b) stressed that eyewitness reports and compiled works or journal articles must certainly not be placed at the same level. Historical data analysis consists of evaluating the trustworthiness of written reports. The fact that an item of information is repeated in several successive compilations cannot grant more veracity to the data per se. Actually, QNA detected and commented upon some errors in the date of one particular event that had been wrongly repeated in several documents. Another problem, also taken into consideration by QNA and Q&N, deals with the reports of authors who tended to find periodicities in the meteorological manifestations (e.g., 35-year Bruckner or 11-year sunspot cycles). However, QNA relied heavily upon some authors (Labarthe 1914; Taulis 1934) who might have been influenced by such cyclical theories and who, additionally, did not fully acknowledge the precise sources of the data that they used. The indiscriminate use of data from compilers who do not give information on their original sources may seriously weaken the value of the El Niño reconstructions.

El Niño Event Reconstruction

The reconstruction of paleometeorological situations from documentary sources is necessarily speculative. The destruction of a bridge produced by a river flood, an exceptional thunderstorm, and a single shower in the coastal desert of Peru are pieces of information that have been used to infer the occurrence of former El Niño events. In other more favorable cases, independent reports of climate anomalies or meteorological conditions from different regions of Peru (and neighboring countries) are available and provide much more satisfactory and precise criteria for the reconstruction of El Niño (or La Niña) conditions. As can be easily understood, the strongest former events are those which are most likely to have been commented upon as catastrophic phenomena. Of course, this is why the QNA record dealt only with the strong and very strong events of the sixteenth, seventeenth, and eighteenth centuries. Moderate and weak El Niño events had been identified, by QNA, only for the nineteenth and twentieth centuries, when more written data were at hand. It was only when Quinn (1992, 1993) incorporated the Indian drought sequence and the Nile River flood record, produced on an annual basis, that it became possible to evaluate the strengths of moderate events for the previous centuries. Quinn and Neal (1992) thus provided a series of new sources to strengthen the original QNA sequence of El Niño occurrences in South America. The additional evidence then provided by Q&N included more data on anomalies in Chile, northeastern Brazil, and Bolivia.

Paleo–El Niño studies are seriously hampered by the fact that no two events are alike. Recent El Niño events present large variability in terms of intensity, location, and season of occurrence (Philander 1991). Events of similar strength may show large variations in their impacts. Huertas (1987, 1993) stressed that during very strong events, the maximum effects of the El Niño phenomenon could be located either in the Trujillo area (as in 1578 or 1728) or in the Piura region (as in 1983). This spatial variability of the effects constitutes another obstacle for the assessment of the strength of former events.

The El Niño phenomenon, as defined a century ago (Carranza 1891; Carrillo 1893; Eguiguren 1894), is characterized by anomalous rains in the coastal desert of northern Peru. Based on twentieth-century observations, it can be added that these exceptional rains in the arid coastal region of Peru do not normally extend southward to the latitude of Lima. During the most recent strong or very strong events, particularly in 1982–83, the coastal area of southern Peru, as well as the cordilleran region of southeastern Peru and Bolivia, suffered from severe droughts. The nature of El Niño impacts on southern Peru constitutes one of the major problems raised by H&O with respect to a series of historical events identified by QNA on the basis of flood evidence. These cases will be discussed below.

Confidence Rating

The "confidence rating" attributed by QNA to every event exemplifies the difficulty of reaching consistency within the sequence of reconstructed occurrences. On a theoretical basis, and as expressed by QNA (and Q&N), such a rating is determined by the number of different sources that lead to the interpretation of a former El Niño event. The validity of such a confidence rating in the cases where the sources are not independent of each other, or where the sources have not been previously submitted to a critical evaluation, was already discussed. As was stressed by H&O, as well as by Ortlieb (1994) regarding the Chilean record, there is an intrinsic difference in the quality of an original source or a contemporaneous witness report, on one hand, and newspaper articles or compiled studies written two or three centuries after the fact, on the other hand. Quinn and Neal (1992), who referred to this aspect of happenstance, were aware of the problem and actually revised the confidence ratings for many events listed by QNA, but they did not qualifiy their sources accordingly. As no information was given by QNA and Q&N regarding the nature of the evidence leading to the reconstruction of every El Niño event (only references are listed), the reader must rely heavily upon the indicated confidence rating. In some cases, major discrepancies with respect to the values expressed by QNA and Q&N may be justified.

Quinn et al. (1987) explained (p. 14,454) that their published record did not include events with confidence ratings of 1 (meaning a single source) because they had required at least one confirmation of any single piece of information. If this requirement were strictly applied, and if only independent sources were selected, this criterion would be too drastic: Many reconstructed events of the sixteenth and seventeenth centuries would be excluded from the present records! A more appropriate solution would seem to be to perform a stricter data analysis, to rely more on reliable informants, and to minimize the importance of all references that constitute only repetitions of previously published data.

A Contribution to the Revision of the Quinn Record for Peru

Presentation of the Revised Peruvian Record (Sixteenth through Nineteenth Centuries)

Table 7.1 presents an analysis of the main data upon which the Quinn records (QNA; Q&N; and Quinn 1992, 1993) were based, along with the revised chronological sequence that I propose. Unlike the tables published in 1987, Table 7.1 includes information on the location (Fig. 7.1) and time of year of the phenomena or anomalies that led to the interpretation of every event. It eventually includes some comments regarding the accuracy, relevance, and reliability of the sources. The table also includes the

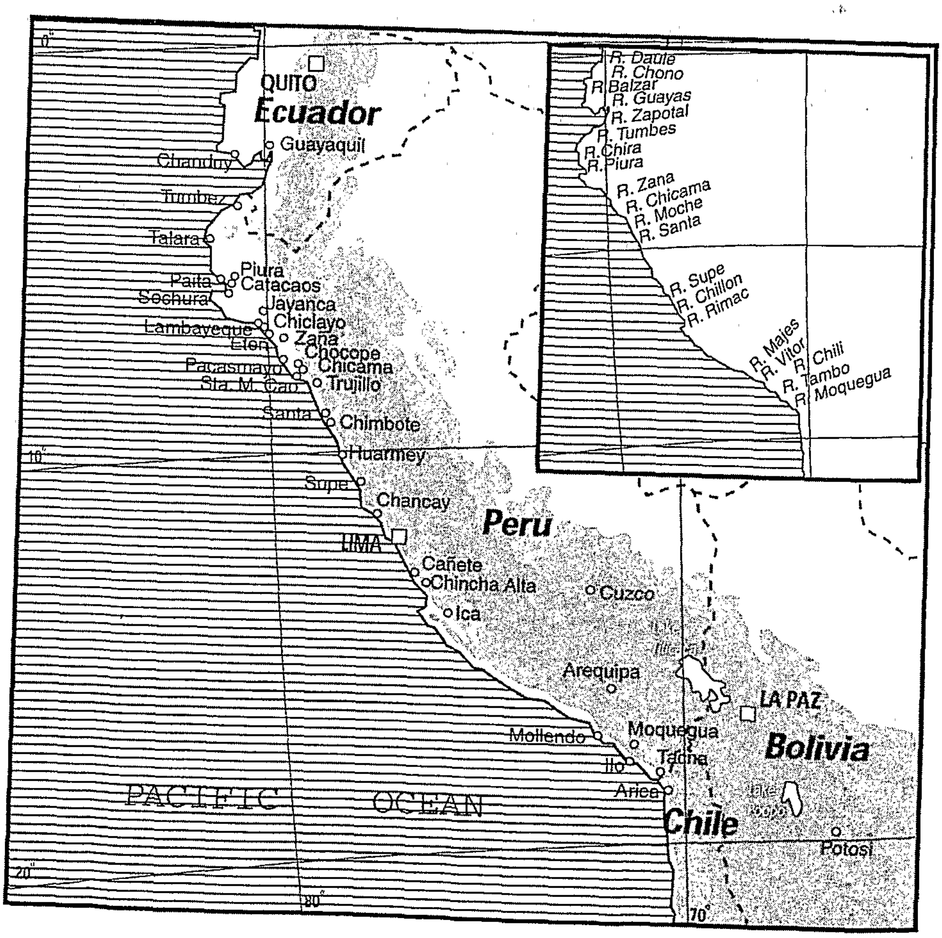

Fig. 7.1 Map of the Peruvian coastal region, with most of the localities mentioned in the text and Table 7.1.

Table 7.1 *Compilation of main available historical documentary data from Peru on which can be based reconstructions of El Niño anomalies between 1525 and 1900. Indicated documentary sources are those used by QNA and/or Q&N to which were added new references (in italics and shaded areas), partly taken from H&O. Not all the sources referred to by QNA and Q&N are indicated: Some were eliminated because they were mere repetitions of original information (e.g., Portocarrero 1926), and others were not included because they deal specifically with central Chile anomalies (Taulis 1934, Vicuña Mackenna 1877, Vidal Gormaz 1901) or with northeast Brazil droughts (Andrade 1948, Brooks 1971). The last column summarizes the proposed updated interpretations as to the occurrences and strengths of El Niño events (lack of event occurrence and new event occurrences are underlined). The sign § (fifth column) designates the reproduction of quotes of original information in H&O. EN = El Niño. Strength of events: VS = very strong, S = strong, M = moderate, W = weak.*

Years	Event intensity in QNA (*Q&N)	Confidence rating in QNA (*Q&N)	Major original sources in QNA and (*) in Q&N	Precise location of relevant quote (§: in H&O)	Location of climatic/ oceanographic anomaly	Phenomenon/effects leading to the reconstruction of EN event	Remarks	Proposed interpretation
1525–1526	S	3	Xerez 1534	QNA, pp.197–198 §	Eastern equatorial Pacific	Thunderstorms and heavy squalls off Colombia and Ecuador	Insufficient data to assess EN conditions	No EN ?
1531–	S	4	Xerez 1534	QNA, p. 200 §	Eastern Pacific	Sailing time (only 13, or 7?, days) from Panama to Ecuador in a 1531 trip . . .	. . . but other route than in 1525 (H&O)	
1532			Prescott 1892	p. 175 (in Spanish ed.) §	Piura, N Peru	"Flooded" rivers in N Peru (actually perennial)	Unreliable source (H&O)	No EN
			*Murphy 1926				Ref. not seen	
1539–			Montesinos 1642	See QNA: 14454	Cuzco, SE Peru	Death of 30,000 Indians due to drought (?) in 1539	Real cause of those deaths?	
1540–	M/S	3			Cuzco, SE Peru	Storm and hail in South Peru Andes in 1540	Not a clear EN signal	No EN ?

Table 7.1 (*cont.*)

Years	Event intensity in QNA (*Q&N)	Confidence rating in QNA (*Q&N)	Major original sources in QNA and (*) in Q&N	Precise location of relevant quote (§: in H&O)	Location of climatic/ oceanographic anomaly	Phenomenon/effects leading to the reconstruction of EN event	Remarks	Proposed interpretation
1541			Cobo 1653	(1): 90 §	Lima	Rain and flood in 1541	Rainfall in Lima	
			QNA	p. 14454	Lima (?)	Red tide ("Aguaje") on 12 July 1540	Which original source?	
			*Raimondi 1876				Ref. not seen	
*1544	Not in QNA		*Albenino 1549				Ref. not seen	
	*M+	*4	*Montesinos 1642	(1): 140–158		Data not found in ref.		?
*1546–1547	Not in QNA *S	— *4	*Benzoni ("1565") 1572	p. 57	Guayaquil, S Ecuador	Rio Chiono flood and reconstruction of Guayaquil (?)	Possible EN conditions	M?
			*Albenino 1549				Ref. not seen	
			*Raimondi 1876				Ref. not seen	
1552	S	4	Moreno 1804, in Palma 1894, and in Unanue 1806	p. 1151 § p. 38 §	Lima	Two lightning bolts and a single thunderstroke (no rain) in Lima on 13 July 1552	Very poor (and only) evidence for El Niño manifestation!	<u>No EN</u>
			*Humboldt 1804	p. 11	Lima	Same source as Moreno, Unanue, and Palma		

			Actas Cabildo Trujillo 1549–60 (in H&O)	*p. 213*	*Trujillo, N Peru*	*No mention of any rain between 1549 and 1560; see also Lizárraga 1609*	*No EN conditions in N Peru?*	
*1558–	Not in QNA		*Montesinos 1642	p. 158	Central Peru	Epidemic diseases	EN conditions?	
*1559– *1560– *1561	*M/S	*3	*Martinez y Vela 1702 (=Arzans de Orsúa y Vela 1965)	(1): 115	Potosí, Bolivia	Drought from October 1560 to January 1561 (see Table 7.2)	No clear relation with EN conditions (see text)	<u>No EN</u> ?
			*Garcia Rosell 1903			Data not found in ref.		
*1565	Not in QNA *M+	*2	*Montesinos 1642	(2):18	Ayacucho, central Peru	Famine in Huamanga (no explicit reason given)	Single source and poor evidence!	<u>No EN</u> ?
1567–			Oliva 1631	See QNA, p. 14453	Eastern Pacific	Panama-Lima trip in 26 days (March 1568) . . .	. . . instead of 6 (?) months	
1568	S+	5	Cobo 1639, as cited by Labarthe 1914	p. 307	Lima	Destruction of a bridge: See text (erroneous quote!)	Misreading: "1567" (=1607)	<u>No EN</u> ?
			*Montesinos 1642			Data not found in ref.		
1574	S	4	García Rosell 1903	(3): 334 §	Piura, N Peru	Strong rains which led to emigration of Piura population toward Paita	Single source	M?
			Acosta 1590	p. 82 §	Trujillo, N Peru	Heavy rains and floods	The first well-documented (very) strong EN event	
			Cobo 1639	p. 311 §	Lima	Rímac River flood		
			Cobo 1653	(1): 90 §	Trujillo, N Peru	Second record of rainy episode in N Peru (after 1541)		

Table 7.1 (*cont.*)

Years	Event intensity in QNA (*Q&N)	Confidence rating in QNA (*Q&N)	Major original sources in QNA and (*) in Q&N	Precise location of relevant quote (§: in H&O)	Location of climatic/ oceanographic anomaly	Phenomenon/effects leading to the reconstruction of EN event	Remarks	Proposed interpretation
1578	VS	5	García Rosell 1903	(3): 334 §	Piura, N Peru	Heavy rains		VS
			*1580 anon. ms. in Brüning 1922–23	pp. 13, 119, 180	N Peru coast	Very strong rains in February–March with much destruction and food shortage		
			*Huertas 1984			(See Huertas 1987 below)		
			*Cabello Valboa 1586	pp. 223–224 §	N Peru coast	Rainfall, weakening of trade winds, and strong northerly winds	Print mistake: "1576" = 1578 (see H&O)	
			Lizárraga 1603–1609	*(17): 14–15 §*	*Chicama-Trujillo, N Peru*	*Very strong rainfalls, "never seen before"*		
			Anon. ms. published by Huertas 1987	*pp. 39–40 §*	*Lambayeque, Trujillo (N Peru)*	*Rains and floods (24 Feb – 6 Apr.)*	*Detailed eyewitness report*	
			Rostworowski, in Peralta 1985	*pp. 122–124*	*Lambayeque and N of Peru*	*Compilation of socio-economical impacts*		
*1582	Not in QNA *M	*3	*Montesinos 1642	(2): 86	Ayacucho, central Peru	Drought in the Andes	EN conditions?	?
*1585	Not in QNA *M+	*2	*Montesinos 1642			Data not found in ref.		?

