

Hold the Anchovies: Fisheries & the PDO

Lesson Time : 90 minutes

Grade Level : 9-12

Vocabulary: El Niño, Pacific decadal oscillation (PDO), Upwelling, Global-average Surface Air Temperature Anomalies (GSATA), Atmospheric Circulation Index (ACI), Mauna Loa CO2

Summary

Using Microsoft Excel, graph atmospheric and fisheries data from the Monterey Bay Aquarium Research Institute to look for evidence of the Pacific Decadal Oscillation (PDO) and its connection to fish abundance.

Objectives

- Explain the processes involved in the Pacific Decadal Oscillation (PDO).
- Graph and evaluate atmospheric and fisheries data over time to look for evidence of the PDO and its connection to fish abundance.
- Describe the relationship between warm and cold regimes of the PDO and the abundance of sardines and anchoveta.

Introduction

Most everyone has at least heard of the El Niño climate phenomenon that happens once every 3 to 7 years. In “regular,” non-El Niño years, warm seawater piles up in the western half of the Pacific Ocean. Scientists aren’t sure exactly what causes this, though one theory is that Tradewinds push the water toward the west. During El Niño years, the warm water piled up in the western Pacific flows toward the east bringing, heavy rains with it. But recent findings indicate that El Niño may be just the tip of the iceberg of a much larger climate pattern in the Pacific.

Scientists have begun examining historical climate and oceanography data back 100 years and are finding indications of a much larger climate swing in the Pacific. This large-scale cyclical climate change, called the Pacific decadal oscillation (PDO), is marked by warmer than average sea surface temperatures for 10-30 years, followed by colder than average sea surface temperatures for another 10-30 years. Because nutrient upwelling and atmospheric circulation are closely linked to sea surface temperature, the PDO also causes changes in the Pacific’s food web and affects the climate of North America.

Dr. Francisco Chavez at the Monterey Bay Aquarium Research Institute studied historic fisheries landings data and found that two fish species seem to be greatly influenced by the PDO. The South

American sardine (*Sardinops sagax*) and the Peruvian anchoveta (*Engraulis ringens*) are both pelagic, plankton-feeding fish found in large schools off the coast of South America. Both have high commercial value, sardines for fish meal, bait, and human consumption, and anchoveta for fish meal and oil. The sardine, which can also be found along the coast of southern Africa, feeds on copepods and phytoplankton and lives an average of 15 years. The anchoveta, which is dependent on the Peruvian Current for its food, feeds mainly on diatoms and lives to be only 3 years old. It appears that depending on the current PDO temperature regime, anchoveta stocks are high when sardine stocks are low, and vice versa. In fact, the notorious collapse of anchoveta stocks in the 1950s that has been blamed on overfishing could very well be due in part to a natural 50-year cycle in stock abundance.

In the following data exercise, we will use Microsoft Excel to graph Pacific atmospheric and fisheries data over time and look for evidence of the PDO and its connection to fish abundance.

Data Activity

Open the [MBARI Anchovy Data](#) using Excel. The data include:

1. **Year** – from 1900 to 2002
2. **Global-average Surface Air Temperature Anomalies (GSATA)** – difference between the annual air temperature and the mean air temperature over the past century (° celsius)
3. **Atmospheric Circulation Index (ACI)** – relative amount of wind blowing east-west versus north-south
4. **Mauna Loa CO₂** – atmospheric CO₂ measured at Mauna Loa, Hawaii (parts per million)
5. **Sardines** – annual landings from Peru (metric tons)
6. **Anchovy** – annual landings from Peru (metric tons)

In the first graph, we will plot the deviation from the mean for GSATA, ACI and CO₂ over time using the following step-by-step instructions:

1. Highlight cells B13 through D116. Open the Chart Wizard by going to **Insert** then **Chart**. Under the *Standard Types* tab, select **Area**. Choose the first **Chart sub-type** option. Click *Next*.
2. In Step 2 of the Chart Wizard, click on the *Series* tab. In the *Category (X) axis labels box*, click on the icon at the right end of the box and then highlight cells A14 through A116. Click on the icon at the right end of the box to get back to the Chart Wizard. Click *Next*.
3. In Step 3 of the Chart Wizard, enter titles for the chart (example: “Pacific Air Temperature, Atmospheric Circulation and CO₂ Levels”), X axis (example: “Year”) and Y axis (example: “Deviation from Mean”). Under the *Legend* tab, select **Bottom** placement. Click *Next*.

