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El Niño Update – Informational Report

Submitted to the PFMC by:

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Summary of Conditions and Forecast

In March 2015, forecasters with NOAA's National Weather Service Climate Prediction Center (CPC) announced the onset of El Niño conditions[1]. At the September 2015 meeting of the PFMC we will provide an update on the status of this year's El Niño conditions, as well as discuss possible scenarios for U.S. West Coast conditions from the fall of 2015 through spring of 2016. At the time of this Informational Report's preparation (11 Aug 2015), the CPC reported that *"There is a greater than 90% chance that El Niño will continue through Northern Hemisphere winter 2015-16, and around an 80% chance it will last into early spring 2016."*[2]

Presently, the signatures of El Niño are mainly in the tropics, along the Equator from the coast of South America most of the way across the tropical Pacific. Expressions include very warm water in the eastern half of the tropical Pacific, much weaker than normal trade winds and a dramatic shift in areas of heavy rainfall in the tropics. Thus, places that are usually wet, like Indonesia and parts of southwest Asia, have been suffering dry conditions.

Collectively, these atmospheric and oceanic features reflect an ongoing and strengthening El Niño. At the same time, nearly all models predict El Niño conditions to continue into the Northern Hemisphere winter 2015-16, with many multi-model averages predicting a strong event at its peak strength. At this time, the forecaster consensus favors a significant El Niño in the tropics, but the range of forecasts spans weak to exceptionally strong El Niño conditions by the end 2015.

Estimating the evolution of the 2015/16 El Niño

While there are general characteristics that are common to all El Niños, there are also differences between them. In a recent paper[3] Capotondi et al. (2015) described the diversity in amplitude, temporal evolution, spatial patterns, and high-latitude climate anomalies associated with El Niño-Southern Oscillation (ENSO) events. As such,

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[1] http://www.noaanews.noaa.gov/stories2015/20150305-noaa-advisory-elnino-arrives.html

[2] http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/enso_advisory/index.shtml

[3] Capotondi, A., A.T. Wittenberg, M. Newman, E. Di Lorenzo, J-Y. Yu, P. Braconnot, J. Cole, B. Dewitte, B. Giese, E. Guilyardi, F-F. Jin, K. Karnauskas, B. Kirtman, T. Lee, N. Schneider, Y. Xue, and S-W. Yeh (2015) Understanding ENSO Diversity. *Bull. Amer. Meteor. Soc.*, **96**, 921–938. doi: http://dx.doi.org/10.1175/BAMS-D-13-00117.1

accurate predictions of any El Niño in the tropics and its high latitude impacts are challenging. That said, and despite the added presence of the "warm blob"[4] and related effects in the California Current[5] that make this El Niño event particularly unique, we can anticipate gross effects of the arrival of El Niño conditions to the U.S. West Coast.

Effects of El Niño on the U.S. West Coast

El Niño, which typically develops in the summertime in the tropics, has its most profound influences on the U.S. West Coast and over North America during fall and winter. There are at least three ways that tropical El Niño events may impact the U.S. West Coast: a) atmospheric teleconnections that alter the behavior of winter storm tracks and surface wind patterns over the North Pacific, b) changes in oceanic currents related to altered North Pacific winds, and c) tropical-origin oceanic coastally trapped Kelvin waves that depress the thermocline in the coastal regions. Typical physical changes include increased rainfall in California (most reliably in Southern California), intense winter downwelling along the Pacific coast, warmer upper-ocean temperatures, a deepened thermocline/nutricline, higher sea level, and greater transport of subtropical waters from the south. The biological response to these changes include reduced primary and secondary production, with subsequent impacts on the population viability and distribution of higher trophic level species, as well as changes in community structure. The U.S. Pacific Northwest typically experiences warmer and drier winter conditions during El Niño events, while Alaska and Canada experience very mild winter temperatures.

Relation to the warm conditions in the North Pacific and off the U.S. West Coast

Ocean waters throughout much of the northeast Pacific continue to be remarkably warm. The pattern of high pressure over the Gulf of Alaska (GOA) since winter 2013/14 that has maintained fair weather and reduced the loss of heat from the ocean to the atmosphere remained throughout much of this spring and summer. The anomalous fair weather resulted in exceptionally warm ocean temperatures off the Pacific Northwest coast (3 to 4 °C warmer than average) that extended ~1,500 miles, from coastal British Columbia into the offshore waters of the GOA south of the Aleutians. Unusually weak spring and summer upwelling off Central, Southern, and Baja California contributed to exceptionally warm coastal ocean temperatures that are now about 3 to 4 °C above average, and these warm waters also extend far offshore.

