Upwellings Impacting the Orca Population?

Taking a Look at Upwellings Effect on the Southern Resident Orca Whale Population

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Introduction

At the start of this semester, coastal upwellings was introduced. Many have never heard about the phenomenon of coastal upwellings. Upwelling is the process caused by "winds blowing across the ocean surface push[ing] water away. Water then rises up from beneath the surface to replace the water that was pushed away" (National Oceanic Atmospheric Administration [NOAA], 2018). When upwelling occurs, this results in water that is rich in nutrients typically causing good fishing grounds (NOAA, 2018). While it is clear that upwellings positively impact species lower on the food chain, the question that came out of this new information was: do upwellings impact animals higher up in the food chain such as orca whales?

"The nearshore waters off the Pacific Northwest coast are known internationally as one of the best places- if not THE best place-to view killer whales in the wild" (Ford, 2011, p.15). From spring through fall, the Southern Resident Killer Whales are seen off the coast of Washington State to British Columbia (Center for Whale Research [CWR], 2018). The Northwest Fisheries Science Center, a part of the NOAA Fisheries, states "an important process affecting primary productivity [fishing] during the spring and summer off the Pacific Northwest is coastal upwelling" (n.d.). The phenomenon of orca whales present at the same time as frequent coastal upwellings leaves one to hypothesize that the coastal upwellings has an impact on the population of the Southern Resident orca whales.

Methods

The population numbers for the orca whale population for the Southern Resident Orca Whales can be found by year on the Center for Whale Research [CWR] website. The CWR has collected data on orcas since 1976 (CWR, 2017). "Every year for over four decades we have

collected detailed demographic data on the Southern Resident killer whale population, recording all observed births and deaths" (CWR, 2017). The CWR identifies and tracks the Southern Resident orca population "using photographic ID techniques that were pioneered by Dr. Michael Bigg" (2017). The technology of digital cameras has allowed a catalog for photo-identification to be established (Durban & Deecke, 2011, p. 7). Durban and Deecke state "Photo-identification has become the stick tool for research on killer whales" and that "using long-term photographic records of the same individuals has proven this to be a robust method for individual-based monitoring over the long time periods required to study killer whales with life spans similar to humans" (2011, p. 7). Many scientists have used photo-identification and have shared their results with the other scientist and "thanks to this collaborative effort, field studies continued without interruption and complete annual censuses of the resident population were possible" (Ford, 2011, p.21). Ford states using "the photo-identification technique… have facilitated highly accurate annual censuses of both norther and southern resident populations since the early 1970s" (Ford, 2011, p. 22).

To gather the upwelling data, research was gathered from the Pacific Fisheries Environmental Laboratory [PFEL], a branch of NOAA. PFEL states "On a monthly basis, the Pacific Fisheries Environmental Laboratory generates indices of the intensity of large-scale, wind-induced coast upwelling at 15 standard locations along the west coast of North America" (PFEL, n.d. c). "The indices are based on estimates of offshore Ekman transport driven by geostrophic wind stress…The pressure fields are provided by the U.S. Navy Fleet Numerical Meteorological and Oceanographic Center" (PFEL, n.d. c). The upwelling indices was created to give a time series to "represent variations in coast upwelling. Daily and monthly index time series are provided regularly" (PFEL, n.d. c).

The PFEL have 15 locations where they monitor the upwelling index data. PFEL give the longitude and latitude of those locations (n.d. a). In order to analyze the upwelling data, one location needed to be chosen. The location chosen needed to be closest to where the orca whales spend spring and summer. According to the CWR, "The Southern Resident Killer Whales are frequently seen, from spring through fall, in the protected inshore waters of the Salish sea. The Salish Sea includes the Strait of Juan de Fuca, Strait of Georgia, and Puget Sound, and all their connecting channels and adjoining waters, and the waters around and between the San Juan Islands in Washington State and the Gulf Islands in British Columbia" (2018). Analyzing the data map from PFEL, the data set for 48N and 125W is the best data set to use for approximation to the orca whales (PFEL, n.d. b). PFEL, provides the upwelling index, by month, from January 1946 until May of 2018 (n.d. a). Since, according to the CWR, the orca population census is done by July of each year since 1976 (2018), the monthly index data analyzed was collected from the month of July from 1976 to 2017.