*1589–	1589 & 1590: Not in QNA		*Montesinos 1642	(2): 111	Cuzco, central Peru	Epidemic diseases in 1590	Relation with EN conditions?	
*1590–	*M/S	*3	*Barriga 1951	p. 47	Arequipa, S Peru	Only data found refers to lack of rain in December 1589	No (?) evidence for EN conditions	No EN ?
1591–1592	S 1592: Not in Q&N	2	Martinez y Vela 1702 (=Arzans de Orsúa y Vela 1965)	(1): 217–218	Potosí, Bolivia	Drought in Potosí in late 1591–early 1592 (see Table 7.2)	No clear relation with EN conditions (see text)	
1593	*Not in QNA and Q&N*	—	*Lizárraga 1603–09*	*pp. 14–15 §*	*Trujillo, N Peru*	*Heavy rainstorm, but less strong than in 1578*	Single (but reliable) source	M?
*1596	Not in QNA *M+	*3	*Montesinos 1642	(2): 130–131	Central S Peru	Cauca and Magdalena River floods; heavy rains	EN conditions?	S
			Ocaña and Alvarez 1969	*p. 38 §*	*Paita, N Peru*	*Heavy rainfall in Paita (destruction) and floods*	Possibly strong EN conditions	
*1600	Not in QNA *S	*3	*Barriga 1951		Arequipa, S Peru	Data not found in ref.	Confusion with volcanic effects?	No EN
*1604	Not in QNA *M+	*3	*Montesinos 1642	(2): 168–169	Huamanga, central S Peru	Miraculous rainfall under a blue sky (after a drought)	Untrustworthy data	No EN
1607*–1608	S	5	Cobo 1639	(1): 313 §	Lima	Rímac River flood, and bridge destruction in February 1607	(See 1567 and 1671)	M?
			Alcedo y Herrera 1740	pp. 122–123	Eastern Pacific	Unusually (?) easy travel between Panama and Lima in December 1607	NE winds, possibly En related	

Table 7.1 (*cont.*)

Years	Event intensity in QNA (*Q&N)	Confidence rating in QNA (*Q&N)	Major original sources in QNA and (*) in Q&N	Precise location of relevant quote (§: in H&O)	Location of climatic/ oceanographic anomaly	Phenomenon/effects leading to the reconstruction of EN event	Remarks	Proposed interpretation
	1608: Not in QNA		*Martinez y Vela 1702 (= Arzans de Orsúa y Vela 1965)	(1): 265	Potosí, Bolivia	Snowfalls and rains in late 1607 (see Table 7.2)	Not clear manifestation of EN	
1614	S	5	Cobo 1653	(1): 90 §	Chancay, central Peru	Single (and local?) rainfall event in March	Poor evidence for EN	<u>NO EN</u> ?
			*Haenke 1799			Data not found in ref.		
1618–1619			Vásquez de Espinoza 1629		S Peru	Data not found in ref.		
1618–1619	S	4	Cobo 1653	(1): 90 §	Ilo, S Peru	Lightning, thunderstorm, and rain on 12 June 1619	Winter rainstorm in 1619	M?
			Anon. ms. cited by Huertas 1992	*p. 105 §*	*Zaña. N Peru*	*Strong rainfall, but casualties possibly more related to 1619 earthquake*	No precise EN evidence (single rainfall?)	
1622	*Not in QNA and Q&N*	—	*H. Brüning, cited by Gorbitz 1978*	*p. 36*	*Jayanca, N Peru*	*Rains and floods in 1622 "and previous years"*	Single source	M?
1624	S+	4	Cobo 1653	(1): 90 §	Zaña and Trujillo, N Peru	"Copious" rainfall and floods	Possibly EN conditions	M?
		*5	*Montesinos 1642	(2): 228	Central Andes	Drought between Cajamarca and Huamachuco!	EN conditions?	
			Puente 1885	p. 38	Lima	Rímac River flood	*Not sufficient*	*1634:*

1634–				Palma 1894	p. 42 §	Lima	Rímac River flood	evidence	Not in Q93
*1635	S	4		*Montesinos 1642	(2): 249		Data not found in ref.		No EN
1634– **1635*	*1635: Not in QNA*	*3		*Suardo 1634*	*(2): 13–15 §*	*Lima and coast of S Peru*	*Rain in Lima; floods in S Peru (February–March 1634)*	EN (or La Niña) evidence?	?
*1640–1641	Not in QNA S*	*2		*Martinez y Vela 1702 (=Arzans de Orsúa y Vela 1965)		Potosí, Bolivia	Data not found in ref.	No source from Peru	No EN
*1647	Not in QNA *M+	*3					Only data on central Chile	No source from Peru	No EN
1652	S+	4		Cobo 1653	(1): 90 §	Lima	Single rainfall in February	Very poor EN evidence	No EN ?
*1655	Not in QNA *M	*3		*Alcedo y Herrera 1740	p. 164	Eastern Pacific	Easy trip from Colombia to Lima in early 1655	Data reliability?	No EN
				Actas Cabildo Guayaquil 1650–57	*p. 154*	*Guayaquil, S Ecuador*	*Drought in 1654–55*	La Niña conditions?	
1660	S	3		Anon, ms. cited by Labarthe 1914	p. 309	Supe, central Peru	Supe River flood	Insufficient data (and from central Peru)	Not in Q93 No EN
1671	S	3		Anon. ms. cited by Labarthe 1914	p. 309	Supe and Lima, central Peru	Rímac and Supe River floods	Reliable data? (see text)	No EN
				*Martinez y Vela 1702 (=Arzans de Orsúa y Vela 1965)	(2): 259	Potosí, Bolivia	Drought in October–December 1671	No clear manifestation of EN	?
1678	*Not in QNA and Q&N*	—		*Gorbitz 1978*	*p. 30*	*Jayanca, N Peru*	*Complete destruction of Jayanca Vieja*	Single source (to confirm)	M?

Table 7.1 (*cont.*)

Years	Event intensity in QNA (*Q&N)	Confidence rating in QNA (*Q&N)	Major original sources in QNA and (*) in Q&N	Precise location of relevant quote (§: in H&O)	Location of climatic/ oceanographic anomaly	Phenomenon/effects leading to the reconstruction of EN event	Remarks	Proposed interpretation
1681	S	3	Rocha 1681	(2): 168–169	Lima	Two thunderstrokes E of Lima (no rain) on 3 July 1680 (not 1681!)	Phenomenon probably not related to EN	No EN
*1684	Not in QNA *M+	*2	*Martinez y Vela 1702 (=Arzans de Orsúa y Vela 1965)	(2): 316	Potosí, Bolivia	Drought in late 1683–early 1684	No clear manifestation of EN	No EN ?
1686	*Not in QNA and Q&N*	—	*1780 anon. ms. cited by Schlüpmann 1988*	*p. 40 §*	*Yapatera (E Piura), N Peru*	*Abundant rains that caused destruction of the hacienda Yapatera*	Rains possibly EN related	1686–
1687–1688	S+	4	Juan and Ulloa 1748	(2, 1): 20 §	Zaña, N Peru	Erroneous mention of the destruction of Zaña (see 1720)	Reference suppressed in Q&N	1687–1688:
			Unanue 1806			Data not found in ref. (quote of Juan and Ulloa?)	Repetition of Juan and Ulloa	M?
			Melo 1913	p. 152	Zaña, N Peru	Reproduction of Juan and Ulloa misinterpretation	Unreliable source!	
			Remy 1931, in Petersen 1935	(2): 36 §	Lima	Single rainstorm (2 Dec. 1687) with destruction	Evidence for EN conditions?	

*1692– *1693	Not in QNA *S	*3	*Martinez y Vela 1702 (=Arzans de Orsúa y Vela 1965)	(2): 368, 393	Potosí, Bolivia	Drought in January–March 1693 (+1694 and 1695!)	Not reliable data from Bolivia	<u>No EN</u>
1696–	S	3	Palma 1894	p. 42 §	Lima	Rímac River flood on 11 Feb. 1696	Poor evidence for EN conditions	1696: Not in Q93
*1697	*M+ 1697: Not in QNA		*Actas Cabildo Guayaquil, in Estrada Ycaza 1977*	*pp. 111–112*	*Guayaquil, S Ecuador*	*Guayas River flood in May 1696*	Possibly EN conditions in S Ecuador	1696: M? 1697: <u>No EN</u>
1701	S+	4 *5	Feijoo de Sosa 1763	1: 158 §	Trujillo, N Peru	Abundant rainfalls	Concordant sources for EN conditions in N-central Peru, but no information for Piura	S
			Bueno 1763	P. 50 §	Trujillo, N Peru	Anomalous rainstorms in 1701 (as in 1720 and 1728)		
			Haenke 1799	p. 234	Trujillo, N Peru	Unusually strong rains		
			Anon. ms., cited by Labarthe 1914	p. 309	Zaña, N Peru	Zaña River flood and impacts on crops		
			*Humboldt 1804	p. 12	Lima and N Peru coast	Strong rainfalls (secondhand information taken from Bueno 1763)		
			*Unanue 1806	pp. 38–39 §	Trujillo, N Peru			
			1706 ms. cited by Huertas 1992	*pp. 105–106*	*Zaña, N Peru*	*Strong rains with severe destruction of crops*		
			Cook 1712				Ref. not seen	

Table 7.1 (*cont.*)

Years	Event intensity in QNA (*Q&N)	Confidence rating in QNA (*Q&N)	Major original sources in QNA and (*) in Q&N	Precise location of relevant quote (§: in H&O)	Location of climatic/ oceanographic anomaly	Phenomenon/effects leading to the reconstruction of EN event	Remarks	Proposed interpretation
1707– 1708– 1709	S	3	Alcedo y Herrera 1740	pp. 228–230	Eastern Pacific	Easy navigation between Panama and Lima, in June–July 1707	Reliable EN oceanographic conditions?	No EN
	Not in QNA *M/S		*Schlüpmann 1994*	*p. 61*	*Piura*	*Drought in Piura in 1706–15*	Well-documented study	
1714–	1714: Not in Q&N		Le Gentil 1728	p. 88	Cañete, S Lima	Flood of Cañete River in September 1715	Not clear EN indication	1714–1715: No EN
1715–	S	4	Odriozola ms. cited by Labarthe 1914	p. 309	Arequipa, S Peru	Chili River flood in 1714, but "no data from other Peruvian rivers"	EN or La Niña evidence?	
*1716	1716: Not in QNA	*3	*Schlüpmann 1994*	*p. 61*	*Piura*	*Drought in Piura in 1706–15*	1716: normal (or EN) year?	1716: No EN?
	Not in QNA		*Bueno 1763			Data not found in ref.		
			*Barriga 1951			Data not found in ref.		
*1718	*M+	*3	*1718 ms. cited by Schlüpmann 1994*	*p. 61*	*Piura*	*Flood of Piura River that caused destruction*	Sierra rains, or EN conditions?	M?
1720			Shelvocke 1726	p. 103 §	Paita, N Peru	"Wet rainy weather" in Paita (March)		

			Feijoo de Sosa 1763	1 (12): 158–161 §	Zaña and Lambayeque, N Peru	Consistent rains (weaker rains than in 1728) which led to Zaña destruction	Manifestations of a strong EN event in N Peru	
			Bueno 1763	pp. 50, 53 §	Trujillo, Zaña, N Peru	Heavy rains and flooding; destruction of Zaña on 15 March 1720	(Not as strong as 1728, but stronger than 1701?)	
			Haenke 1790	pp. 234, 245	Trujillo, Zaña, Lambayeque, N Peru	Unusual heavy rains, stronger than in 1701; alternating NE and S winds		
	S+	4	Alcedo 1786–89			Data not found in ref.		
1720	*VS	*5	Moreno 1804, cited by Palma 1894	p. 1151 §	Lima	Second thunderstorm noted after 1552 in Lima	Only source on Lima	S
			Bachmann 1921	p. 14	Zaña, N Peru	Zaña destruction in 1720	Secondhand (compiled) data	
			*Humboldt 1804	pp. 11, 12	Coast of N Peru	Destructive rainfalls in January 1720, with thunder		
			*Unanue 1806	pp. 29–30 §	Coast of Peru	Quote of Bueno 1763		
			*Raimondi 1876			Zaña destruction in 1720?		
			*Adams 1905	p. 97	Zaña, N Peru	Zaña destruction in 1720		
			*Huertas 1984 (1987)	p. 16	Zaña, N Peru	Zaña destruction in 1720		

Table 7.1 (*cont.*)

Years	Event intensity in QNA (*Q&N)	Confidence rating in QNA (*Q&N)	Major original sources in QNA and (*) in Q&N	Precise location of relevant quote (§: in H&O)	Location of climatic/ oceanographic anomaly	Phenomenon/effects leading to the reconstruction of EN event	Remarks	Proposed interpretation
			Rubiños y Andrade 1782, in H&O	*pp. 228–230 §*	*Zaña, N Peru*	*Zaña River flood, and rains during 2 weeks in March*	Detailed report by eyewitness	
*1723	Not in QNA *M+	*3				Only data concerning central Chile and Brazil		No EN
			Feijoo de Sosa 1763	1 (12): 158–160 §	Trujillo, N Peru	In February–March 1728 stronger rains than in 1720 (not 1726)	Feijoo de Sosa data more precise than Bueno (see H&O)	
			Bueno 1763	p. 50	Trujillo, N Peru	"Copious rains," less strong than in 1720		
			Alcedo 1786–89	(3): 344 § (4):16, 490	Paita and Zaña, N Peru	Zaña ruined (see 1720!); damage in Paita	Very strong EN conditions in northern Peru region	
			Spruce 1864			Data not found in ref.		
			Eguiguren 1894	p. 247 §	Piura	Rainfall and river flood at Piura (Távara 1854 data)		
			*Anson 1748	p. 178 §	Paita; N Peru	Great destruction in Paita		
1728	VS	5	*Humboldt 1804	p. 12	Coast of Peru	Cites Feijoo de Sosa data	Secondhand (compiled) data	VS

			*Unanue 1806	pp. 29–30	Coast of Peru	Quote of Bueno 1763		
			*Palma 1894			Data not found in ref.		
			*Garcia Rosell 1903	p. 427 §	Paita and Piura	Destruction due to 1728 rains		
			Esquivel y Navia 1746, in Huertas 1993	*p. 366*	*Cuzco, SE Peru*	*Strong rainfall in Cuzco*	Rains in SE Peru Andes	
			Juan and Ulloa 1748	*p. 22 §*	*Chocope, Chicama, N Peru*	*Rainfall during 40 nights in "1726" (in fact 1728)*	Examples of misquotation of the 1728 event	
			Stevenson 1825	*(2): 177–178 §*	*Chocope, N Peru*	*Rains during 34 nights in "1746" (= 1728: H&O)*		
1728			*1752 anon. ms. cited by Schlupmann 1994*	*C 2330 §(see maps)*	*Catacaos and Sechura, N Peru*	*Transformation of Piura valley, after flooding*	Eyewitness descriptions of manifestations of a very strong EN event in N Peru	
			1778 and 1809 ms., in Cruz Villegas 1982	*pp. 138–140 §*	*Piura and Catacaos, N Peru*	*Destruction of the banks of Piura River, after flooding*		
			Lequanda 1793	*pp. 168–169 §*	*Piura*	*Destruction in the city and effects of flooding*		
*1736	Not in QNA *S	*2				Only data from NE Brazil		Not in Q93 No EN
*1740	Not in QNA *M	*3	*Juan and Ulloa 1748	1(1): 20	Lambayeque, N Peru	Lambayeque River limited flood in November 1740	Not an indication of EN conditions	Not in Q93 No EN

Table 7.1 (*cont.*)

Years	Event intensity in QNA (*Q&N)	Confidence rating in QNA (*Q&N)	Major original sources in QNA and (*) in Q&N	Precise location of relevant quote (§: in H&O)	Location of climatic/ oceanographic anomaly	Phenomenon/effects leading to the reconstruction of EN event	Remarks	Proposed interpretation
*1744	Not in QNA *M+	*3				Only data from NE Brazil		No EN
1747	S		Llano y Zapata 1748	pp. 2–3	Moquegua and Abancay, S Peru; Lima	1747: heavy rainstorms and destruction (March) in S Peru; rainfall in Lima on 1 July	Rains in S and central Peru	1747–1748: S
			Feijoo de Sosa 1763	(1): 163 §	Trujillo, N Peru	Two rainstorms in a single day in Trujillo	Only available data on N Peru	
	*S+	5	Moreno 1804, in Unanue 1806	p. 38 §	Lima	Thunderstorm in Lima, like in 1552, 1720, and 1803	Thunderstorm in Lima as evidence for EN conditions?	
			Palma 1894	p. 1151 §	Lima	Same source (Moreno 1804) as Unanue		
			*Humboldt 1804	p. 11	Lima			
1748	*Not in QNA and Q&N*	—	*Anon. ms. cited by Schlüpmann 1994*	*pp. 62, 241 §*	*Sancor (Piura), N Peru*	*Heavy rainfalls and floods E of Piura in 1748 (47?)*	Unconfirmed data (1748?)	
			Stevenson 1825	*(2): 178 §*	*Chocope, N Peru*	*Local (?) exceptional rains during 11 nights*	Unreliable source? (H&O)	
*1750	M	—	QNA	p. 14455	?	No source given by QNA	No source	
	*M+	*4	*Cerdán, cited by Puente 1885	p. 43	Lima area	Rímac River flood	No En conditions?	No EN *Not in Q93*

*1755– *1756	Not in QNA *M	*3	*Garcia Rodriguez 1779				Ref. not seen	No EN
			*Garcia Rosell 1903	p. 453	Paita, Piura	Smallpox epidemic	EN conditions?	
1761	S	5	Bueno 1763	p. 39 §	Santa, N-central Peru	Several mentions of the same story: a flood of Santa River that produced severe damage in the small town of Santa	No data on the origin of the flood; possibly not related to En conditions	M?
			Alcedo 1786–89	(4)				
			Haenke 1790	p. 185				
			Ruschenberger 1835	(2): 309				
			*Garcia Rodriguez 1779				Ref. not seen	
			Cicala 1994	*p. 547*	*Piura*	*Strong rainfalls in 1761 (or 1760?)*	EN conditions?	
*1764	Not in QNA *M	*2				Only data from central Chile		No EN
*1768	Not in QNA *M	*2	*Garcia Rodriguez 1779				Ref. not seen	?
1775	S	4 *3	*Cerdan, cited by Puente 1885	p. 43	Lima area	Rímac River flood (same source)	EN conditions?	No EN
			Cerdan, cited by Labarthe 1914	p. 311	Lima area			
			Estrada Ycaza 1977	*p. 112*	*S Ecuador*	*Drought in 1775–80*	No EN conditions	
			Schlüpmann 1994	*p. 62*	*N Peru*	*Drought in N Peru between 1766 and 1776*	No strong EN in the decade	Not in Q93

Table 7.1 (*cont.*)

Years	Event intensity in QNA (*Q&N)	Confidence rating in QNA (*Q&N)	Major original sources in QNA and (*) in Q&N	Precise location of relevant quote (§: in H&O)	Location of climatic/ oceanographic anomaly	Phenomenon/effects leading to the reconstruction of EN event	Remarks	Proposed interpretation
			QNA	p. 14455		No source given by QNA		
1778–	M?	—	*Garcia Rodriguez 1779				Ref. not seen	No EN ?
1779	*M+	*4	*Cerdan, cited by Puente 1885	p. 43	Lima area	Rímac River flood in 1779		1779: Not in Q93
			QNA	p. 14455		No source given by QNA		
	M?	—	Q&N	p. 630		Only data from central Chile and NE Brazil		
1783	*S	*3	*Ms. cited by Huertas 1993*	*p. 366*	*Ica, central Peru*	*Drought in 1783–84–85 in S-central Peru*	Data from S Peru difficult to interpret (EN conditions?)	No EN ?
			1785 ms., in Galdós 1988, in Huertas 1993	*p. 365*	*Arica, N Chile*	*Drought in 1783–85 at Azapa (Arica)*		
1784	*Not in QNA and Q&N*	—	*Castillo 1931 (p. 219), cited by Hamerly 1973*	*pp. 68, 105*	*S Ecuador*	*Daule River flood; destruction of banana and tobacco fields in 1784–85*	EN conditions in Ecuador in December 1784–January 1885	1784–1785:
1785–	1785: Not in Q&N	4	Cerdan, cited by Labarthe 1914	pp. 311–312	Lima	Rímac River flood on 26 Feb. 1786	(No?) EN ***conditions in 1786?***	*M*