4. In Step 4 of the Chart Wizard, select *as new sheet* and give it a name such as PDO graph. Click *Finish*.

Return to Sheet 1 in the spreadsheet and graph the sardine and anchovy landings.

1. Highlight cells E13 through F116. Click on the Chart Wizard icon. Under the *Standard Types* tab, select **Line** and choose the first chart sub-type. Click *Next*.
2. In Step 2 of the Chart Wizard, click on the *Series* tab. In the *Category (X) axis labels* box, click on the icon at the right end of the box and then highlight cells A14 through A116. Click on the icon at the right end of the box to get back to the Chart Wizard. Click *Next*.
3. In Step 3 of the Chart Wizard, enter titles for the chart (example: “Peruvian Sardine and Anchovy Landings”), X axis (example: “Year”) and Y axis (example: “Sardine Landings (metric tons)”). Under the *Legend* tab, select **Bottom** placement. Click *Next*.
4. In Step 4 of the Chart Wizard, select *As new sheet* and give it a name such as Fisheries graph. Click *Finish*.
5. On the graph, right click on the Anchovy line and select **Format Data Series**. Under the *Axis* tab, select **Secondary** axis. Click *OK*.
6. Right click in the white background area of the page and select **Chart Options**. Under the *Titles* tab in the **Second value (Y) axis box** enter “Anchovy Landings (metric tons)”. Click *OK*.

Print the graphs and compare them to the [Bridge MBARI Anchovy Graphs](#). Use your graphs to answer the following discussion questions.