Possible interactions of El Niño conditions with "the blobs" (here, "blobs" refer to broad areas of warm ocean temps in the northeast Pacific)

A likely scenario, as indicated by observations and models, would see the El Niño continue to develop in the tropics this fall, which would likely favor a mid-latitude jet stream pattern in the fall and winter that replaces that persistent ridge of high atmospheric pressure in the GOA with a trough of low pressure. Low atmospheric pressure in the GOS causes a broad pattern of counter-clockwise surface winds that

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[4] Bond, N.A., M.F. Cronin, H. Freeland, and N. Mantua (2015) Causes and impacts of the 2014 warm anomaly in the NE Pacific. *Geophys. Res. Lett.*, **42**, 3414–3420. doi: 10.1002/2015GL063306.

[5] Leising et al. State of the California Current 2013-2014: El Niño Looming. CalCOFI Rep., Vol. 55, 2014. http://www.calcofi.org/publications/calcofireports/v55/Vol_55_SOTCC_51-87.pdf

include strong south to north winds along most of the U.S. West Coast. This scenario has happened in El Niño winters of the past. Under this scenario, this fall (2015) we would see the warm SST anomalies of the "blob" cool down on the offshore side where westerly winds intensify, but within a few hundred km of the U.S. West Coast ocean temperatures would rise dramatically under the influence of the strong southerly winds. This shift in North Pacific winds happened last fall, but then reverted to the high-pressure ridge and fair weather in the winter. With El Niño, the persistence of a broad trough of low pressure in the GOA is likely to persist through the entire fall and winter. If this plays out as it has in the past it would result in more intensified warming off the coast that could persist through the end of winter.

Coastal warming related to shifting North Pacific wind patterns would likely be boosted within 10 to 20 km of the coast by the influence of tropical-origin coastally trapped Kelvin waves. These Kelvin waves typically deepen the U.S. West Coast thermocline by 10's of meters, raise coastal sea levels, and reverse nearshore upper ocean currents. During the exceptional El Niño of 1997/98 the first signs of coastally trapped Kelvin waves appeared in Central California in mid-August 1997, and off Newport, OR, in early September. Given the similarities between recent tropical climate conditions and those observed in summer 1997, it is likely the U.S. West Coast will be impacted by coastally-trapped Kelvin Waves in the next few months.

By the end of the winter of 1998 (and 1983), the combined effects of altered North Pacific wind patterns and tropical-origin Kelvin waves caused an upper ocean warming along the Pacific coast of North America that extended to 100m depth. This kind of surface warming strongly inhibits the upwelling of cold, nutrient-rich water into the euphotic zone, and has been associated with delays in the spring bloom of plankton and onset of high food-web production that is normally observed off the U.S. West Coast when the seasonal upwelling season gets underway.

Spring Fishery Conditions off the California Coast (April/May/June 2015)
The 2015 data collected during surveys by the SW/NW Fisheries Science Centers generally show a continuation of very high catches of juvenile rockfish and Pacific sanddab in the central, southern and northern California areas. However, the abundance of krill was at or below average levels for all regions, and the abundance of adult Pacific sardine and northern anchovy remained very low as well (although larval catches for both species were at high levels in most areas). The abundance of market squid continued to remain very high in the central California area, although catches were lower in the southern region where the bulk of the market squid fishery takes place. Catches of octopus, lingcod, juvenile Pacific hake and several other juvenile groundfish were also high. North of Cape Mendocino, catches of young-of-the-year (YOY) rockfish and other groundfish were at very low levels in both 2014 and 2015.

In addition to the high catches of YOY rockfish and other groundfish off Central California, catches tended to be very high for a suite of both less commonly encountered and less consistently reported (over the course of the time series) species. Catches of scyphozoan jellyfish were unusually low in 2015, although catches of "crystal" jellies and pelagic tunicates were at high levels. Finally, despite the high abundance (inferring high productivity and transport of subarctic water) of both YOY groundfish and of pelagic tunicates, the 2015 survey also encountered unusually high numbers of warm water species (many of which had never previously been encountered), which are typically considered to be harbingers of strong El Niño events, northward transport of subtropical waters, and unusually low productivity. These included record high numbers of pelagic red crabs, California spiny lobster phyllosoma (pelagic larvae), and largely subtropical krill in both southern and Central California waters, as well as oddities such as the greater argonaut, the slender snipefish, and subtropical krill. The 2015 survey was highly unusual in that species characteristics of all three of what might very generally be considered nominal ecosystem states (YOY groundfish dominated catches, pelagic tunicate dominated catches, and subtropical species dominated catches) were encountered in high abundance throughout Central California coastal regions.