1786	S *M+	*3	Estrada Ycaza 1977	p. 122	S Ecuador	Strong rainfalls and Daule and Balzar River floods in 1785	1784–85: EN conditions	1786: <u>No EN</u>
1791	VS	5	Unanue 1806	pp. 29–30 §	Peru coast	Abundant summer rains, like in 1701, 1720, 1728	No precise data	S
			Ruschenberger "1834" (=1835)	(2): pp. 354–355	Lambayeque, N Peru	Great destruction and loss of lives in March 1791, because of snowmelt	No evidence for rainfall in Lambayeque; only snowmelt in the Andes	
			Hutchinson 1873	p. 211	Lambayeque, N Peru	Great destruction by floods from the sierra		
			Spruce 1864	p. 29 §	Piura, N coast	Major flood of Piura River, as remembered in 1864	No rain in Piura but upstream rainfall led to the catastrophic flood	
			Távara 1854, in Eguiguren 1894	p. 247 §	Piura	Violent Piura River flood and bridge destruction in summer 1790–91 (upstream rains)		
			Diario de Lima, in Labarthe 1914	p. 312	Lima area	On 13 Feb., rainstorm in Caraballo valley	Single event?	
			Bachmann 1921			Data not found in ref.		
			*Garcia Rosell 1903	(4): 461	Piura	Piura River flood story		
			*Adams 1905	p. 97	Lambayeque	Lambayeque River flood		

Table 7.1 (*cont.*)

Years	Event intensity in QNA (*Q&N)	Confidence rating in QNA (*Q&N)	Major original sources in QNA and (*) in Q&N	Precise location of relevant quote (§: in H&O)	Location of climatic/ oceanographic anomaly	Phenomenon/effects leading to the reconstruction of EN event	Remarks	Proposed interpretation
			*Leguia y Martinez 1914	p. 182	Piura	Comparison (?) with the exceptional rainfall of 1891	Inaccurate comparison!	
			García Rosell 1904	*p. 102*	*Piura*	*Last rains before 1804*		
			Mercurio Peruano 1791 (7Aug.) [1964]	*(2): 253 §*	*Lambayeque, N Peru*	*Destructive floods on 1–3 March 1791*	Snowmelt in the Andes?	
1803–1804	S+	5	Moreno 1804, in Palma 1894	p. 1150 §	Lima	Rainstorm and high air temperature in 1803	Warm air temperature in central Peru	S
			Unanue 1806	pp. 34, 36–38, 39 §	Lima and central Peru	Warm temperature in January and February 1803 and early 1804; rainfall on 1 April 1803		
			Stevenson 1829			Data not found in ref.		
			Spruce 1864	p. 29 §	Piura	In 1804, first rains after 1791	No strong EN conditions?	
			Eguiguren 1894	pp. 250–251	Piura	1803: weak rainfall 1804: abundant rainfalls	EN conditions in central and N Peru in summer 1803–04	
			Labarthe 1914	p. 313	Chiclayo, N Peru; Lima	Floods in February 1804; for Lima, cites Unanue 1806		

			Petersen 1935	(2): 4, 35–36	Lima	Quotes of Moreno 1804 and Palma 1894		
			*Humboldt 1804	p. 11	Lima	Thunderstroke in Lima on 19 April 1803		
			*Lastres 1937			No full ref. given by Q&N	Ref. not seen	
			Humboldt 1804	*p. 22*	*Callao (Lima)*	*Positive (3°C) SST anomaly in January 1803*	Oceanographic EN conditions	
			Garcia Rosell 1904	*pp. 102–103*	*Piura*	*Abundant rains in February 1804*	EN conditions in N Peru	
			1804 ms. cited by Hamerly 1973	*p. 68*	*Guayaquil, S Ecuador*	*Heavy rainfall and floods for 7 months in 1803–04*	EN conditions in S Ecuador	
1806–1807 1806–1807	M *S+	3 *5	Unanue "1815" (=1806)		Lima?	Data not found in ref. (written in 1806!)		No EN
			Stevenson 1829			Data not found in ref.		
			Remy 1931 in Petersen 1935	(2): 36	Lima	Single rainfall (15 Dec. 1806)	Poor evidence for EN	
			Eguiguren 1894	*pp. 250–251 §*	*Piura*	*Drought in 1806 and 1807*	No EN conditions in northern Peru	
			Schlüpmann 1994	*pp. 63–64*	*Piura*	*1805–14: drought in Piura, affecting cattle*		
	M	4	Palma 1894			Date not found in ref.		
			González 1913		Lima	Data (which begin in 1832) not found in ref.		

Table 7.1 (*cont.*)

Years	Event intensity in QNA (*Q&N)	Confidence rating in QNA (*Q&N)	Major original sources in QNA and (*) in Q&N	Precise location of relevant quote (§: in H&O)	Location of climatic/ oceanographic anomaly	Phenomenon/effects leading to the reconstruction of EN event	Remarks	Proposed interpretation
1812	*M+	*3	*Eguiguren 1894*	*pp. 250–251 §*	*Piura*	*Drought in Piura*	Drought in N Peru: no EN conditions!	No EN
			Garcia Rosell 1904	*p. 102*	*Piura*	*No rain in 1811–13*		
			Schlüpmann 1994	*pp. 63–64*	*Piura*	*1805–14: drought in Piura, affecting cattle*		
1814	S	4	Spruce 1864	p. 29 §	Piura	Piura River flood (but Chira River not swollen)	Only moderate EN conditions?	M
			Eguiguren 1894	pp. 250–251 §	Piura	Exceptional (?) rainfall (1 Feb.) after earthquake	Single rainfall event?	
			Anon. ms. cited by Schlüpmann 1994	*p. 64*	*Trujillo, N Peru*	*First rainfalls after years of drought*	Only moderate EN conditions?	
1817	M+	5	Eguiguren 1894	pp. 250–251 §	Piura	Abundant rainfalls	EN conditions in N Peru and S Ecuador in 1817 and 1818	
			Labarthe 1914	p. 313	N Peru	Floods in N Peru rivers		
			1825 anon. ms. in Hamerly 1973	*pp. 68, 131*	*Guayaquil, S Ecuador*	*Strong rains in 1817–18*		1817–
			Eguiguren 1894	pp. 250–251 §	Piura	1819: abundant rainfalls	EN conditions in N Peru and S Ecuador in *1819* but also in 1818	1818–

1819	M+	4	*Ms. in Seminario Ojeda 1994*	*p. 62*	*Coast of N Peru*	*Strong rains that limited communications in May*		1819: M
			1825 anon. ms. in Hamerly 1973	*pp. 68, 131*	*Guayaquil, S Ecuador*	*Strong rains in 1818–19*		
			1820 anon. ms. in Schlüpmann 1994	*p. 64*	*Piura*	*Rainfall that destroyed Lancones church in 1819*		
1821	M	5	Eguiguren 1894	pp. 250–251 §	Piura	Abundant rainfalls		M
			Fuchs 1925	p. 524	Trujillo, N Peru	Strong rainfalls during 3 months "near 1821"	Accurate data? (see Petersen)	
			Remy 1931		Lima?		Ref. not seen	
			1825 anon. ms. in Hamerly 1973	*pp. 68, 131*	*Guayaquil, S Ecuador*	*Strong rains in 1820–21*	Moderate (?) EN conditions in N Peru and S Ecuador	
			Garcia Rosell 1907	*p. 91*	*Piura*	*Abundant rainfalls which favored 1822 crops*		
			Petersen 1935 (=1956)	*(2): 33*	*Trujillo, N Peru*	*Doubts about data on Strong rains in Trujillo*	Unreliability of Fuchs data?	
1824	M *M+	5	Spruce 1864	p. 29 §	Piura	Moderate rainy season	Moderate EN?	M?
			Basadre 1884	p. 3	Ilo region, S Peru	Uncommon winter grass vegetation on the coast	EN conditions in S Peru?	
			Eguiguren 1894	pp. 250–251 §	Piura	Abundant rainfalls	(See Spruce!)	
			1825 anon. ms. in Hamerly 1973	*p. 68*	*Guayaquil, S Ecuador*	*Intense rains in 1824–25; Zapotal River floods*	Moderate (?) EN conditions	

Table 7.1 (*cont.*)

Years	Event intensity in QNA (*Q&N)	Confidence rating in QNA (*Q&N)	Major original sources in QNA and (*) in Q&N	Precise location of relevant quote (§: in H&O)	Location of climatic/ oceanographic anomaly	Phenomenon/effects leading to the reconstruction of EN event	Remarks	Proposed interpretation
1828	VS	5	Ruschenberger "1834" (=1835)	(2): pp. 354–355	Lambayeque, N Peru	Floods and destruction of Lambayeque hospital	Snowmelt (like in 1791?)	
			Spruce 1864	p. 29 §	Piura and S Ecuador	Chira River flood; rainfalls in N Peru and Ecuador	Strong (VS) EN manifestations in N and N-central Peru	VS
			Hutchinson 1873	p. 211	Lambayeque	Large river flood		
			Eguiguren 1894	pp. 248, 251	Piura	Exceptional rainfall with thunderstrokes in Piura		
			Paredes n.d., cited by Eguiguren 1894	pp. 247–248 §	Piura and Trujillo, N Peru	14-day rainfall with thunderstorms in N Peru, in March; Sechura flood		
			Sievers 1914				Ref. not seen	
			Bachmann 1921			Data not found in ref.		
			*Middendorf 1894				Ref. not seen	
			*Adams 1905	p. 97	Lambayeque	Lambayeque River flood		
			1868 ms. cited in Schlüpmann 1994	*p. 64*	*Piura*	*Changes in the course of flooded rivers*	Very strong EN conditions	

			Garcia Rosell 1907	*p. 107*	*Piura, Santa, N Peru*	*Rains in N Peru; very strong flood of Chira River*		
1832	M *M+	5	Spruce 1864	p. 29 §	Tumbes and Piura, N Peru	Limited rains N of Piura and in Chira area	Moderate EN conditions?	M
			Eguiguren 1894	pp. 250–251 §	Piura	Abundant rainfalls		
			*Basadre 1884	p. 3	Ilo region, S Peru	Abundant winter vegetation in 1831 (not in 1832)	Not pertinent data (1831)	
			Távara 1854, cited in Mabres et al. 1993	*p. 398*	*Piura*	*Abundant rains, but less strong than in 1828*	Moderate EN conditions?	
1837	M *M+	5	Eguiguren 1894	pp. 250–251 §	Piura	Abundant rainfalls	Moderate EN conditions?	M
			Labarthe 1914	p. 314	Piura	Floods, less strong than in 1828		
1844– 1845– 1846	S+ *M/S+	5	Spruce 1864	p. 29 §	N Peru and S Ecuador	Heavier rains in 1845 than 1828 at Guayaquil	Strong rains in S Ecuador	1844– 1845: S?
			Eguiguren 1894	pp. 250–251 §	Piura	1844: abundant rainfalls 1845: exceptional (?) rains 1846: regular rains	Moderate (?) EN effects in N Peru in 1844–45	
1844– 1845– 1846	1846: Not in QNA	*4	*Basadre 1884	p. 3	Ilo region, S Peru	Winter vegetation on the coast of S Peru in 1846	EN (or La Niña?) conditions in 1846?	1846: No EN?
			*Adams 1905			Data not found in ref.		
1850	M	5 *4	Eguiguren 1894	pp. 250–251 §	Piura	Regular rainfalls		W?
			Fuchs 1925	p. 524	Peru coast	Strong (?) rains	No detail given	
			Petersen 1935	*(2): p. 36*	*Peru coast*	*Questions Fuchs data*	No evidence!	

Table 7.1 (*cont.*)

Years	Event intensity in QNA (*Q&N)	Confidence rating in QNA (*Q&N)	Major original sources in QNA and (*) in Q&N	Precise location of relevant quote (§: in H&O)	Location of climatic/ oceanographic anomaly	Phenomenon/effects leading to the reconstruction of EN event	Remarks	Proposed interpretation
			Spruce 1864	*p. 29*	*N Peru and S Ecuador*	*No strong rains in 1845–64*	Less than moderate intensity?	
*1852	Not in QNA *M	*4	*Spruce 1864	p. 29	N Peru and S Ecuador	No strong rains in 1845–64	Not more than weak EN conditions	W?
			*Eguiguren 1894	pp. 250–251	Piura	Regular rainfalls		
1854	W/M	4	Spruce 1864	p. 29	N Peru and S Ecuador	No strong rains in 1845–64	Not more than weak EN conditions	W?
			Eguiguren 1894	pp. 250–251 §	Piura	Regular rainfalls		
1857– 1858	M+ *M	5	Eguiguren 1894	pp. 250–251 §	Piura	1857: regular rainfalls 1858: drought	No EN conditions in 1858	1857: M? 1858: <u>No EN?</u>
			Labarthe 1914	p. 315	Piura, Moquegua, S Peru	1857: rain in Piura and large floods in Moquegua	1857: rains in N and S Peru	
			Gaudron 1925	pp. 362, 365	Peru coast	Strong rains in 1858	Trustworthy?	
			Zegarra 1926	p. 23	Trujillo, N Peru	Exceptional rains in 1858	"Exceptional"?	
			León Barandiarán 1938, in Huertas 1993	*pp. 356, 380*	*Lambayeque, N Peru*	*Flood and destruction in Lambayeque in 1857*	Moderate EN conditions?	

			Labarthe 1914	pp. 315–316	Lima, coast of S Peru	Rímac River flood; rains in Ica, Moquegua, Arequipa	Rains in S Peru: La Niña conditions?	
1860	M	4	**El Comercio* 1860 (7 Jan.)		Lima	(Very small) Rímac River "flood"	No relevant data	No EN
			idem (4 Feb.)		Lima?		Ref. not seen	
			Eguiguren 1894	*pp. 250–251 §*	*Piura*	*Drought in Piura*	No EN conditions!	
1861	*Not in QNA or Q&N*	—	*Ramirez Zenon 1888, in San Cristoval 1938*	*p. 424*	*Piura and Paita*	*Strong rains in March 1861*	Reliability of this single source?	1861–(?)
*1862	Not in QNA *M–	*4	*Spruce 1864	p. 30 §	Chanduy, S Ecuador; Piura	Heavy rains with thunder in February–March, but only two short showers in Piura	Only weak (?) EN conditions for both 1861 and 1862?	–1862: W?
			*Eguiguren 1894	pp. 250–251 §	Piura	Regular rainfalls		
1864	S	5	Spruce 1864	pp. 25–30 §	Piura, Tumbes, and S Ecuador	Warm temperatures (January–February) and rain in March (Chira)	Strong or moderate EN conditions?	S?
			Eguiguren 1894	pp. 248, 251 §	Piura	Exceptional rainfalls		
1866	M *M+	4 *5	Eguiguren 1894	pp. 250–251 §	Piura	Regular rainfalls	Weak or moderate EN conditions?	M?
			Labarthe 1914	p. 316	Lambayeque, N Peru	Rainfall and floods with destruction		
			Bachmann 1921			Data not found in ref.		
			*Adams 1905	p. 97	Lambayeque	Lambayeque River flood		
			El Comercio 1872 (10 Jan.)			Data not found in ref. (wrong reference?)		

Table 7.1 (*cont.*)

Years	Event intensity in QNA (*Q&N)	Confidence rating in QNA (*Q&N)	Major original sources in QNA and (*) in Q&N	Precise location of relevant quote (§: in H&O)	Location of climatic/ oceanographic anomaly	Phenomenon/effects leading to the reconstruction of EN event	Remarks	Proposed interpretation
1867– 1868	M *M+	4	Eguiguren 1894	pp. 250–251 §	Piura	1867: drought in Piura 1868: weak rainfalls	No EN conditions in 1867 and 1868!	No EN
			Raimondi 1897, in Schweigger 1964	p. 151 §	Guañape and Sta Magdalena de Cao, N Peru	November 1867: thunder (?) and rainfall; warm SST, red tide; yellow fever epidemic	Interpreted as submarine volcanic eruption!	
			*Bachmann 1921			Data not found in ref.		
			Raimondi 1874	*p. 363 §*	*Piura*	*Chira River flood*	Sierra rains and no EN conditions?	
			El Amigo del Pueblo 1906, in Mabres et al. 1993	*p. 398*	*Piura*	*Drought in 1867–70*		
1871	S+	5	Hutchinson 1873	(2): 147, 211–212 §	Trujillo and N Peru coast	Large flood (and locust plague) in 1870 (not 1871)	Date confusion 1870/1871	S
			Eguiguren 1894	pp. 250–251 §	Piura	Exceptional rainfalls		
			Tizón y Bueno 1907				Ref. not seen	
			Sievers 1914			Data not found in ref.		
			Labarthe 1914	p. 316	Piura, Lambayeque, and Lima	Floods and destruction in February–March in Lambayeque; 450 m^3/s in Rímac River	Coincidence of Rímac flood and rains in N Peru	

			Bachmann 1921			Data not found in ref.		
			Gaudron 1925	p. 365	Peru coast	Strong rains	33-year solar cycle	
			*Middendorf 1894				Ref. not seen	
			*Adams 1905	p. 97	Lambayeque	Lambayeque River flood		
			*Leguia y Martinez 1914	pp. 45, 211	Piura and Lambayeque	Very strong rainfall, like in 1891 (?); change of course of Chira River		
			*Anonymous 1925	p. 238	Peru coast	Only mention of strong rains (but less than in 1925)	No firsthand data	
			León B. 1938, cited by Huertas 1993	*p. 380*	*Lambayeque, N Peru*	*Flooding of Lambayeque in March*		
1874	M	4	*La Patria*, 9 Feb. 1874	p. 2	Cañete, central Peru (S Lima)	Thunder and rainstorm in February on coast S of Lima	EN, or La Niña, evidence?	<u>No EN</u>
			Bravo 1903	p. 14	Santa, N-central Peru	Santa River blocked by a landslide; no rain excess	Source suppressed in Q&N	
			Bachmann 1921			Data not found in ref.		
			*Adams 1905			Data not found in ref.		
1874			*Eguiguren 1894*	*pp. 250–251 §*	*Piura*	*Drought*	No EN conditions!	
			Eguiguren 1894	pp. 250–251 §	Piura	Exceptional rainfalls in 1877 and 1878		

Table 7.1 (*cont.*)

Years	Event intensity in QNA (*Q&N)	Confidence rating in QNA (*Q&N)	Major original sources in QNA and (*) in Q&N	Precise location of relevant quote (§: in H&O)	Location of climatic/ oceanographic anomaly	Phenomenon/effects leading to the reconstruction of EN event	Remarks	Proposed interpretation
			Palma 1894	p. 1150 §	Lima	On 31 Dec. 1877, strong rainfall with exceptional thunderstrokes	Impressive meteorological phenomenon in Lima, but not typical of EN conditions	
			Remy 1931, in Petersen 1935	(2): 37 §	Lima	Thunderstorm and 18-minute rainfall (31 Dec.)		
			Portal 1932, in Petersen 1935	(2): 3, 35 §	Lima	Eyewitness report on 31 Dec. 1877 thunderstorm		
			Melo 1913	p. 156	Mollendo, S Peru	Rains that lasted 14 (?) months and floods	Rains also in S Peru	
			Sievers 1914	p. 276 §	Piura	1877–78 rainfalls compare with 1884 and 1891		
			Labarthe 1914	p. 317	Pacasmayo, N-central Peru	Floods and casualties on railway in 1877	Heavy rains in N-central Peru	
1877–1878	VS	5		p. 317	Chimbote, N-central Peru	Santa River flood, with railway destruction in 1878		VS
			Bachmann 1921			Data not found in ref.		