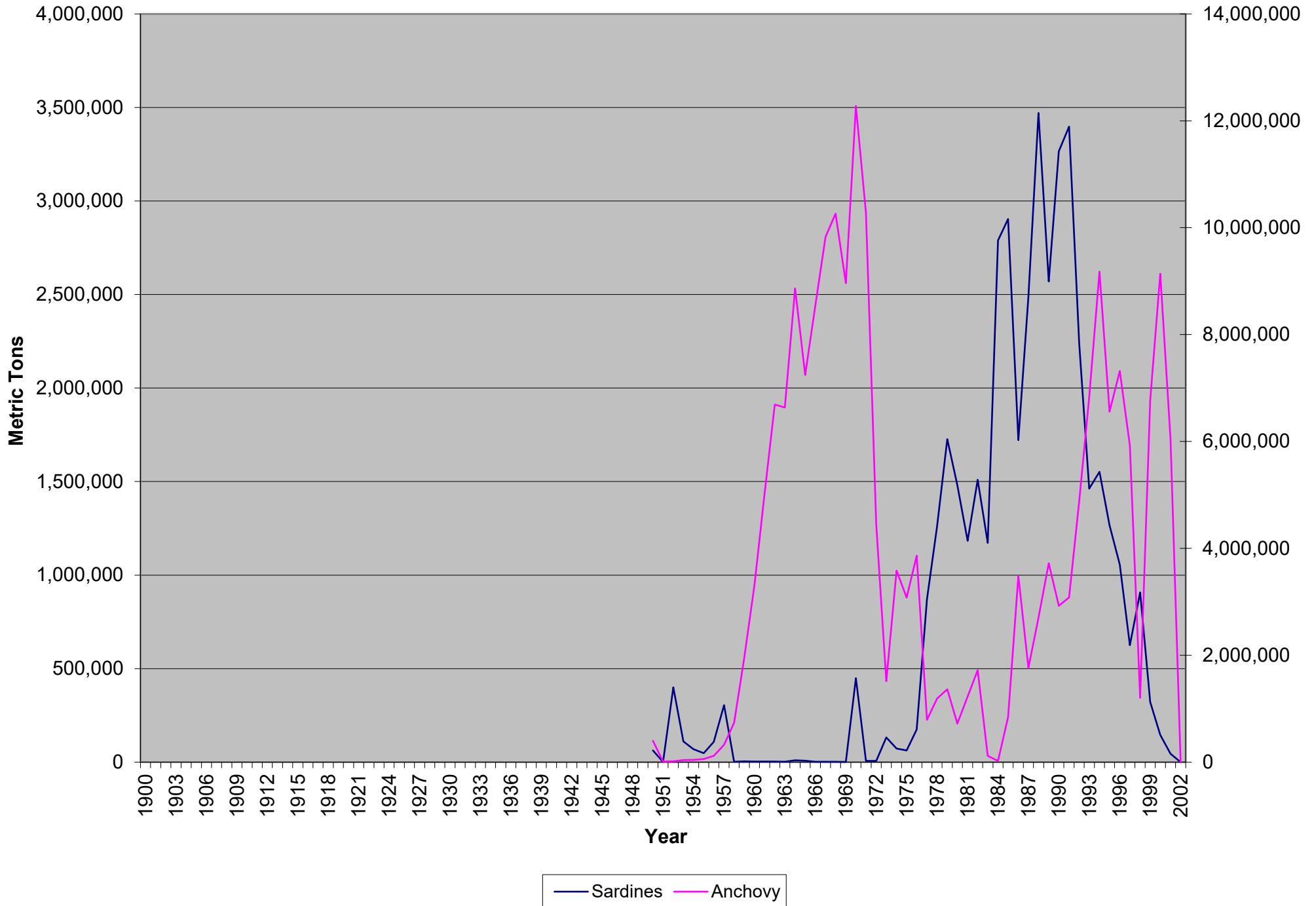
Discussion

1. From Table 1 and either the graph students created (Figure 2) or the completed graph (Figure 2a), what is the trend in air temperatures moving from west to east?
2. From Table 1, Figure 2/Figure 2a and Figure 3, what is the trend in air temperature range versus water temperature range?
3. In addition to the applications discussed in the introduction, how else can water’s high heat capacity be used?
4. Discuss the implications of global climate change as it affects ocean water temperatures. How will ocean warming affect land?
5. Describe advantages and disadvantages of using buoys to record data.

This lesson was written by staff educators at the Bridge Ocean Education Resource Center in collaboration with Virginia Sea Grant. If reusing, presenting, or adapting this lesson please credit the Bridge Ocean Education Resource Center and include the URL below.

For more data-based lessons, visit: bridgeoceaneducation.org/data-series.

Peruvian Sardine and Anchovy Landings



Pacific Decadal Oscillation & Fisheries Data Tip

A Bridge collaboration with Monterey Bay Aquarium Research Institute

Data published in:

Chavez, F.P., J.Ryan, S.E. Lluch-Cota, and M. Niquen C. 2003. From Anchovies to Sardines and Back: Multidecadal Change in the Pacific Ocean. *Science* 299, p 217-221.

GSATA = Global-average Surface Air Temperature Anomalies (degrees Celsius)

ACI = Atmospheric Circulation Index (no units)

Mauna Loa CO₂ - atmospheric carbon dioxide measured at Mauna Loa, Hawaii (parts per million)

Sardines - Yearly landings from Peru (metric tons)

Anchovy - Yearly landings from Peru (metric tons)

Year	GSATA	ACI	Mauna Loa CO ₂	Sardines	Anchovy
1900					
1901					
1902					
1903	0.153644405	-1.718538542			
1904	-0.094614064	-1.718538542			
1905	-0.452777603	-1.554449548			
1906	-0.701036072	-1.390360555			
1907	-0.773446429	-1.062182567			
1908	-1.043685912	-1.25908936			
1909	-1.511754521	-1.062182567			
1910	-1.386335751	-0.865275775			
1911	-1.238935968	-1.062182567			
1912	-0.761820973	-1.127818165			
1913	-0.108857867	-1.095000366			
1914	0.082503945	-1.062182567			
1915	-0.209716552	-1.062182567			
1916	-0.216183867	-0.865275775			
1917	-0.420480308	-0.930911372			
1918	-0.712700805	-0.799640177			
1919	-0.411433923	-0.602733385			
1920	-0.022242985	-0.340190995			
1921	0.169118827	-0.2089198			
1922	0.030765428	-0.2089198			
1923	-0.019663914	0.053609265			