Based on CalCOFI survey data, conditions off Southern California during spring 2015 were extremely warm in the surface mixed layer (~1.5° C above the long term seasonal mean) with low nitrate values, and concomitantly low chlorophyll-*a* (an indicator of primary productivity) values. Mixed-layer chlorophyll-*a* was the lowest during spring 2015 than at any time since 1985 when such measurements were first taken. Such values of these surface properties are similar to those observed during the 1997-98 El Niño. However, temperature and salinity of subsurface waters in fall 2014 and spring 2015 were markedly different from conditions in 1997-98, suggesting that these anomalous surface conditions are not the direct result of the developing El Niño. Instead, it is more likely that conditions in Southern California are a result of the reduced upwelling and intrusion of the "blob" warm water into the area; although, due to the infrequency of CalCOFI sampling, it is not possible to directly infer the exact mechanism from these data alone. In spring 2015, concentrations of sardine, anchovy, and jack mackerel eggs were the lowest observed at any time during the past 15 years. These low abundances follow a trend that has been ongoing for the past 15 years, and does not necessarily reflect an impact of the developing El Niño, although El Niño conditions are known to typically result in lowered stocks of anchovy. The few sardine eggs encountered were found near the CA-OR border; sardine eggs are rarely found north of San Francisco during this survey, a condition that again can more likely be attributed to the anomalously warm waters rather than the developing El Niño.

El Niño's effect on marine ecosystems

Past El Niños have been characterized by:

- Warmer, more subtropical ocean conditions, with reduced primary and secondary production,
- Declines in anchovy stocks, market squid and high mortality of CA sea lion pups,
- Whiting and sardines migrate much farther north, into Canadian waters,
- Improved growth and recruitment for some species, such as sardines, but reduced recruitment for rockfish, squid, anchovies, etc.,
- Tropical fish like mahi-mahi, swordfish, and marlin, and subtropical fish like Albacore and Pacific bonito, move north/onshore.

Based on previous El Niños, the above scenarios suggest that in the fall of 2015 if the offshore warm waters shift onshore, we would likely see further dramatic changes in marine life including the presence of tropical and subtropical species. Warm-water species would continue to be favored: bluefin tuna, yellowtail, yellowfin tuna, mahi-mahi, and the occasional marlin, as would a northward shift of hake and sardine populations. At the same time, this type of warm ocean state is not ideal for recruitment of rockfish, or for juvenile or maturing salmon off the Pacific Northwest. These conditions may also exacerbate the recent negative conditions experienced by California Sea Lion populations. In Southern California, where the impacts of the warm water anomaly are likely manifested by the lowest observed primary productivity since 1984, El Niño can only serve to further decrease productivity, leading to increased restrictions to the spawning areas for, and thus decreased productivity of, small coastal pelagic species, with ramifications likely to be felt throughout the food web.

Recovery from El Niño conditions

Several past El Niño events have been followed by multi-year La Niña (cold) conditions[6] (including the 1982/83 and 1997/98 extreme El Niño events). Our last strong El Niño (in 1997/98) was followed by a dramatic recovery instigated by increased upwelling of nutrient-rich waters[7]. In fact, the 1997/98 El Niño event was followed by a regime shift to a cooler, high-productivity era in the northeast Pacific that characterized much of the period from 1998 to 2013. All this said, the demonstrated skill in predicting the future climate of the Pacific is limited to about one year into the future, and is highly dependent on our ability to accurately predict the evolution of ENSO. Confidence in the current ENSO forecast is about as high as it ever gets right now, similar to the situation that existed in the summer of 1997 when the tropical event and its teleconnections to the North Pacific and North America were predicted with remarkable skill

[6] Okumura, Y. M., and C. Deser (2010) Asymmetry in the duration of El Niño and La Niña. *J. Climate*, **23**, 5826-5843.

[7] Bograd S.J. and R.J. Lynn (2001) Physical-biological coupling in the California Current during the 1997–99 El Niño-La Niña Cycle. *Geophysical Research Letters*, **28** (2), 275-278