			Murphy 1926	p. 53 §	Piura and N Peru	Heavy rainfalls compare with 1884, 1891, and 1918, but are less than in 1925	Possibly very strong intensity EN	
			Kiladis and Diaz 1986			Global comparisons, and similarities with 1982–83		
			*Basadre 1884	p. 44	Tarapaca, N Chile	Strong rains and floods in Pampa del Tamarugal	N Chile evidence	
			*Adams 1905	p. 97	Lambayeque	Lambayeque River flood in 1878	Strong intensity of EN in 1878	
			*Leguia y Martinez 1914	pp. 73, 77	Chira River area (Piura)	Chira River flood with destruction in 1878		
			*Anonymous 1925	p. 238	Peru coast	Only mention of strong rains (but less than 1925)	No firsthand data	
			El Amigo del Pueblo. 1906, in Mabres et al. 1993	*p. 398*	*Piura*	*Very abundant rains in 1878*		
1880	M	4	Eguiguren 1894	pp. 250–251 §	Piura	Regular rainfalls	Weak EN conditions?	W?
			Puls 1895				Ref. not seen	
			Eguiguren 1894	p. 250–251 §	Piura	Exceptional rainfalls	Strong EN manifestations in N Peru	
			Sievers 1914	p. 276 §	Piura	Comparison between 1877–78, 1884, and 1891		

Table 7.1 (*cont.*)

Years	Event intensity in QNA (*Q&N)	Confidence rating in QNA (*Q&N)	Major original sources in QNA and (*) in Q&N	Precise location of relevant quote (§: in H&O)	Location of climatic/ oceanographic anomaly	Phenomenon/effects leading to the reconstruction of EN event	Remarks	Proposed interpretation
1884			Labarthe 1914	pp. 317–318	Peru coast, from N to S	Rains and floods all along the coast		
1884	S+	5	Bachmann 1921 Murphy 1925	pp. 169–170	Eten, N Peru	Data not found in ref. High fish mortality (QNA: 14457)	Impacts on marine resource	S
			*Anonymous 1925	p. 238	Peru coast	Only mention of strong rains (but less than 1925)	No firsthand data	
			Weberbauer 1914, in Petersen 1956	*(1): 91*	*Paita, N Peru*	*Vegetation linked to heavy rains as in 1891*		
			Murphy 1926	*p. 53 §*	*Piura*	*Heavy rainfalls compare with 1878, 1891, and 1918, but are less than in 1925*	As strong EN as in 1878 and 1891?	
			Eguiguren 1894	pp. 250–251 §	Piura	1887 and 1888: regular rains 1889: weak rains	No EN conditions in 1889?	
1887–			Labarthe 1914	pp. 318–319	Lima	Rímac River flood and bridge destruction in 1889	1889 Rímac River flood not necessarily related to EN	
1888	W/M	5	*Bravo 1903	p. 14	Verrugas, N-central Peru	Landslide with bridge destruction in March 1889		W?

1889	*M/M+	*4	*El Amigo del Pueblo 1906, in Mabres et al. 1993*	*p. 398*	*Piura*	*Rains more abundant in 1888 than in 1887 and 1889*	Not consistent data (see also Eguiguren 1894)	
			Ramos Seminario n.d., cited by H&O	*pp. 267–268 §*	*Piura*	*Some rains in March 1887 and in February 1889*		
			Carranza 1891, in Schweigger 1964	p. 59 §	Offshore N Peru coast	Combination of oceanic and climatic effects on the S Ecuador/N Peru coast		
			Eguiguren 1894	pp. 248–249 §	Piura and Paita, N Peru	60-day rains (February–April) stronger than in 1828, 1871, 1877–78, and 1884		
			Fuchs 1907	p. 288	Huarmey and Chimbote, N-central Peru	Elevated temperature and strong rainfalls coming from the sea		
			Labarthe 1914	p. 319	Peru coast, from Piura to Lima	Floods in Piura, Lambayeque, Pacasmayo, Santa, Supe, and Lima	Very strong EN event which led to the concept of a combined climatic and oceanographic El Niño phenomenon (Carranza 1891)	
			Sievers 1914	p. 276 §	Piura	Comparison between 1877–78, 1884, and 1891		

Table 7.1 (*cont.*)

Years	Event intensity in QNA (*Q&N)	Confidence rating in QNA (*Q&N)	Major original sources in QNA and (*) in Q&N	Precise location of relevant quote (§: in H&O)	Location of climatic/ oceanographic anomaly	Phenomenon/effects leading to the reconstruction of EN event	Remarks	Proposed interpretation
1891	VS	5	Bachmann 1921	pp. 40–43, 46	N Peru coast	Comments on Carranza 1891	To be noted: no rain excess in central or S Peru!	VS
			1922 ms. in Murphy 1926	p. 36 §	Talara, N Peru	Very strong rainfalls in February		
			Petersen 1935	(2): 37 §	Tumbes and Zorritos, N Peru	Strong rainfalls with electrical storms		
			Zegarra 1926	pp. 23, 34	Trujillo, N Peru	Exceptional rains		
			*Adams 1905	p. 97	Lambayeque	Lambayeque River flood		
			*Leguia y Martinez 1914	pp. 43–44, 45, 51, 71, 288–289	Chira River area (Piura)	Large floods of Chira and Piura rivers, with destruction; Chira flow: 5,400 m^3/s		
			*Anonymous 1925	p. 238	N Peru coast	Strong rains from Piura to Huarmey (not Lima)		
			Weberbauer 1914, in Petersen 1956	*(1): 91*	*Paita*	*Vegetation linked to heavy rains, as in 1884*		
			López Martinez n.d., in Peralta 1985	*pp. 128–130*	*Lima and N coast of Peru*	*El Comercio articles on impacts of 1891 rains*		
	1896: Not in Q&N		*El Comercio* 1897 22 Feb., not 3 Feb.)		Chiclayo, N Peru	Strong rains on 12–13 Feb. 1897 in Chiclayo	1897: single episode of rain?	*1896:* Not in Q93

1896–1897	M+	4	Bravo 1903	p. 18	Lima region	Large landslide in Rímac River valley in 1897	Rainfall E of Lima	1896: No EN
			Bachmann 1921			Data not found in ref.		
			*Jones 1933	p. 18	Piura	Abundant rains in 1897 (and drought in 1896)	No EN conditions in 1896	
			El Comercio 1897 (30 Jan. and 1 Feb.)		*Trujillo, Pacasmayo, N Peru*	*Chicama and Moche River floods in 1897*	EN conditions in N Peru in 1897	1897: M
			El Comercio 1897 (11 Feb.)		*Lima, Cuzco*	*Rain at Lima (January 1897) and flood in Cuzco (February)*	Rains in central and SE Peru	
			El Amigo del Pueblo 1906, in Mabres et al. 1993	*p. 398*	*Piura*	*Drought in 1892–96; some rains in 1897*	No EN conditions in 1896	
1899–			*El Comercio* 1899 (10 Feb.)			Data not found in ref. (apparently wrong ref.)		
			Labarthe 1914	p. 320	N-central and S coast of Peru	Floods in Ferreñafe, Lima, and Moquegua in 1900	Rains in central and S Peru	
			Bachmann 1921		Trujillo, N Peru	Strong rains in 1899		
			Murphy 1923				Ref. not seen	
			Hutchinson 1950				Ref. not seen	
			*Jones 1933	p. 18	Piura	Drought in 1899 and abundant rains in 1900	Contradicts data from other refs.!	1899: S?
			*Schott 1938				Ref. not seen	

Table 7.1 (*cont.*)

Years	Event intensity in QNA (*Q&N)	Confidence rating in QNA (*Q&N)	Major original sources in QNA and (*) in Q&N	Precise location of relevant quote (§: in H&O)	Location of climatic/ oceanographic anomaly	Phenomenon/effects leading to the reconstruction of EN event	Remarks	Proposed interpretation
1900	S	5	*El Comercio 1899 (15 and 21 Feb.)*		*Lima, Piura, and Paita*	*1899: Chillon River flood and rainfalls in Piura area*	Strong rainfalls in S, central, and N Peru in 1899 (including Lima)	1900: No EN
			El Comercio 1899 (17 Feb.)		*Mollendo and Moquegua*	*Tambo and Moquegua River floods in 1899*		
			El Comercio 1899 (22, 24, 25 Feb.)		*Arequipa, Moquegua, S Peru*	*1899: Tambo and Vitor River floods; heaviest rains since 1884 in Arequipa*		
			Bravo 1903	*p. 20*	*Lima*	*Local rainfall in April 1899 in Rímac valley*		
			El Amigo del Pueblo 1906, in Mabres et al. 1993	*p. 398*	*Piura*	*Regular rains in 1899; drought in 1900*	1899: only moderate (?) EN conditions 1900: no EN!	
			Leguia y Martinez 1914	*pp. 9, 45, 180–181*	*Piura*	*(Relative) drought in the 22 years following 1891*		

page references of the sources, with the aim of making further research easier. It also indicates when excerpts of the original text were reproduced in H&O (unfortunately, it was not possible to reproduce here all the excerpts; these should soon be gathered in a database on a web site). In the last column, updated interpretations are proposed for the occurrence and strength of El Niño events during the studied period.

Table 7.1 recapitulates the sources listed by QNA and Q&N, some sources indicated by H&O, and some recently found references. All the sources not mentioned by QNA or Q&N are indicated in italics and shaded areas. For the sake of conciseness, and to reduce any unnecessary "noise," I eliminated a series of references originally listed by QNA or Q&N from authors who merely repeated previously available data, without adding any relevant information (e.g., Portocarrero 1926) and from an author (Taulis 1934), cited twenty times for the 1525–1900 period by QNA, who does not qualify as a reliable source.

In the following section, a series of cases are discussed. They concern interpretations at odds with those proposed by QNA and/or Q&N, and they illustrate problems of text interpretation, unreliability of some sources, fragility of the evidence of inferred events, and validity of the teleconnected manifestations of the El Niño phenomenon between Peru and the Bolivian altiplano. The problem of the evidence of rainfall anomalies limited to southern Peru and of the Rímac floods, with respect to El Niño reconstruction, will then be presented.

Critical Analysis of the Foundation of Some of the Earliest Historical Events

Definitely, the Second "Event" of the QNA Record (1531–32) Did Not Occur!

The first two El Niño events identified by Quinn (QNA; Q&N; Quinn 1992, 1993) would have occurred during the years 1525–26 and 1531–32. The arguments in favor of such an interpretation, developed by QNA, bear upon the duration of ship time between Panama and Ecuador and the crossing of rivers (supposedly swollen by heavy rainfall). These arguments were extensively and specifically discussed by Hocquenghem and Ortlieb (1990, 1992a,b), and it may be considered as well established now that, at least during the years 1531–32, and probably also in 1525–26, no excess precipitation occurred in northern Peru. All the available written information from the earliest "cronistas" of the Peruvian history supports that interpretation.

Quinn et al.'s (1987) misinterpretation of the 1531–32 "event" is due to the confidence that Quinn and collaborators had in a text written at the end of the nineteenth century (Prescott 1892). Prescott (1892) tried to explain that the conquest of Peru benefited from anomalous climatic conditions in the coastal desert of northern Peru. Thus, Prescott (1892) wrote, for instance, that on 24 September 1532, Pizarro left San Miguel de Piura and crossed "the smooth water of the Piura River." Quinn et al. (1987) took this information at face value and noted that this river, normally dry, is known to be flooded only during rainy (El Niño) episodes. This indication is misleading in several ways. In 1532, the village of San Miguel de Piura was built on the banks of the Chira (not Piura) River (the village of Piura was moved to the Piura

River banks much later; Raimondi 1876; Eguiguren 1894; Schweigger 1959). Thus, the river crossed by Pizarro and his party was the perennial Chira River, the second most important of the country. In September (certainly not a typical period for El Niño manifestation, by the way), the Chira River is normally fed by water from the cordilleran winter rainfall (the "smooth waters" do not indicate any anomalous excess of precipitation).

Another argument used by QNA in favor of an El Niño event reconstruction in 1531–32 is that Pizarro's party was blocked in Puna Island (southern Ecuador) by heavy rains. However, one of the conquistadores, Xerez (1534), indicated that the party had been exhausted and clearly stated that they remained on the island because they needed some rest. Then, according to QNA, the party is said to have had difficulties in crossing the Tumbes River (located at the present-day boundary between Ecuador and Peru), which is normally a large, flooded river in winter. Another argument presented by QNA is that the Zaña River was also flooded. Actually, the same "cronista" (Trujillo 1571), who wrote that the river was swollen, explained (in the same sentence) that it was because the Indians had intentionally directed all the water from their agricultural diversion canal system.

In unambiguous contradiction to Prescott's theory, all the documents left by the participants in the conquest – namely, Ruiz de Arce (1545), Estete (1535), Xerez (1534), Cieza de Leon (1553), and Trujillo (1571) – insist on the fact that at the end of 1532 the conquistadores crossed a warm desert, without enough water supply, where it "never rains." From this unanimous observation, it may be inferred that, even in the year preceding the conquest (1531), it had not rained. These eyewitness reports should be given much more weight than a historian's adventurous interpretation proposed three and a half centuries afterward!

In fact, for more than a century, several authors have been discussing the idea that anomalous rains helped the Spaniards in their rapid conquest of Peru (Raimondi 1876; Schweigger 1959; Hamilton and Garcia 1986), and they all reached the same conclusion and dismissed this hypothesis. This "romantic" theory had likely been developed to flatter the national Peruvian pride, at a time when repeated El Niño heavy rainfalls struck the north of the country (1871, 1877, 1884, and 1891; see Table 7.1). It is surprising that QNA overlooked it. Finally, it may be noted that Quinn (1993) had downgraded his confidence rating from 4 (in QNA and Q&N) to 2 for the 1531–32 so-called event, and altogether modified its strength evaluation from "strong" to "moderate."

For the supposedly "strong" event of 1525–26, the original sources of information are much less abundant than for 1532. The most important available information (actually the only original source, despite the confidence rating of 3 noted in QNA) was provided by Xerez (1534), who indicated that, off the coast of (present-day) Colombia and Ecuador, in 1525–26, the sea was rough, with northerly winds, thunderstorms, and lightning. Nothing is known about the onshore weather. Such oceanic conditions per se can hardly be considered as depicting typical El Niño manifestations. As was previously indicated by H&O, it will be difficult to assess whether these were (or were not) El Niño years. In 1993, Quinn considered the event as a moderate one, with a confidence rating of only 2.

A Transcription Problem: The 1567–68, 1607, and 1671 Cases

As an example of trivial, but real, problems sometimes met in the historical reconstruction of El Niño records, it is interesting to examine in some detail the consequences of a typographical error in a seventeenth-century manuscript. This work is an important book on the early history of Lima, by Father Bernabé Cobo (1639), which was extensively referred to by most of the authors who subsequently wrote about climate features at Lima, including many of those mentioned by QNA for the sixteenth through seventeenth centuries.

The story starts with the mention of a Rímac River flood that destroyed a pillar that supported one of the six or seven arches of the first bridge built in stone and bricks in Lima. The bridge fell down in February of 1607. Cobo then explains that the Virrey Montesclaro decided that it would be more convenient to build another bridge than to repair the old one. The new bridge was finished in 1610. The problem arose from the fact that in the original manuscript, Cobo wrote "167" instead of "1607" (see the note in the 1964 edition of the Cobo work). From the context (p. 313, Cobo 1964), and thanks to the well-written date of the construction of the new bridge (1610), there is no question that the old bridge had been destroyed in 1607. The river flood that occurred in 1607, known to us (through Cobo) because of its consequences, may (or may not) be interpreted as evidence of an El Niño manifestation (see below).