The upwelling index did not have a range for a typical upwelling. In order to identify a high upwelling index year vs. a low index year, the average of all the upwelling index numbers for the month of July from 1976 to 2017 was found to receive an upwelling index average of 41.4 for the month of July at 48N 125W over the 42 years of data used in this study.

Since orca whales are at the top of the food chain, have long gestation periods and long gaps between pregnancies (NOAA Fisheries, 2017), the upwelling index is compared to the orca whale population of the following year to allow time to see the result of the impact of the coastal upwelling on the orca whale population.

Observations

Upwelling index and orca whale populations were put in Table 1. In the upwelling side of the table, the color pink was assigned to years in which the upwelling index for that July was below the average of 41.4 cubic meters per second per 100 meters of coastline. Years in which the upwelling index was greater than the average was assigned the color blue. In the orca population side of the table, the color pink was assigned in the population was lower than the previous year, the color blue was assigned if the population was the same or greater than the previous year. When the orca population stayed the same as the previous year it was left blue since the population did not decrease.

Table 1.
Upwelling Index Compared to the Orca Population the Following Year 1976-2017

Year for Upwelling Index	**Upwelling Index**- July (cubic meters/sec/100 meters of coastline)	**Orca Population**- July	Year for Orca Population
1976	5	80	1977
1977	42	80	1978
1978	58	82	1979
1979	25	84	1980
1980	63	82	1981
1981	80	79	1982
1982	36	76	1983
1983	18	74	1984
1984	72	77	1985
1985	79	81	1986
1986	57	84	1987
1987	39	85	1988
1988	54	85	1989
1989	31	88	1990
1990	61	92	1991
1991	27	91	1992
1992	52	97	1993
1993	38	96	1994

1994	58	98	1995
1995	37	97	1996
1996	63	92	1997
1997	25	89	1998
1998	24	85	1999
1999	44	82	2000
2000	25	78	2001
2001	68	79	2002
2002	48	82	2003
2003	30	83	2004
2004	30	88	2005
2005	30	89	2006
2006	54	86	2007
2007	12	85	2008
2008	29	85	2009
2009	32	86	2010
2010	59	87	2011
2011	16	84	2012
2012	39	82	2013
2013	84	78	2014
2014	34	81	2015
2015	35	83	2016
2016	26	76	2017

Note. Upwelling Index Data collected from NOAA's Pacific Fisheries Environmental Lab Retrieved June 11, 2018 from https://www.pfeg.noaa.gov/products/PFELData/upwell/monthly/upindex.mon and Data for Orca Population from Center for Whale Research (2018).

Key:

	Upwelling Index	**Orca Population**- when compared to the previous year
	Upwelling Index is below the average for July	Decrease in population
	Upwelling index is above the average for July	Increase in population

Twelve times the orca whale population increased the year after the upwelling index was above its average. Twelve times the orca whale population decreased the year after the upwell index was below its average. This indicates that neither the upwelling being above or below average had a greater impact than the other. The increases and decreases matched between the

upwelling index and the orca population 24 out of 41. Therefore, 58.5% of the time the upwelling index fluctuations matches the fluctuation in the orca whale population.

Conclusion and Discussion

Based on the data provided in Table 1, at least 58.5% of the time the upwelling index and the orca population appear to have a direct correlation. Proving the hypothesis that coastal upwellings has an impact on the population of the Southern Resident orca whales may have a basis of truth. While the data resulting in a correlation greater than half of the time over the last 41 years might indicate a direct relationship between the upwell index and the orca population, it is also clear that there are other factors that influence the orca whale population off the coast of Washington. The question that came up was do high upwellings or low upwellings affected the orca population more than the other? Since high upwellings and low upwellings each matched the orca population twelve times, based on this data set, both seem to have an equal impact on the orca population.