1924	0.149716884	0.316138331		
1925	0.319097681	0.283320532		
1926	0.356592395	0.250502733		
1927	0.196257982	0.480227324		
1928	0.321676752	0.709951915		
1929	0.315209437	0.775587513		
1930	0.440628207	0.972494305		
1931	0.346236836	0.972494305		
1932	0.845332844	0.972494305		
1933	0.72896046	1.038129903		
1934	0.546645033	1.235036695		
1935	0.694044817	1.300672293		
1936	1.347007923	1.431943488		
1937	1.560350749	1.694472553		
1938	1.729731547	1.957001619		
1939	2.009017415	1.957001619		
1940	2.068493142	1.628836956		
1941	1.908158729	1.300672293		
1942	2.275368653	1.165577018		
1943	2.422768437	1.030481743		
1944	2.042623884	0.895386469		
1945	1.662479331	0.760291194		
1946	1.282334778	0.413858889		
1947	0.528512986	0.027453626		
1948	-0.093422722	-0.358951637		
1949	-0.099890036	-0.405826593		
1950	0.047509747	-0.373008794	63000	400000
1951	0.370757643	-0.340190995	1000	12000
1952	0.166461203	-0.274555398	400000	15950
1953	0.159993888	-0.2089198	111000	37113
1954	-0.374017763	-0.176102002	69000	43028
1955	-0.380485078	-0.143284203	48000	58707
1956	-0.408933407	-0.405826593	108000	118726
1957	-0.063704496	-0.422235492	305000	325624
1958	0.215581371	-0.438644391	0.74338701	2107 737019
1959	0.780620422	-0.537097788	0.70540725	4414 1942386
1960	0.686229051	-0.504279989	0.61276177	2980 3310157

1961	0.503913624	-0.47146219	0.40176011	2710	5010930
1962	-0.140003097	-0.651960083	0.18514701	3030	6691521
1963	-0.564109679	-0.832457976	0.034359048	2201	6634836
1964	-0.834349161	-1.012955869	-0.15562667	10097	8863367
1965	-1.126569659	-1.193453762	-0.34936667	7419	7242394
1966	-1.55067624	-1.127818165	-0.45733714	1874	8529821
1967	-1.073561246	-1.062182567	-0.51394286	2138	9824627
1968	-0.86021842	-1.25908936	-0.51890381	1847	10262661
1969	-1.218381959	-1.226271561	-0.51682762	1121	8960640
1970	-1.290792315	-1.193453762	-0.41183905	449000	12277022
1971	-0.989525434	-1.193453762	-0.36429524	6051	10276833
1972	-1.523537085	-1.062182567	-0.33467238	6338	4447365
1973	-1.793776568	-1.062182567	-0.40999429	132252	1512976
1974	-1.932129967	-0.865275775	-0.40990381	72605	3583476
1975	-1.740768155	-0.73400458	-0.29452	62851	3078810
1976	-2.054969666	-0.602733385	-0.17229524	174701	3863050
1977	-1.599835686	-0.537097788	-0.12811048	870903	792106
1978	-1.188663734	-0.47146219	-0.01018	1257948	1187041
1979	-0.469757585	-0.143284203	0.12649619	1727031	1362763
1980	-0.564148956	-0.077648605	0.33334667	1480396	720124
1981	-0.043071933	0.316138331	0.50215714	1182947	1225168
1982	-0.203406346	0.348956129	0.63018952	1509675	1720437
1983	-0.495626843	0.381773928	0.72113429	1172191	118160
1984	-0.67794227	0.742769714	0.78106286	2788744	22988
1985	-0.354694374	0.923267607	1.00438	2903728	844255
1986	-0.405123717	1.1037655	1.2370381	1720905	3481869
1987	-0.125837849	1.169401098	1.3932038	2489000	1764635
1988	0.571087286	1.431943488	1.492639	3470422	2701369
1989	0.93829721	1.431943488	1.4687962	2569910	3720173
1990	0.690038741	1.563214682	1.3388181	3265297	2926408
1991	0.4857423	1.431943488	1.1953238	3398000	3081000
1992	0.589180056	1.300672293	0.94890857	2243000	4870000
1993	0.604693755	1.399125689	0.72790571	1462000	6827000
1994	0.3784163	1.497579085	0.46172	1552000	9176000
1995	0.921474337	1.399125689	0.38058952	1266000	6558108
1996	1.684342514	1.300672293	0.40201429	1056000	7319782
1997			0.46373238	625000	5923000

1998	0.49536476	908000	1205000
1999	0.47913143	321000	6770000
2000	0.45082381	145000	9137000
2001		45000	6045000
2002		0	0