In a general historical study on river floods in Peru, Labarthe (1914, p. 307) refers to Cobo's work and tells the story of the river flood and its consequences on the first stone bridge of Lima, but he incorrectly states that it occurred in the year 1567. Labarthe, who read a previous edition of Cobo's work (without the note of the 1964 editor), misinterpreted the "167" mention. For their interpretation of an El Niño event in 1567–68, QNA explicitly referred to four sources: Cobo (1639), Labarthe (1914), Portocarrero (1926), and Oliva (1631). The first source (Cobo) had been taken from the erroneously cited text of Labarthe. The third one (Portocarrero) only repeated in a condensed way Labarthe's data. Thus, the only remaining acceptable source is that of Oliva, who mentions that in 1568 a Father Geronimo Ruiz Portillo sailed from Panama to Lima in only (?) 26 days, "a trip which usually took six months" (quote from QNA, p. 14,453). Quinn et al. (1987) add, "An accomplishment such as this in a sailing vessel would indicate the presence of highly favourable winds and currents during their journey southward." Hocquenghem and Ortlieb expressed reservations regarding the interpretation of the normal and unusual (?) travel time between Panama and Peru, and they stressed that neither provincial archives (Actas del Cabildo de Trujillo, 1566–71, 1969) nor Lizárraga (1603–09, 1969) mentioned heavy rainfalls in these years in northern Peru. Considering the Labarthe misreading (1567 instead of 1607), the erroneous reference to Cobo's work, and the weak argument on sailing times, I conclude that neither for 1567 nor for 1568 is there enough information to reconstruct an El Niño event (Table 7.1). Additional information for 1568, given by Labarthe (1914, who himself refers to Montesinos 1642), concerns a river flood in Cuzco, in the southeastern Peruvian Andes. These data rather imply that La Niña conditions were prevailing in 1568.

The transcription problem may also affect a hypothetical El Niño reconstruction for 1671. Quinn et al. (1987) inferred a "strong" event from only two references for this year: Labarthe (1914) and Portocarrero (1926). Portocarrero, as has already been said, only reproduced Labarthe data and thus cannot be viewed as a relevant informant. For 1671, Labarthe mentioned floods of the Supe and Rímac Rivers. He provided some details (but no reference) from an anonymous manuscript concerning the Supe River but did not say from which source he interpreted a Rímac flood. I wonder if he did not consider that "167" may also be interpreted as 1671! This suspicion is supported by the fact that Labarthe (p. 308) did repeat for 1607, with other words than those used for the year 1567 (!), the same story of the destruction of the first stone bridge built in Lima.

Quinn (1993) maintained the confidence rating of 3 and the assignation of a "strong" intensity for the 1671 event. Because of a lack of confidence in Labarthe and for additional reasons dealt with below, I express serious doubts regarding the occurrence of an El Niño event in 1671.

Events Related to Single Rainfalls (or Thunderstrokes): 1552, 1614, 1619, 1652, and 1687

For the earliest two centuries, for which the documentary sources are naturally much less abundant than for later on, QNA were led to identify El Niño events on what may be viewed as particularly weak evidence. In several cases, the mention of a single rainstorm is the unique information that supports the recognition of an event (furthermore qualified as a "strong" event). Such were the cases for the years 1614, 1619, and 1652. In 1552, it was not rainfall but a couple of lightning bolts that constituted the evidence for a "strong" event (confidence rating of 4, although only two references are given by QNA and three by Q&N, with the latter ones being a mere repetition of the earlier one). The interpretation of the 1614 event relies upon the occurrence of one rainfall at some distance north of Lima (Cobo 1653), information that was repeated and exaggerated by Labarthe (1914); the latter was subsequently repeated by Portocarrero (1926). In 1619, a winter (12 June) thunderstorm with lightning was reported at Ilo (coast of southern Peru) by the same Cobo (1653). The 1652 rainfall, also reported by Cobo (with subsequent repetitions by Labarthe and then Portocarrero), occurred in February in Lima.

After H&O, I tend to conclude that the years 1552, 1614, 1619, and 1652 should not be considered as El Niño years until more data are found in each case. Up to now an additional source has been found only for the 1619 event (anonymous manuscript cited by Huertas 1992), mentioning a rainfall in Zaña, in northern Peru (Table 7.1).

In 1687, several anomalies were reported (Table 7.1), but as is shown below, the only one that endures the analysis is a single shower on 2 December (Remy 1931). So, in this case also, detecting the occurrence of an El Niño event is based on a single rainfall event in Lima.

About the 1591–92 Case: The Teleconnection with Bolivia

In spite of an apparent confidence rating of 2, QNA relied on a single source (Martínez y Vela 1702) to reconstruct a strong event for 1591–92. Later, Quinn (1992, 1993) and Q&N modified and extended the duration of the event (1589–91) and downgraded its strength (M/S). In QNA, no information other than a mention of a drought in the Potosí area of Bolivia was thus available for an El Niño event reconstruction for these years. This posed a problem of internal consistency in the QNA record, since no other data for the Bolivian altiplano were considered in the rest of the historical sequence. If the 1591–92 (or 1589–91) event were confirmed, relying more on Bolivian historical data to consolidate the El Niño record would be justified. Conversely, if no correlation can be established between dry years in Bolivia and identified El Niño events, it would not be justified to include a 1591–92 event in the record. Later on, in 1992, Q&N added two other sources for a 1589–91 (not 1591–92) event, the first one (Montesinos 1642) referring to epidemic diseases in 1590, and a second one (Barriga 1951) that mentions a lack of rains in December 1589 in southern Peru. Both sources provide rather weak evidence for El Niño event reconstruction. Furthermore, Q&N relied more heavily on the same source to infer the occurrence of six more El Niño events (1558–61, 1607–08, 1640–41, 1671, 1684, and 1692–93).

The source used by QNA and Q&N is a reliable chronicle of the Potosí mining district that covers the 1545–1737 period. Several versions of this major source for the history of Bolivia have been edited, and apparently QNA did not refer to the most complete one (Arzans de Orsúa y Vela 1965). A peculiarity of this work is that it has been published under several names: Bartolomé Martínez y Vela was also known as B. Arzáns de Orsúa y Vela.

Through a preliminary analysis of the huge work of Arzans de Orsúa y Vela, I looked for climatic data that might be significant and useful for paleo–El Niño studies. In Table 7.2, I recapitulate the major drought and heavy rainfall episodes counted for the 1545–1737 period and compare them to different records (QNA; Q&N; Quinn 1993; the present study). Table 7.2 indicates that among the twenty-three detected episodes of drought (of variable intensity), only four would coincide with QNA El Niño events (1591–92, 1671, 1714–15?, and 1728), ten coincide with the Q&N record, and up to twelve of them would be coeval (at least partly) with events of the Quinn (1993) record. At the same time, it can be noted that three strong (or M/S) El Niño events of the Q&N and Quinn (1993) records are coeval with rainfall excess in Potosí (1600, 1607–08, and 1707–09) and that none of these three events are documented as rainy years in northern Peru (see Table 7.1).

With respect to evidence of northern Peru rainfall anomalies, which I tend to consider as primary criteria for assessment of El Niño reconstruction, only two coincidences with Potosí drought were found: 1678–79 and 1728 (Table 7.2). Two coincidences between northern Peru rainfall and heavy rainfall in Potosí (1593 and 1607) must also be noted. Until ongoing studies (by M. R. Prieto, at Mendoza, and A. Gioda, at Cochabamba, in collaboration with the author; see also Prieto 1994; Prieto et al., 1999) on historical teleconnections between Peru, Chile, northern Argentina, and Bolivia are completed, it is difficult to formally conclude that drought evidence for Potosí can be used straightforwardly to reconstruct El Niño past occurrences.

Table 7.2 *Compilation of indications of drought (bold) and rainfall excess (italics) anomalies in Potosí (Bolivia) during the period 1560–1737, as recorded by Arzans de Orsúa y Vela (1965, written in 1705–37). Quinn et al. (1987) had based their interpretation of a strong El Niño event, for 1591–92 (shaded), on the only reference of Arzans de Orsúa y Vela (work referred to by QNA as "Martínez y Vela 1702"). Later, Q&N used the "Martínez y Vela 1702" source to reconstruct El Niño events in 1558–61, 1589–91 (instead of 1591–92), 1607–08, 1640–41, 1671, 1684, and 1692–93 (shaded areas). Actually, a poor correlation is observed between dry years in Potosí and reconstructed El Niño events according to QNA, Q&N, and Quinn (1993). El Niño events generally occurred coeval with droughts in Potosí (but not always). However, notice that many dry years in Potosí were not interpreted as El Niño years. EN = El Niño; VS = very strong; S = strong; M = moderate strength.*

Year & months (I = January)	Drought in Potosí	Rainfall excess in Potosí	Quote in Arzans de Orsúa y Vela 1965	QNA	Q&N	Quinn 1993	EN anomaly recorded in N Peru (Table 7.1)	Interpretation of EN occurrence (Table 7.1)
1557 (VIII–IX)		*Snowfall and icy cold*	*(1): 102–103*	—	—	—	—	—
1560 (X–XII)–1561 (I)	**Drought**		**(1): 115**	—	**1558–61 M/S**	**1558–61 M/S**	**No**	**No EN?**
1582–83	**Drought**		**(1): 192**	—	**1582 M**	**1581–82 M+**	**No**	**?**
1588 (I–III)		*Disastrous rainfalls*	*(1): 203*	—	—	—	—	—
1591 (X–XII)–1592 (I)	**Drought**		**(1): 217, 218**	**1591–92 S**	**1589–91 M/S**	**1589–91 M/S**	**No**	**No EN?**
1593 (I–IV)		*Abundant rains*	*(1): 218*	—	—	—	*Yes*	*M event?*
1600		*Abundant rains*	*(1): 244*	—	*1600 S*	*1600 S*	*No*	*No EN*
1605 (X–XII)–1606 (I–III)	**Strong drought**		**(1): 263**	—	—	—	—	—

1607 (VIII–IX)		*Snow (VIII) and rains (IX)*	*(1): 265*	*1607 S*	*1607–08 S*	*1607–08 S*	*No*	*M event?*
1609 (?)	**Strong drought**		**(1): 263 (Note 1)**	—		—	—	—
1671 (X–XII)	**Drought**		**(2): 259**	**1671 S**	**1671 S**	**1671 S**	**No**	**No EN?**
1677		*Abundant rains*	*(2): 285*	—	—	—	—	—
1678 (X–XII)–1679 (I)	**Strong drought**		**(2): 293–294**	—	—	—	**Yes**	**M event?**
1683 (X–XII)–1684 (I)	**Drought**		**(2): 316**	—	**1684 M+**	**1684 M+**	**No**	**No EN?**
1693 (I–III)–1694–95	**Drought**		**(2): 368, 393**	—	**1692–93 S**	**1695 M**	**No**	**No EN**
1698–1699	**Regional drought**		**(2): 393, 394**	—	—	—	—	—
1705 (X–XII)	**Drought**		(2): 435	—	—	—	—	—
1709 (XII–1710 (I–II)		*Abundant rains*	*(2): 479*	—	1707–09 M/S	1707–09 M/S	**Drought in Piura between 1706 & 1715 (Schlüpmann 1994: 61)**	*No EN*
1712 (II–III & X–XI)	**Drought**		**(2): 495, 501**	—	—	—		*No EN*
1713 (II–III & X–XII)	**Strong drought**		**(3): 3, 12**	—	—	**1713 M**		*No EN*
1714 (I–II)		*Abundant rains*	*(3): 14*	*1714–15* S	—	—		*No EN*
1715 (I)	**Limited drought**		**(3): 26**		**1715–16**	**1715–16**		**No EN**

Table 7.2 (*cont.*)

Year & months (I = January)	Drought in Potosí	Rainfall excess in Potosí	Quote in Arzans de Orsúa y Vela 1965	QNA	Q&N	Quinn 1993	EN anomaly recorded in N Peru (Table 7.1)	Interpretation of EN occurrence (Table 7.1)
1716 (I–III)	**Regional drought**		**(3): 43**	—	S	S	**No**	**No EN**
1719 (I–III)		*Abundant rains*	*(3): 78*	—	—	—	—	—
1721 (I)	**Drought**		**(3): 124, 163**	—	—	—	—	—
1722 (I & X–XII)	**Drought**		**(3): 138, 150–151, 163**	—	—	—	—	—
1723 (I–VII)	**Drought**		**(3): 153, 156, 163**	—	**1723 M+**	**1723 M+**	**No**	**No EN**
1724 (I–II)		*Abundant rains*	*(3): 162*	—	—	—	—	—
1728 (X-XII)	**Drought**		**(3): 287**	**1728 VS**	**1728 VS**	**1728 VS**	**Yes**	**Very strong event**
1729 (I–II)	**Drought**		**(3): 289**	—	—	—	—	—
1732 (X)	**Drought**		**(3): 349**	—	—	—	—	—
1732 (XII)–1733 (I–II)		*Disastrous rainfall*	*(3): 350*	—	—	—	—	—
1734 (I–II & X–XI)	**Drought**		**(3): 363, 378**	—	—	**1734 M**	—	—
1736 (X–XII)–1737 (I)	**Drought**		**(3): 411–412**	—	**1736 S**	**1737 S**	**No**	**No EN**

The Date of the Destruction of Zaña by a Huge Flood: 1720, Not 1687–88 or 1728

Large floods that lead to the destruction of a city and the emigration of its inhabitants may constitute reliable indicators of anomalous rains, and hence of El Niño past occurrences in coastal northern Peru. Quinn et al. (1987) were apparently confused by misleading references to the destruction of Zaña (or Saña) by different sources that mention that it happened in 1687–88, or in 1720, or else in 1728. As was shown by H&O (pp. 225–226, 228–231), who reproduced a text including eyewitness reports of Zaña destruction (Rubiños y Andrade 1782), and as indicated by Bueno (1763, p. 53), the large flood that caused the complete destruction of the city occurred on 15 March 1720, after several days of uninterrupted rainfall. This disaster occurred only once, so authors who erroneously mention other dates for the same destruction episode should not be trusted.

For the two years 1687 and 1688, QNA based their interpretation of a "strong +" El Niño event on four sources (excluding Taulis 1934): Juan and Ulloa (1748), Unanue (1806), Melo (1913), and Remy (1931). The latter reference deals with data for Lima (a single rainfall on 2 December 1687). I did not find the information concerning 1687–88 in Unanue's work (1806). The latter two sources actually correspond to a single one, because Melo (1913, p. 152) only repeated information from Juan and Ulloa, a century and a half later. Juan and Ulloa (1748) mentioned that Zaña was pillaged in 1685 by the English pirate Edward David and was then completely destroyed "some years later" by a formidable flood. Quinn et al. (1987) concluded that this flood occurred in 1687 or 1688. As we know that this actually happened in 1720, and as no mention of heavy rainfall or flood was found for the years 1687–88 by Huertas (1987, 1992) in his studies on the history of Zaña (H&O), it is confidently inferred that no such flood occurred in these years. Actually, Q&N suppressed the Juan and Ulloa (1748) source in their revised record but still included the Unanue (1806) and Melo (1913) sources. Another indication of the destruction of Zaña (by a large flood) was given by Alcedo (1786–89, p. 344) for 1728. Quinn et al. (1987) cite this source as an additional reference among those that support the 1728 El Niño event. Curiously, QNA also used the Alcedo work as a source for the 1720 event. Actually, abundant information confirms the occurrence of El Niño events in both 1720 and 1728 (Table 7.1).

Meteorological Anomalies Restricted to Central and Southern Peru

One of the major points made by the earlier H&O analysis of the QNA record concerns the evidence for climatic anomalies restricted to Lima and the southern coast of Peru. As rainfall and thunderstrokes are exceptional in Lima, in the arid coastal fringe of Peru, and because more precise and abundant information is available from the capital, it is easily understandable that such phenomena were recorded in colonial times. Anecdotes and comments on these matters from many authors were then used by QNA. However, the problem of the relationship between Rímac River floods, or Lima showers, and El Niño manifestations was scarcely tackled. In their interpretations, QNA apparently relied much on the exceptional character of rainfall in Lima and did not question whether these phenomena were related to El Niño, or La Niña, conditions. It must be noted, for instance, that they did not address the fact that the typical "garúa" of Lima is winter precipitation, and as such this may rather be linked to La Niña meteorological conditions. Quinn et al. (1987) may have amalgamated the anomalous rainfall signals of northern Peru, central Peru, and southern Peru. These premises may be wrong.

El Niño Impacts along the Peruvian Coast

From a climatological point of view, the El Niño phenomenon was defined in the Piura–Paita area, far north of Lima. There is no doubt whatsoever that the Sechura Desert, which is different from the narrow coastal desert that borders the whole country, constitutes the core of the El Niño "land" (see Eguiguren 1894; Petersen 1935; Ortlieb and Macharé 1993). The amount of anomalous rainfall in the coastal region of extreme northern Peru remains the most reliable indicator of the strength of the El Niño events. While a clear relationship links river flooding in the northern reaches of the country and the precipitation that falls within the wide coastal area of the Sechura Desert, there are uncertainties as to the significance of river floods in the central coast of Peru. In Lima and in central Peru, the river floods imply upstream rainfalls that occur either at the foot of the nearby Andes or within the 4,000 m high cordillera. A Rímac River flood is never produced by rainfall in Lima, and thus the report of a past flood should not be interpreted as evidence for rainfall in the coastal desert of central Peru. In fact, not even rainfall in Lima can be linked directly to El Niño episodes.

The amount of annual rainfall at Lima varies between a few millimeters and less than 10 cm (Fig. 7.2). It must be stressed that unlike northern Peru or central Chile, the hyperarid coastal desert that stretches between 6° and 25°S latitude (including the Atacama Desert of northern Chile) never registers "heavy" rainfalls. The exceptional showers that may fall in this coastal desert do not exceed a few centimeters of precipitation, while the Sechura Desert may receive hundreds of centimeters (up to 400 cm locally in 1982–83) of precipitation during El Niño years (Huaman Solis and Garcia Peña 1985; Woodman 1985). But what is most important is that even the small amounts of precipitation that occur in the coastal desert of central and southern Peru do not seem to be related to El Niño conditions. Figure 7.2 shows that during the past forty years (1950–91) it did not rain more during El Niño years than in "normal" years or La Niña years. The amount of precipitation during the very strong 1982–83 event does not depart from the overall mean of the past thirty years. This observation for the second half of the twentieth century must be taken into consideration when one looks at the historical climatic record of Lima.

The coastal region of southern Peru and the southern Peruvian Andes are known to suffer deficits of precipitation during El Niño years (Huaman Solis and Garcia Peña 1985; Francou and Pizarro 1985; Garcia Peña and Fernández 1985; Ropelewski and Halpert 1987). In a study on the relationship between precipitation in the coast of southern Peru and the well-established occurrences of El Niño events during the past forty years, Minaya (1994) showed that for Lima there is no direct and unequivocal link between rainfall (or drought) and El Niño (or La Niña) conditions (Fig. 7.2; Table 7.3). At Tacna, in the coastal area close to the Chilean border, as well as in Arequipa on the high inland plateau, no relationship can be established between the strengths of the

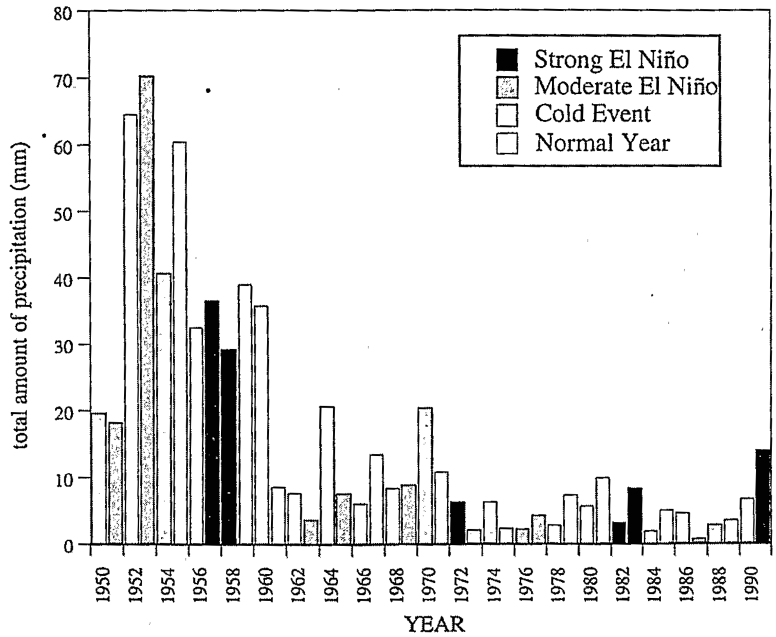

Fig. 7.2 Annual rainfall variation in Lima for the 1950–91 period. No evidence is seen for a straightforward relationship with recent El Niño events (data from Corporación Peruana de la Aviación Civil [CORPAC] compiled by Minaya 1994). Neither strong nor moderate events are characterized by rainfall more abundant than the decadal mean. If extrapolated to the past few centuries, this observation leads one to question the occurrence of a series of events as proposed by QNA, Q&N, and Quinn (1993).

events and the amounts of precipitation. The very strong 1982–83 El Niño event was characterized by a total drought in Arequipa and a strong deficit of the Majes River flow (Table 7.3), but during strong events (such as in 1972–73) exceptional rainfall at Arequipa and maximum flows of the Majes River were registered (Minaya 1993). Moderate events also correspond to opposite extremes, in Tacna for instance: total drought in the 1965 and 1969 events and maximum annual rainfall in the 1953 event (Table 7.3).

Based on instrumental data of the past decades, it thus appears that neither droughts, nor anomalous precipitation episodes, nor river floods in the southern half of the country can be used to predict El Niño conditions. This conclusion has serious implications for the elaboration of the historical record of El Niño events.

Rímac River Floods and El Niño Events

Quinn et al. (1987) and Q&N often refer to evidence of floods of the Rímac River as an indication of anomalous rainfall, and hence of El Niño conditions. We saw that actually the floods of this river, like others in the central part of the Peruvian coastal desert, do not reflect properly rainfall excess in the coastal region; this observation, however, does not preclude the hypothesis that precipitation on the western flank of the Andes is, in some way, related to El Niño circulation patterns. A careful study of the

Table 7.3 *Amounts of annual precipitation in southern Peru localities during the last El Niño events of the past forty years, from Corporación Peruana de la Aviación Civil (CORPAC) data (Minaya 1994). No clear relationship can be established between the rainfall in southern Peru and the occurrence of El Niño events: Some events are characterized by strong deficits and others by rainfall excess. Rio Majes flow data (from Dirección General de Aguas, Ministerio de Agricultura, Lima, in Minaya 1993) show the same extreme variability with the recent El Niño events.*

ENSO events 1950–90		Annual precipitation (mm)				Streamflow (m^3)
Year	Strength	Lima	Pisco	Arequipa	Tacna	Rio Majes
1951	M−	18	0	72	25	3,304
1953	M+	70	0	248	114	2,855
1958	S	29	4	55	63	3,177
1965	M+	8	1	33	0	1,079
1969	M−	9	0	30	0	1,801
1972–	S	7	6	253	81	3,337
1973	S	2	0	95	7	4,227
1976	M	2	1	112	53	n.d.
1983	VS	9	0	0	34	426
1987	M	8	0	49	6	1,393
Mean 1950–90		16	2	93	26	2,391

twentieth-century Rímac River floods in regard to El Niño events is hampered by the inadequacy of the instrumental record of precipitation in the first half of the century (precise locations of the rainfalls) and by the intense development of human activities (hydroelectric power station, water supply plant) upstream in the Rímac valley. Otherwise, it should be useful to try to determine in the historical record how tight the relationship is between Rímac floods and El Niño events that were unambiguously identified.

Table 7.4 recapitulates eighteen cases of Rímac floods known to have occurred between 1567 and 1900, sixteen of which are mentioned in the QNA record. Practically all of these floods had been identified by Labarthe (1914), a source that was not entirely reliable, as has been mentioned (e.g., the 1567/1607/1671 problem). In several cases, the original sources of information of Labarthe could not be verified. In other instances, as for the four eighteenth-century cases of Rímac River floods, Labarthe indicated that he relied upon a newspaper (*Mercurio Peruano*) review article written by a journalist, Ambrosio Cerdán. It can be noted that several of the so-called events identified by QNA on the basis of Rímac River floods (1634, 1696, 1750, 1755, and 1779) were not confirmed in the 1993 Quinn record (Table 7.4).

Among the sixteen events that QNA correlated with Rímac River floods, only seven are confirmed as El Niño episodes (Table 7.1) by assessing evidence of rainfall in northern Peru (indicated in bold in Table 7.4). These reconfirmed events coincided with floods of other rivers in northern, central, and eventually southern Peru. It is certainly

Table 7.4 *Chronological list of El Niño years (according to QNA and Quinn 1993) that were (partially or exclusively) identified on the basis of evidence for Rímac River floods, at Lima, in the sixteenth through nineteenth centuries. In some cases (in boldface), Rímac River floods appear to be coeval with rainfall excess in northern Peru, or southern Ecuador, and thus seem to have occurred during El Niño events. In other instances (shaded areas), Rímac floods are rather correlated with southern Peru rains. It is deduced that by themselves floods at Lima should not be used to reconstruct El Niño events.*

Years	Rímac River flood (month of occurrence)	Original source and quote in Labarthe 1914 (L.)	El Niño intensity according to QNA (confidence)	El Niño intensity according to Quinn 1993	Evidence for N Peru and S Ecuador rains	Proposed interpretation (see Table 7.1)	Remarks
1567	Yes	Cobo 1639 L., p. 307	1567–68 S+ (5)	1567–68 S+ (5)	No	No EN event?	Transcription problem: 1567/1607 (see text)
1578	**Yes**	**Cobo 1639 L., p. 308**	**1578 VS (5)**	**1578–79 VS (5)**	**Yes**	**Very strong event**	**Large floods at Lima and in N Peru**
1607	February	Cobo 1639 L., p. 308	1607 S (5)	1607–08 S (5)	No	Moderate event?	No other data available
1634	February/ March	Source? Palma 1894, p. 42	1634 S (4)		No	No EN event?	Floods at Lima and in S Peru
1671	Yes	Source? L., p. 309	1671 S (3)	1671 S (3)	No	No EN event?	Transcription problem: 1671/1607 (see text)
1696	**11 Feb.**	**Source? Palma 1894, p. 42**	**1696 S (3)**		**Yes**	**Moderate event?**	**Flood in S Ecuador**
1750	Yes	A. Cerdan L., p. 311	1750 M (p. 14455)		No	No EN event	Only source for QNA?
1775	Yes	A. Cerdan L., p. 311	1775 S (4)		No	No EN event	No report on destruction; drought in N Peru
1779	Yes	A. Cerdan L., p. 311	1778–79 M		No	No EN event?	No report on destruction

Table 7.4 (*cont.*)

Years	Rímac River flood (month of occurrence)	Original source and quote in Labarthe 1914 (L.)	El Niño intensity according to QNA (confidence)	El Niño intensity according to Quinn 1993	Evidence for N Peru and S Ecuador rains	Proposed interpretation (see Table 7.1)	Remarks
1786	Yes	A. Cerdan L., p. 311	1785–86 S (4)	1785–86 M+ (2)	No	No EN event	No other data for 1786
1804	**February/ March**	**Guía de Forasteros L., p. 313**	**1803–04 S (5)**	**1803–04 S+ (5)**	**Yes**	**Strong event**	**Limited destruction but warm temperature**
1860	8 Mar.	L., p. 315	1860 M (4)	1860 M (4)	No	No EN event	Coeval with rains in S Peru (drought in N Peru)
1871	**February**	**L., p. 316**	**1871 S+ (5)**	**1871 S+ (5)**	**Yes**	**Strong event**	**Large flood coeval with N Peru rainfalls**
1872	January & 28 Feb.	L., p. 316			No		Rains in southern and central Peru
1884	**7 Jan.**	**L., p. 317**	**1884 S (5)**	**1884 S+ (5)**	**Yes**	**Strong event**	**Rains in N, S, and central Peru**
1889	**12 Mar.**	**L., p. 318**	**1887–89 M (4)**	**1887–89 M (4)**	**Some rain**	**Weak event?**	**Bridges destroyed E of Lima**
1891	**20 Mar.**	**L., p. 319**	**1891 VS (5)**	**1891 VS (5)**	**Yes**	**Very strong event**	**Bridges destroyed E of Lima**
1900	February	L., p. 320	1899–1900 S (5)	1899–1900 S (5)	No	No EN event?	Rains in S and central Peru; drought in N Peru

significant that the few Rímac floods that occur only along with floods in southern Peru do not seem to be associated with El Niño events (Table 7.1).

As was hypothesized by H&O, some of the events proposed by QNA on the basis of climatic anomalies and river floods in southern Peru might actually be manifestations of La Niña conditions. This may apply to the years 1540, 1634, 1714, 1775, 1806–07, 1812, 1860, 1874, and 1900. The best candidates for cold event (La Niña) years are those for which there are combined indications of drought in northern Peru and above average rainfall in the southern half of the Peruvian coast (1714–15, 1775, 1806–07, 1812, 1860, and 1874). Further historical studies planned for the Piura area and aimed to complement the century-old Eguiguren (1894) work should help to discriminate El Niño, La Niña, and normal years of the past few centuries.

New Data from Southernmost Ecuador

Among the new data gathered to assess the reconstruction of former manifestations of El Niño events, some information relative to northernmost Peru and the southern part of Ecuador is included here. Quinn et al. (1987) previously referred to two informants who reported information from southern Ecuador: Spruce (1864) and Estrada Ycaza (1977). The former provided trustworthy data, especially for the first half of the nineteenth century (Table 7.1). Estrada Ycaza's (1977) work was referred to by QNA in a single case (1785–86), although the book contains a series of relevant data on flooding and particularly heavy rainfalls that occurred in the past centuries in the Guayaquil region. Quinn and Neal (1992) cited a 1565 (or 1572) book, by Benzoni, in which is mentioned that the first settlement of Guayaquil suffered from a large flood of the Chiono River to the point that the town was reconstructed some distance to the south. This flood occurred in 1546 and is probably related to an El Niño manifestation.

Table 7.1 includes relevant additional data on climatic anomalies reported in South Ecuador. Evidence for heavy rainfalls and floods of several rivers in southern Ecuador is presented for the following years: 1696, 1760, 1784–85, 1804, 1817, 1819, 1821, 1824–25, and 1850 (Table 7.1). This information suggests or reconfirms the occurrence of El Niño events. In a few cases, reports on drought in southern Ecuador may be used to infer that no El Niño event occurred (1654–55, 1775–80).

Certainly further investigations into the documentary record of southern Ecuador should be encouraged. Unlike the central Chilean data, there is no question that meteorological anomalies that occurred in northern Peru and those reported in southern Ecuador are closely related and (most often) directly linked with the El Niño phenomenon. In fact, there are much closer similarities between El Niño manifestations within an area that encompasses southern Ecuador and northern Peru, than between northern and southern Peru.

The Northern Peru–Central Chile Teleconnection

The El Niño Record for Central Chile

For several reasons explained previously, the Taulis (1934) reference was suppressed from the critical analysis of the QNA record (Table 7.1). This source, extensively used by QNA, Q&N, and Quinn (1992, 1993), consists of a mere chronological table, in which every year between 1535 and 1933 is graphically depicted as either normal, dry, very dry, wet, or very wet. No precise indication of documentary sources is given by Taulis, a major inconvenience for this kind of work. As was demonstrated in a previous work (Ortlieb 1994), many indications for rainy or anomalously rainy years as reported by Taulis were compiled from a well-documented work written by a respected historian and national figure, Benjamin Vicuña Mackenna (1877). A close correspondence between Taulis and Vicuña Mackenna records is observed for the period 1723–1877 (Table 7.5). It is assumed that Taulis used instrumental records of precipitation for the period 1877–1933, but we totally ignore his sources for the sixteenth and seventeenth centuries.

In his most recent papers, Quinn relied even more heavily on Taulis as well as on Vicuña Mackenna (1877) and an informant on wreck occurrences related to storminess in central Chile (Vidal Gormaz 1901). As a result, the sequences presented by Q&N and Quinn (1992, 1993) include some fourteen additional events (with respect to the QNA chronology) that were partly inferred from evidence that came from central Chile.

Through a comparison between Taulis's and Vicuña Mackenna's records, which also includes a third chronicle of past climatic anomalies extracted from a historical review of natural disasters in Chile (Urrutia de Hazbún and Lanza Lazcano 1993; hereafter U&L), Ortlieb (1994) intended to consolidate the chronological sequence of rainfall excess in central Chile. The proposed sequence of rainy years thus included Taulis's data only when additional confirmation was obtained in Vicuña Mackenna or U&L (Table 7.5). Precipitation excesses were qualified as regular, strong (S), and very strong (VS) (bold characters in Table 7.5). In this way, only two rainy years were assessed in the sixteenth century, and eight in both the seventeenth and eighteenth centuries, while up to twenty years (with varying amounts of excess rainfall) were counted in the nineteenth century (Table 7.5). The much larger number of rainy events recognized during the nineteenth century should be related primarily to the major accessibility of documentary sources. But the possibility cannot be excluded that the nineteenth and twentieth (see Ruttlant and Fuenzalida 1991) centuries were actually more "rainy" than the previous centuries.

The comparison of available instrumental records of precipitation at Santiago for the past century and a half and El Niño sequences (Kiladis and Diaz 1989; Ruttlant and Fuenzalida 1991) suggests that some proportionality exists between the amount of winter rainfall in central Chile and the strength of El Niño events. Therefore, it can be expected that the record of the major historical rainfall anomalies at Santiago may correspond to the strongest events of the past few centuries. How could this hypothesis be tested? The record of well-assessed rainy years in pre–nineteenth century times (Ortlieb 1994) can be compared neither with QNA nor with the last published regional chronologies by Quinn, since these were developed with central Chile data. Verifying the evolution through time of the relationship between precipitation excess in central Chile and El Niño manifestations cannot be performed if the historical record of El Niño events was built (at least partially) upon rainfall data for central Chile.

Table 7.5 *Historical reconstruction of rainfall excess anomalies in central Chile compared to Quinn's records of El Niño events (QNA; Quinn 1993). The sequences of rainy years were deduced from analysis of reports from Vicuña Mackenna (1877), Taulis (1934), and Urrutia de Hazbún and Lanza Lazcano (1993). The sequence of Ortlieb (1994) synthesized the three previous studies, after respective evaluation. Strength of El Niño events: VS = very strong, S = strong, M = moderate, W = weak. Years with the strongest rainfall excess are indicated in boldface and shaded; "No" means: No evidence for rainfall excess.*

Rainy years in central and north-central Chile				QNA EN chronology	Revised EN chronology
Vicuña M. 1877	Taulis 1934	U&L 1993	Ortlieb 1994	Quinn et al. 1987	Quinn 1993
No data	No data	No data	No data	**1525** S **1526**	1525 M 1526
				1531 S **1532**	1531 M 1532
	1535?		?		1535 M+
1536			?		
				1539 1540 M/S 1541	1539 1540 M/S 1541
1544	**1544**		**1544** S		1544 M+
					1546 S **1547**
	1548 1550 1551		? ? ?		
				1552 S	**1552** S
	1559		?		1558 1559 M/S 1560 1561
	No data				1565 M+
				1567 S+ **1568**	**1567** S+ **1568**
	1574	**1574**	**1574** S	**1574** S	**1574** S
	1575		?		
				1578 VS	**1578** VS **1579**

Table 7.5 (*cont.*)

Rainy years in central and north-central Chile				QNA EN chronology	Revised E… chronolog…
Vicuña M. 1877	Taulis 1934	U&L 1993	Ortlieb 1994	Quinn et al. 1987	Quinn 1993
	1581	1581	?		1581 M- 1582
	No data				1585 M-
					1589 1590 M/ 1591
				1591 S **1592**	
					1596 M+
		1597	?		
					1600 S
					1604 M+
	1607	1607	1607	**1607** S	**1607** S **1608**
1609	**1609**	**1609**	**1609** S		
				1614 S	**1614** S
1618	1618		1618	**1618** S **1619**	**1618** S **1619**
					1621 M+
				1624 S+	**1624** S+
					1630 M
				1634 S	
					1635 S
					1640 M 1641
1647	**1647**	**1647**	**1647** S		1647 M+
	1648 1650	1650	? 1650		1650 M
				1652 S+	**1652** S+
	1655		?		1655 M
		1657	No		

Table 7.5 (*cont.*)

Rainy years in central and north-central Chile				QNA EN chronology	Revised EN chronology
Vicuña M. 1877	Taulis 1934	U&L 1993	Ortlieb 1994	Quinn et al. 1987	Quinn 1993
		1660	No	**1660** S	
					1661 S
				1671 S	**1671** S
		1679	No		
				1681 S	**1681** S
	1683		?		
					1684 M+
	1686		?		
?	1687	1687	1687	**1687** S+	**1687** S+
?	1688	1688	1688	**1688**	
					1692 S
		1694	No		
	1695		?		1695 M
				1696 S	
1697	**1697**		**1697** S		1697 M+
	1698		?		
				1701 S+	**1701** S+
					1704 M
	1705		?		
				1707 S	1707
				1708	1708 M/S
					1709
					1713 M
				1714 S	
				1715	**1715** S
					1716
					1718 M+
				1720 S+	1720 VS
		1722	No?		
1723	1723	1723	1723		1723 M+
				1728 VS	**1728** VS
					1734 M
					1737 S

Table 7.5 (*cont.*)

Rainy years in central and north-central Chile				QNA EN chronology	Revised EN chronology
Vicuña M. 1877	Taulis 1934	U&L 1993	Ortlieb 1994	Quinn et al. 1987	Quinn 1993
		1743	**No?**		
1744	1744	1744	1744		1744 M+
		1745	**No?**		
1746	**1746**		**1746** S		
				1747 S	**1747** S+
1748	1748	1748	**1748** S		
	1751	1751	1751		1751 M+
					1754 M 1755
					1758 M
				1761 S	**1761** S
1764	**1764**	1764	1764		
					1765 M
1768	1768		1768		1768 M
					1772 M
				1775 S	
					1776 **1777** S **1778**
1779?		1779	**No**		
		1779	**No**		
					1782 S
1783	**1783**	**1783**	**1783** VS		**1783**
				1785 S **1786**	1785 M+ 1786
1790?			**No**		
				1791 VS	**1791** VS
				1803 S+ **1804**	**1803** S+ **1804**
				1806 M 1807	1806 M 1807

Table 7.5 (*cont.*)

Rainy years in central and north-central Chile				QNA EN chronology		Revised EN chronology	
Vicuña M. 1877	Taulis 1934	U&L 1993	Ortlieb 1994	Quinn et al. 1987		Quinn 1993	
						1810	M
				1812	M	1812	M+
	1813		?				
				1814	S	**1814**	S
1817	**1817**		**1817** S	1817	M+	1817	M+
1819	1819		1819	1819	M+	1819	M+
1820	1820		1820				
1821	1821		1821	1821	M	1821	M
		1823	No?				
				1824	M	1824	M+
		1826	No				
1827	**1827**	1827	**1827** S				
1828	1828	1828	1828	**1828**	VS	**1828**	VS
1829	**1829**		**1829** S				
						1830	M
				1832	M	1832	M+
1833	**1833**	**1833**	**1833** S				
		1835	No?				
		1836	No				
1837	1837	1837	1837	1837	M	1837	M+
1841	1841		1841				
1843	**1843**		**1843** S				
				1844	S +	**1844**	
1845	1845		**1845** VS	**1845**		**1845**	S
						1846	
		1848	No				
1850	1850	**1850**	**1850** S	1850	M	1850	M
1851	**1851**		**1851** S				
						1852	M
						1853	
1854			No	1854	W/M	1854	M
1855	1855	1855	1855				
1856	1856	1856	1856				
		1857	No	1857	M+	1857	M
1858	1858		1858	1858		1858	

Table 7.5 (*cont.*)

Rainy years in central and north-central Chile				QNA EN chronology	Revised EN chronology
Vicuña M. 1877	Taulis 1934	U&L 1993	Ortlieb 1994	Quinn et al. 1987	Quinn 1993
1860	1860		1860	1860 M	1860 M
1862			**No**		1862 M–
1864	**1864**	1864	**1864** S	**1864** S	**1864** S
				1866 M	1866 M+
				1867 M	1867 M+
1868	**1868**		**1868** S	1868	1868
				1871 S+	**1871** S+
1873			**No?**		
1874			**No?**	1874 M	1874 M
		1875	**No**		
1877	**1877**	**1877**	**1877** VS	**1877** VS	**1877** VS
		1878	1878	**1878**	**1878**
	1880	**1880**	**1880** S	1880 M	1880 M
		1884	**No**	**1884** S+	**1884** S+
No	1887		?	1887	1887
	1888	**1888**	**1888** S	1888 W/M	1888 M
data				1889	1889
	1891	**1891**	**1891** S	**1891** VS	**1891** VS
		1896	**No**	1896 M+	
No				1897	1897 M+
	1899	**1899**	**1899** VS	**1899** S	**1899** S
data	**1900**	**1900**	**1900** VS	**1900**	**1900**

Revised Peruvian Record versus Revised Chilean Record

Previous studies (Ortlieb 1994, 1995; Ortlieb et al. 1995) evaluated the consistency of reconstructed sequences of El Niño events for central and northern Chile with different chronologies of regional events (QNA; Quinn 1993; H&O). The new Peruvian sequence proposed here constitutes a more internally consistent reference, since it excludes all data from central Chile and is, furthermore, supposedly better consolidated. As has been discussed, it is inferred here that the southern Ecuador historical data, and maybe that of the high Andes of Peru or Bolivia, are open to being more directly linked to the regional climate of coastal northern Peru than to the climate system of central Chile. The so-called Peruvian record derived from the interpretation of Table 7.1 is summarized in the second column of Table 7.6.

Table 7.6 *Western South American El Niño records compared to summarized Indo-Pacific ENSO records. The Chile (Ortlieb 1994, and Table 7.5) and Peru (Table 7.1) records are based on documentary records, while the Galapagos sequence (Dunbar et al. 1994) is deduced from SST reconstructions based on ^{18}O composition of an emerged coral reef. The eastern Pacific record of Quinn (1993), indicated in the fourth column, is his last published sequence of El Niño events (modified from the QNA record). The fifth column, also reproduced from Quinn (1993), represents a global combination of ENSO manifestations in Egypt, India, China, and South America. The sequence of India droughts and the synthetic eastern ENSO chronology were compiled by Whetton and Rutherfurd (1994). Legend: (a) El Niño events (based on documentary records): In bold and shaded = strong rainfall anomaly (underlined = very strong); italics = small anomaly; ? = insufficient data. (b) ENSO reconstruction from ^{18}O data from UR-86 coral record; strongest events in bold. (c) Quinn records with ranking of El Niño event intensity: W = weak; M = moderate; S (+shaded) = strong; VS (+shaded and underlined) = very strong. Period of occurrence in the year: E = early (January–March); L = late (September–December). (d) Droughts in India according to several sources (see Whetton & Rutherfurd 1994), considered as coeval with ENSO events. Less well assessed data in italics. (e) ENSO years determination based on coincidence of at least three indicators from the Nile region, Java, North China, India, and Peru (Quinn's data); years in bold are the best correlated (four coincidental indicators within the five areas; underlined: five coincidences).*

South America El Niño records			Quinn's (1993) revised chronology and ranking		Eastern Hemisphere ENSO compilation		India droughts	South America El Niño records
Chile	Peru	Galapagos	E Pacific El Niño events		Global ENSO events			
Ortlieb 1994	Present work	Dunbar et al. 1994	Quinn 1993		Quinn 1993		Whetton & Rutherfurd 1994	
(a)	(a)	(b)	(c)		(c)		(d)	(e)
							1520–21?	
	No?		1525–	M	1525–	M		
	No?		E1526		E1526			
	No		1531–	M	1531–	M		
	No		E1532		E1532			

Table 7.6 (*cont.*)

South America El Niño records			Quinn's (1993) revised chronology and ranking		Eastern Hemisphere ENSO compilation		India droughts	South America El Niño records
Chile	Peru	Galapagos	E Pacific El Niño events		Global ENSO events			
Ortlieb 1994	Present work	Dunbar et al. 1994	Quinn 1993		Quinn 1993		Whetton & Rutherfurd 1994	
(a)	(a)	(b)	(c)		(c)		(d)	(e)
?			1535	M+	1535	M+		
	No?		1539–		**1539–**			
	No?		1540–	M/S	**1540–**	**S**	1540–	
	No?		1541		**1541**		1541–	
							1542–	
							1543	
1544	?		1544	M+	1544	M+		
	1546–		**1546–**	**S**	**1546–**	**S**		
	1547		**1546**		**1547**			
	No	No	**1552**	**S**	**1552–**	**S**		No
					1553			
	No?	Data	1558–		**1558–**		*1554–56?*	Data
?	No?		1559–	M/S	**1559–**	**S**		
	No?		1560–		**1560–**			
	No?		1561		**E1561**			
	No?		1565	M+	1565	M+		
	No?		**1567–**	S+	**1567–**	S+		

	No?		**1568**		**1568**			
1574	1574		**1574**	S	**1574**	S	*1576–77?*	
	1578		**1578–E1579**	**VS**	**1578–E1579**	S		
?			1581–1582	M+	1581–1582	M+		
	? ?		1585	M+	1585	M		
	No? No?		1589–1590–1591	M/S	**1589–1590–1591**	S		
	No? No? 1593						*1592? 1594–1995–1996–1997–1998?*	
	1596		1596	M+	1596	M		
	?		**1600**	S	**1600–1601**	S		
	No		1604	M+	**1604**	S		
1607	1607–1608	1607	**1607–1608**	S	**1607–1608**	S		
1609								
	No?		**1614**	S	**1614**	S	*1613–1915?*	
1618	1618–1619		**1618–1619**	S	1618–1619	M	*1618–1619?*	
		1621	1621	M+	**1621**	S		
	1622	**1623**					*1623?*	
	1624		**1624**	S+	1624	M+		
			1630	M	**1630–1631**	S+	1629–1630–1631	No
		1633						

Table 7.6 (*cont.*)

South America El Niño records			Quinn's (1993) revised chronology and ranking		Eastern Hemisphere ENSO compilation		India droughts	South America El Niño records
Chile	Peru	Galapagos	E Pacific El Niño events		Global ENSO events			
Ortlieb 1994	Present work	Dunbar et al. 1994	Quinn 1993		Quinn 1993		Whetton & Rutherfurd 1994	
(a)	(a)	(b)	(c)		(c)		(d)	(e)
	No?		**1635**	S	1635	M		
	No		1640–	M	**1640–**	S+		Data
	No		1641		**1641**			
1647	No		1647	M+	1647	M		
?								
1650							1648	
			1650	M	**1650**	S+	*1650?*	
	No?	**1652**	**1652**	S+	1652	M		
?	No		1655	M	1655	M		
							1659–	
	No						1660–	
			1661	S	<u>**1661**</u>	<u>**VS**</u>	1661	
		1670						
	No?		**1671**	S+	1671	M+		
		1674						
	1678							
	No		**1681**	S	**1681**	S		
?								
					1683–	M+		
	No?		1684	M+	1684			
							1685?	

?	1686–							
1687	1687–	1687	**1687**	S+	**1687–**	S	*1687?*	
1688	1688				**1688**			
	No		**1692**	S	1692	M+		
					1694–	**VS**		
?			1695	M	**1695**			
	1696							
1697	No		1697	M+	1697	M		
	1701		**1701**	S+	1701	M		No?
							1702–	No
		1703			**1703–**	S	*1703–*	**1703**
			1704	M	**1704**		*1704?*	**1704**
	No		1707–		1707–			
	No		1708–	M/S	1708–	M		
	No		1709		1709		*1709?*	1709?
								1711
			1713	M	1713–	M+		
	No				1714			
	No		**1715–**	S	**1715–**	S+		
	No?		**1716**		**1716**			
	1718		1718	M+	1718	M	*1718?*	
	1720		**1720**	**VS**	1720	M+		1720
1723	No		1723	M+	**1723**	S		1723
					1725	M		
	1728		**1728**	**VS**	1728	M		
								1729
					1731	M+		1731
								1732
		1733					*1733?*	
			1734	M	1734	M		1734
			1737	S	**1737**	S	*1737?*	**1737**
							1739?	

Table 7.6 (*cont.*)

South America El Niño records			Quinn's (1993) revised chronology and ranking		Eastern Hemisphere ENSO compilation		India droughts	South America El Niño records
Chile	Peru	Galapagos	E Pacific El Niño events		Global ENSO events			
Ortlieb 1994	Present work	Dunbar et al. 1994	Quinn 1993		Quinn 1993		Whetton & Rutherfurd 1994	
(a)	(a)	(b)	(c)		(c)		(d)	(e)
?								**1743**
1744	No		1744	M+	1744	M+	*1744?*	1744
1746							*1746–*	1746
	1747–		**1747**	**S+**	**1747–**	**S**	*1747?*	
1748	**1748**				**1748**			1748
1751			1751	M+	1751	M+		No
							1752?	1752
			1754–	M	**1754–**	**S**		
	No		1755		**1755**			
	No		1758	M	1758	M		
	1761	1761	**1761**	**S**	**1761–**	**S**		
		1762			**1762**			1762
		1763						
1764	No							
			1765	M	1765–	M+		1765
					1766			
1768	?		1768	M	1768–	M+		
					1769		*1769–*	**1769**
							1770	1770

			1772	M	1772–	M		
				M	1773			
			1776–		1776–			
			1777–	**S**	1777–	M+		
			E1778		E1778			1778
	No?							No
	No?	1779	**1782–**	**S**	**1782–**		1782	**1782**
			1783		**1783–**	**VS**	1783	**1783**
1783	No?				**1784**			1784
	1784–							
	1785		1785–	M+	1785–	M+		
			1786		1786			
	No				**1790–**			
	1791	1791	**1791**	**VS**	**1791–**	**VS**	1791	1791
					1792–			
					1793			
					1794–			
					1795–	M+		
		1795						
					1796–			
					1797			
					1799	M		1799
		1800						
					1802–		1802–	1802
	1803–		**1803–**	**S+**	**1803–**	**S+**	1803	1803
	1804		**1804**		**1804**			
	No		1806–	M	1806–	M	1806	
	No	1807	1807		1807			
			1810	M	1810	M		
			1812	M+	1812	M+	1812	
	No							1814
	1814		**1814**	**S**	**1814**	**S**		

Table 7.6 (*cont.*)

South America El Niño records			Quinn's (1993) revised chronology and ranking		Eastern Hemisphere ENSO compilation		India droughts	South America El Niño records
Chile	Peru	Galapagos	E Pacific El Niño events		Global ENSO events			
Ortlieb 1994	Present work	Dunbar et al. 1994	Quinn 1993		Quinn 1993		Whetton & Rutherfurd 1994	
(a)	(a)	(b)	(c)		(c)		(d)	(e)
1817	1817–		1817	M+	1817	M+		1817
	1818–							1818
1819	1819		1819	M+	1819	M+		
1820								
1821	1821		1821	M	1821	M		
		1823					1823–	
	1824		1824	M+	**1824–**	S	1824	**1824**
					1825			**1825**
1827					**1827–**	S+		
1828	**1828**		**1828**	**VS**	**1828**			
1829								
			1830	M	1830	M		
		1831						
	1832		1832	M+	**1832–**	S+	1832–	1832
1833					**1833**		1833	1833?
					1835–	M		1835
					1836			

1837	1837		1837	M+	**1837–**	**S**	1837–	1837
					1838–		1838	
					1839			
		1840						
1841								1842
								No?
1843							1844	
	1844–		**1844–**		**1844–**			
1845	**1845**		**1845–**	S	**1845–**	**VS**		1846
	No?		**E1846**		**E1846**			1850
1850	1850		1850	M	**1850**	**S**		
1851					1852–	M		
	1852		1852	M	E1853		1853	1853?
		1853						No?
	1854		1854	M	**1854–**	**S**		1855
					1855			
1855								
1856								
	1857		1857–	M	1857–			
					1858–	M+		
1858	No?		1858		E1859			
					1860	M	1860	1860?
1860	No		1860	M				
	1861–							1862
	1862		1862	M–	1862	M–	1864–	1864
1864	**1864**		**1864**	**S**	**1864**	**S+**	1865–	
					L1865–	M+		
		1865			E1866		1866	1866?
	1866		E1866	M+				1867
	No		L1867–	M+	**L1867–**			
1868	No		1868		**1868–**	**S+**	1868	**1868**
					E1869			No?
	1871		**1871**	**S+**	1871	M	1871	1873
					1873–	M+		

Table 7.6 (*cont.*)

South America El Niño records			Quinn's (1993) revised chronology and ranking		Eastern Hemisphere ENSO compilation		India droughts	South America El Niño records
Chile	Peru	Galapagos	E Pacific El Niño events		Global ENSO events			
Ortlieb 1994	Present work	Dunbar et al. 1994	Quinn 1993		Quinn 1993		Whetton & Rutherfurd 1994	
(a)	(a)	(b)	(c)		(c)		(d)	(e)
	No		1874	M	1874			No
					L1876–		1876–	1876
1877	**1877**		**1877–**	**VS**	**1877–**	**VS**	1877	**1877**
1878	**1878**		**1878**		**1878**			
1880	1880		1880	M	1880–	M+		
					1881			No?
								1882
	1884		**1884**	S+	1884–	M+		
					1885			
								1886
1887?	1887–	1887	L1887–		**L1887**			No?
1888	1888–	**1888**	1888–	M	**1888–**	**S**		**1888**
	1889		E1889		**E1889**			No?
1891	**1891**		**1891**	**VS**	1891	M	1891	**1891**
	No				1896–	M+		
	1897		1897	M+	1897			
1899	**1899**		**1899–**	**S**	**1899–**	**VS**	1899	**1899**
1900	No		**E1900**		**M1900**			

For the sixteenth century, only one possible coincidence is observed (1574; Table 7.6). For the seventeenth century, there are only three possible coincidences (1607, 1618, and 1687–98). So, in these two early centuries, none of the strongest events in either Chile or Peru correspond to each other (1544, 1574, 1609, 1647, and 1697 in Chile; 1578 and 1596 in Peru). For the eighteenth century, the correlation is scarcely better. One strong event (1748) was identified in both regions (1747–48 in Peru), while four strong events that were identified in Peru (1701, 1720, 1728, and 1791) have no counterpart in central Chile. For the much better documented nineteenth century, the coincidences are more numerous (fifteen episodes). Six strong/very strong events were clearly recognized as such in both areas: 1828 (including 1827 and 1829), 1845, 1864, 1877 (1877–78), 1891, and 1899. Two strong events in Peru have no counterparts in Chile (1871 and 1884). Several strong or very strong events in Chile (1817, 1845, 1850, 1880, 1888, and 1899) are identified with an apparently weaker relative intensity in Peru (strong, moderate, or weak), but this comparison obviously relies upon scales that should be adjusted.

On the whole, it may thus be concluded that a fair correlation between the Peruvian and Chilean records existed only since the early nineteenth century. During the sixteenth, seventeenth, and eighteenth centuries, the best assessed indications of El Niño manifestations seldom coincide in time in both regions (only seven cases total). This observation, which is based on data that are better assessed than they were previously (e.g., Ortlieb 1994), reinforces the hypothesis that the teleconnection pattern that presently links the precipitation regimes in northern Peru and central Chile during El Niño events was different before the early nineteenth century. Such a hypothesis merits further investigation, especially of climatology in northern Peru for the sixteenth through eighteenth centuries. To establish, or reject, the nonsynchronicity of the meterological manifestations assigned to the El Niño system in both regions, we need to exclude the possibility that it is due to the inaccuracy of the documentary data.

A complementary approach would be to validate one or both records from western South America by correlation with other records from the eastern Pacific or from the other rim of the Pacific Ocean.

Comparisons with Other Historical ENSO Records

Among the high-resolution natural records that can be used to establish the El Niño chronological sequence for South America, one of the most favorable is a coral reef sequence of the Galapagos. The other proxy records are provided by high Andes ice caps (see chapter by Thompson et al., this book) and tree rings from subtropical Chile and Argentina (see chapter by Cook et al., this book). The coral record presents the advantage that it reflects more directly oceanic perturbations than the ice sequence (which is linked more to the Atlantic/Amazonian system) or the dendroclimatic records of Chile and Argentina (which are influenced by southern South American circulation patterns). A yearly resolved coral sequence from the Galapagos Islands, covering the past four centuries (1607–1953), has been published by Dunbar et al. (1994). Oxygen isotope measurements on annual growth layers provide information on paleotemperature variations that relate to El Niño conditions. The isotope record shows a satisfactory correspondence with the Quinn record, although a number of warmer annual episodes may need to be shifted by one year (after or before) with respect to the events defined by QNA (Dunbar et al. did not use the more recently published papers of Quinn). Some episodes do not have counterparts in the QNA chronology and are supposed, according to Dunbar et al. (1994), to represent El Niño events that might not have been identified in the Quinn record. The chronological sequence of the Galapagos coral reef is constructed from the thirty largest negative $\delta^{18}O$ excursions (with the strongest sea surface temperature [SST] anomalies, indicated in bold, Table 7.6).

The comparison between the coral record and both the Chilean and Peruvian records is disappointing because the largest isotope anomalies do not correlate with the strongest events as recognized in either Peru or Chile (Table 7.6). In only three instances (1607, 1687, and 1888) are there coincidences between the three records, and it is only in 1888 that the coincidence concerns a strong event (in Galapagos and in Chile). If the intensities of the events/episodes of elevated SST are not taken into consideration, and if quasi-coincidences ($\pm$1-year shift) are accepted, about a dozen fits are observed between the Galapagos data and either the Chilean or the Peruvian records (Table 7.6). The coincidences do not favor one of the two (Chile and Peru) records. No systematic temporal shift with the Peruvian or Chilean records is observed. This situation is somewhat puzzling, to the point that one may wonder if the chronological control is as tight as it seemed to Dunbar et al. (1994), or alternatively whether some bias may explain the general lack of correspondence between the strongest events/episodes of the Galapagos, Chilean, and Peruvian records. Ongoing research on seasonal variations in reconstructed paleotemperatures for the past two centuries on another coral sequence from the Galapagos (R. Dunbar and colleagues, in preparation) should bring new light on this problem.

Table 7.6 also shows chronological series of ENSO events as they were determined in India (Whetton and Rutherfurd 1994), and by way of correlation of different records (India, Java, Nile, North China, and Peru–Chile). The table also includes the global ENSO chronology of Quinn (1993). The two synthetic chronological sequences based on the India and Eastern Hemisphere data are not independent from QNA and regional El Niño chronologies from Quinn (1993), since Quinn also integrated part of this information. Comparison of both sequences – regional evidence of El Niño and global-scale features associated with the large-scale ENSO phenomenon – shows that global ENSO events are more numerous than the regionally experienced El Niño events, and that the former tend to last longer than the eastern Pacific events, particularly in the eighteenth and nineteenth centuries. It may also be noted that a number of strong events identified by Quinn (1993), in both the regional and global El Niño patterns during the sixteenth, seventeenth, and eighteenth centuries, have not been identified, either in the Chilean record (Ortlieb 1994) or in the revised Peruvian record (this work, second column, Table 7.6). For the nineteenth century, the larger number of reconstructed events in all records may be attributed to the increased availability of data, including instrumental data. However, there is also a possibility that the ENSO system behaved differently at the end of and shortly after the LIA and that the teleconnection pattern was modified at the LIA–post-LIA transition. If this is the case, the better correlation observed since the beginning of the nineteenth century would not be an artifact of the documentary records.

Intrinsically, the records from Chile, Peru, and India are based on the same kind of documentary data and include comparable numbers of El Niño/ENSO manifestations. The Galapagos coral record presents a lower number of events, but this is due to the threshold fixed by Dunbar et al. (1994) for the stable isotope excursions. It should be clear that if the records of El Niño/ENSO events proposed by Quinn (1993) are denser than the other ones in Table 7.6, it is basically because Quinn compiled information from Chile, Peru, and India (among other regions) to elaborate these records. Quinn's chronological sequences thus appear much more "complete" than any of the regional series, but, clearly, this does not imply that the former are more accurate than the latter.

Another problem that arises from the comparison shown in Table 7.6 deals with the validity of the reconstruction of the event intensities. As was stressed previously, the Chilean and Peruvian records generally do not present chronological coincidences of the strongest events (except in three instances, at the end of the nineteenth century). The intensity ratings of the events used in Quinn's compilation do not necessarily represent an integration of the widely spaced proxies but seem to rely upon one or another regional record, according to the events. This is how Quinn's record of "regional" El Niño events includes the strongest events documented in Peru and those registered in central Chile. This seems to be true for the first three centuries of the historical sequence.

Conclusions

From QNA and Q&N Chronologies to the "Peruvian" Record of El Niño Events

One of the aims of this chapter was to give an insight into the large body of documents that constitute the background of Quinn's work. After many years of general uncritical acceptance of the QNA chronology, it seemed useful to reexamine critically the nature and quality of the data that support the determination of the event occurrences in the past few centuries. The summary Table 7.1 provides for each of the events of the sixteenth through nineteenth centuries another kind of "confidence rating" than the indices given by Quinn.

Although this critical analysis of the sources used in the QNA record should certainly not be considered as definitive, it takes into consideration a number of sources that had not been previously available to H&O. Table 7.1 also includes some important new data. Of particular relevance are the new sources and unpublished archives revealed by historical studies in northern Peru (Schlüpmann 1988, 1994; Huertas 1987, 1992, 1993).

At this stage of a long-range, ongoing study it might be relevant to state a few points regarding the reliability of the sources used in the reconstruction of El Niño events, the evaluation of the event strengths, the number of historical events, and the concept of a "regional El Niño" record.

Reliability of Sources

As is shown by a few examples in the critical analysis of the Quinn records, evaluation of the source reliability is of major importance in this kind of study. It seemed useful to comment on the trustworthiness of particular sources in Table 7.1. Since the question of the discrimination between reliable and less reliable sources was not given particular emphasis in the QNA paper, one may conclude that they considered as equally reliable all the sources cited by them. It was shown here that several sources are actually unreliable. As a result of the H&O work and this study, a ranking of the trustworthiness of the sources may be proposed.

For the conquest period, the best informants are those who accompanied Pizarro during his rapid march toward Cuzco (i.e., Xerez 1534; Estete 1535; Mena 1534; Trujillo 1571; and Ruiz de Arce 1545). For the rest of the sixteenth century, the most reliable sources proved to be Zárate (1545), Cieza de Leon (1553), Benzoni (1572), Cabello Valboa (1586), Acosta (1590), Ocaña and Alvarez (1596), and Lizárraga (1603–09). For the seventeenth century, trustworthy information was given by Suardo (1629–39) and Cobo (1639, 1653), but not precisely by Montesinos (1642). For the eighteenth century, Anson (1748), Feijoo de Sosa (1763), Bueno (1763), Rubiños y Andrade (1782), Haenke (1790), and Lequanda (1793) are to be considered among the reliable authors, while Juan and Ulloa (1748) and Alcedo (1786–89) committed several errors in their writings and induced several misinterpretations. For the nineteenth century, the most reliable and accurate informants were Unanue (1806), Helguero (1802–03), Spruce (1864), and Eguiguren (1894), while Stevenson (1825), Ruschenberger (1835), Paz Soldán (1862), and Palma (1894) should be classified as compilers who were not always critical enough. Finally, for the twentieth century, it must be noted that, unfortunately, the three authors most frequently cited by QNA and Q&N should not be fully trusted: Labarthe (1914), who provided some erroneous data; Portocarrero (1926), who did not bring any new information with respect to Labarthe; and Taulis (1934), who did not cite any of his sources. Among the twentieth-century authors to be trusted, one may distinguish those from the beginning of the century, such as Garcia Rosell (1903, 1904, 1907), Fuchs (1907), Murphy (1925, 1926), Remy (1931), or Petersen (1935), from those who investigated in a modern way national, provincial, and municipal archives of the past centuries, such as Hamerly (1973), Estrada Ycaza (1977), Huertas (1987, 1993), or Schlüpmann (1988, 1994).

Event Strength Reevaluation

Determination of the strengths, or intensities, of past El Niño manifestations is a demanding endeavor, even when instrumental records are available. Without precise knowledge of the spatial extension of El Niño manifestations, it is hazardous to attempt to make a fair determination of the strengths of the events. And, clearly, this information is seldom available in the documentary records. Consequently, it is natural that subjective elements are involved in the classification of events.

The tendency of H&O to propose a reduction of the strengths of many events, with respect to the QNA evaluation, is generally confirmed here. In many cases for the sixteenth and seventeenth centuries, QNA tended to exaggerate the intensities of El Niño events (Table 7.1). Typical cases are those for which there is only an indication of a single shower, a thunderstroke, or a river flood, and which were related to "strong" events by QNA. Actually, in his latest papers (1992, 1993, Q&N), Quinn downgraded the intensity of a number of events with respect to the original QNA record (compare the last two columns of Table 7.5).

Because of the intrinsically fragmentary information provided by the documentary sources, it may be concluded that the evaluation of the intensities of former events should involve a wider regional analysis of meteorological impacts that include the countries neighboring Peru. This task, beyond the scope of the present study focused on the Peruvian (and southernmost Ecuador) record, should incorporate not only documentary data from Ecuador, Bolivia, and Argentina but also proxy records, particularly dendroclimatic records from southern South America.

Number of Events

This revision of the QNA and Q&N sequences led me to propose the suppression of some events and the addition of some new events (Table 7.1). Four newly proposed events and three cases of extension to a previous or succeeding year of a previously defined El Niño year are supported by evidence of rainfall occurrences in northern Peru or southern Ecuador (Table 7.7). In most cases, the interpretation of an El Niño occurrence relies on a single source and may not be fully accepted until a confirmation is obtained.

For some forty-two events of the Quinn records (QNA and Q&N), the reevaluation of the sources and combination with new sources led me to question the occurrence of El Niño conditions. Two situations were found: Either the available data were precise enough to determine that no El Niño occurred that year or the information at hand was not sufficient to preclude the occurrence of an El Niño event. In some twenty-five cases, it was possible to deny the occurrence of El Niño conditions, most often because drought conditions seem to have been prevailing in northern Peru at those times (e.g., 1531–32, 1552, 1655, 1707–08–09, 1714–15, 1775, 1806–07, 1812, 1860, 1867–68, 1874, and 1900). In some cases, it was because there was a unique, poorly reliable source (e.g., 1600, 1604, 1660, 1681, 1740, 1750) or because data from central Chile, eastern Bolivia, and/or northeast Brazil were provided as the only evidence (e.g., 1640–41, 1647, 1692–93, 1723, 1736, 1744, and 1764). In seventeen other cases (indications "?" or "No EN?" in the last column of Table 7.1), the analysis of the sources on which QNA and Q&N had based their interpretation showed that the data were irrelevant, or insufficient, to support the occurrence of an event, but it could not be demonstrated unequivocally that no event occurred that year.

Finally, there are some instances in which the reconstruction of an El Niño event was confirmed but its duration was restricted, on the basis that no positive evidence was confirmed for the first or the second year, in Peru at least (e.g., 1697, 1786, 1896, and 1900).

Table 7.7 *List of El Niño years not identified by QNA, Q&N, or Quinn (1992, 1993) and for which new evidence has been obtained from northern Peru and southern Ecuador anecdotical records. See Table 7.1 for sources of the records.*

Year	Reference	Location of anomaly	Interpretation of El Niño event occurrence and strength
1593	H&O 1990	Trujillo, N Peru	Moderate (?) event
1622	This work (Table 7.1)	Jayanca, N Peru	Moderate (?) event
1678	This work (Table 7.1)	Jayanca Vieja, N Peru	Moderate (?) event
1686 (–1687–1688)	H&O 1990	Yapatera (Piura), N Peru	Extension to 1686 of the 1687–88 Moderate (?) event
(1747–) 1748	H&O 1990	Sancor (Piura) and Chocope, N Peru	Extension to 1748 of the 1747 Strong event
1784 (–1785)	This work (Table 7.1)	Daule River, S Ecuador	Moderate event
1861–(1862)	This work (Table 7.1)	Paita and Piura, N Peru	Extension to 1861 of the 1862 Weak event?

The "Regional El Niño Record" Concept

The general lack of correlation between the local records in Chile and Peru in pre–nineteenth century times casts some doubts on the concept of a "regional El Niño chronology" in the sense of Quinn (1992, 1993). It appears that the so-called regional character of the chronological sequence of events might have actually resulted from the amalgamation of data from both regions.

The careful revision of the QNA and other sequences of Quinn, and the poor correlation finally observed between the Chilean and Peruvian (revised) records, suggest modifications in the teleconnection pattern of El Niño manifestations during the sixteenth through eighteenth centuries versus the twentieth-century situation. If this were confirmed, it may be due to some interactions between the LIA climatic system and the ENSO mode. Some previous studies, which had relied entirely upon QNA data, had concluded that the frequency of El Niño events did not show variations with respect to the LIA–post-LIA climate change (Enfield 1988, 1992; Enfield and Cid 1991). Since the present study modified part of the database of these statistical studies, it would not be surprising that a reprocessing would produce a different conclusion. It might even be possible that such a treatment could provide some assessment of the teleconnection problem brought up here.

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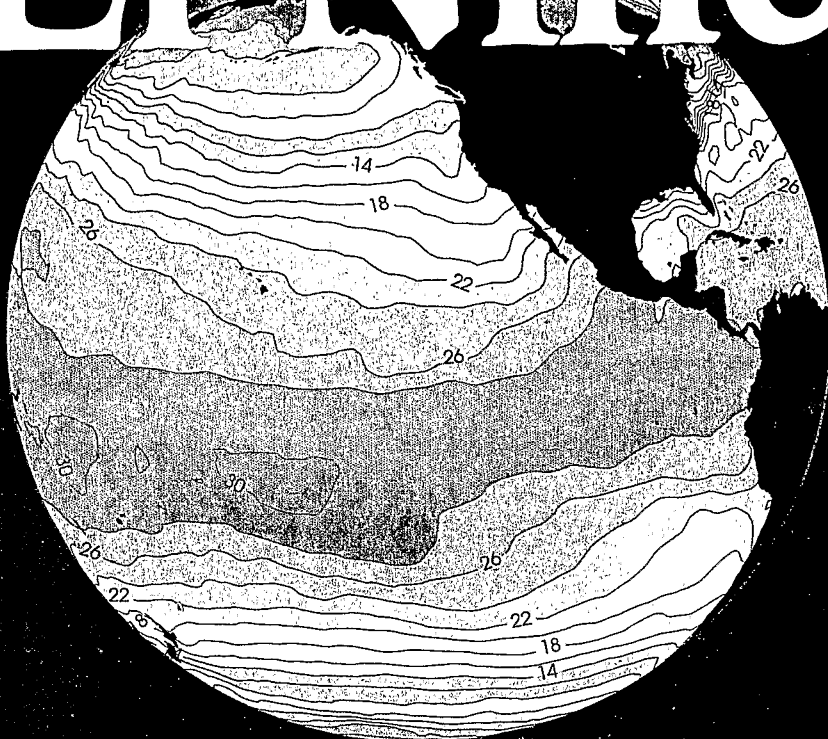
El Niño



AND THE Southern Oscillation

MULTISCALE VARIABILITY AND GLOBAL AND REGIONAL IMPACTS

Edited by Henry F. Diaz and Vera Markgraf

The El Niño/ Southern Oscillation (ENSO) phenomenon is a recurrent feature of the climate in tropical regions. In this volume, leading experts summarize information gained over the past decade concerning diverse aspects of ENSO, which have led to marked improvements in our ability to forecast its development months or seasons in advance. This volume compares ENSO's modern morphology and variability with its recent historic and prehistoric behavior. It expands and updates Diaz and Markgraf's earlier volume *El Niño: Historical and Paleoclimatic Aspects of the Southern Oscillation* (1992, Cambridge University Press). The volume will be of importance to a broad range of scientists in meteorology, oceanography, hydrology, geoscience, ecology, public health, emergency management response and mitigation, and decision making. It will also be used as a supplementary textbook and reference source on graduate courses in environmental studies.

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