However, further research is required to truly understand a full picture of the impact of coastal upwellings on the Southern Resident orca population. For example, the upwelling data looked at was only for the month of July and not the entire length of time the orca whale population spends in the area. In addition, orca whales, while they "are intelligent, long-lived, cooperatively-hunting, intensely social animals-they are enough like humans that we are fascinated by them…[they]are also exemplars of how little we know about the ocean" (Pitman, 2011, p. 4) and how the ocean's ecosystem interacts with all species, including those higher up on the food chain. Also,

> "the oceanic ecosystems in which killer whales live today have changed dramatically in the last few hundred years. Populations of many species of whales and dolphins were

> greatly reduced …and numerous fish populations have been harvested to the point where the populations have collapsed, and few have recovered. Such changes in prey populations not only have influenced what killer whales feed on today, but also what role killer whales have played in food web dynamics" (Baird, 2011, p. 56-57).

Due to the drastic changes to the orca's ecosystem and the struggles the orcas now face, it is important to understand what influences the orca whale population, such as the coastal upwellings, in order to promote a better chance at survival for the orca whales.

However, with a correlation of only 58.5%, it is obvious that other factors play a significant role in the orca whale populations such as birth rate, pollution, and other human impact. According to Baird, "as top predators, killer whales accumulate persistent organic pollutants such as PCBs and flame retardants more so than predators further down the food web" (2011, p.57). So, while a higher coastal upwellings might promote a positive change in the orca population, if the pollutants are high in that location, the upwelling will not have a positive impact, but could instead be detrimental. If the pollutants tend to settle at the bottom of the ocean, then a high upwelling might stir up all the pollutants and endanger the orcas more than the possible benefits from the nutrients also stirred up by the upwelling.

A problem with this study is the lack of information about the increases and decreases in the orca whale population. A decrease might be due to an orca passing away from natural causes. Barrett-Lennard and Heise states "killer whales are long-lived, perhaps 60 and 80 years for males and females, respectively" (2011, p. 58). For example, if three older orcas pass away at the end of their life cycle, then the decrease in the orca population that year would have nothing to do with the upwelling index. The data available limits the ability to determine accurate conclusions of the influence of the coastal upwelling on the orca population. Additionally, according to

Barrett-Lennard and Heise, orcas “have a very low reproductive rate; female killer whales don’t reach sexual maturity until their teens and then produce only one calf at a time. Surviving siblings are usually separated by four years or more… [and] the premature death of an adult female killer whale can lead to the death of other members of her “matriline” (her siblings and offspring)” (2011, p. 58). Therefore, the premature death of a single female orca whale, can have devastating consequences on the orca population due to the dependency of the younger generation on the older generation that cannot be projected or observed in the data provided. Without knowing the causes of death of the individual members of the orca population represented in the chart, it is difficult to say exactly if the upwelling index has much effect on the orca population, especially when taking into account the life cycle span, the low birth rates and pollution.

References

Baird, R. (2011). Predators, Prey, and Play: Killer Whales and Other Marine Mammals. *Journal of the American Cetacean Society*, 40, 54-57. Retrieved from https://www.orcanetwork.org/Main/PDF/WhalewatcheVol40No12011.pdf

Barrett-Lennard, L., Heise, K. (2011). Killer Whale Conservation: The Perils of Life at the Top of the Food Chain. *Journal of the American Cetacean Society*, 40, 58-62. Retrieved from https://www.orcanetwork.org/Main/PDF/WhalewatcheVol40No12011.pdf

Center for Whale Research. (2017). *Southern Resident Killer Whales: Orca Survey* Retrieved on June 29, 2018 from: https://www.whaleresearch.com/orcasurvey

Center for Whale Research. (2018). *Southern Resident Killer Whale Population* Retrieved on June 5, 2018 from https://www.whaleresearch.com/orca-population

Durban, J. & Deecke, V. (2011). How Do We Study Killer Whales? *Journal of the American Cetacean Society*, 40, 6-14. Retrieved from https://www.orcanetwork.org/Main/PDF/WhalewatcheVol40No12011.pdf

Ford, J. (2011). Killer Whales of the Pacific Northwest Coast: From Pest to Paragon. *Journal of the American Cetacean Society*, 40, 15-23. Retrieved from https://www.orcanetwork.org/Main/PDF/WhalewatcheVol40No12011.pdf

NOAA . (2018, June 25). *What is Upwelling?* In Ocean Facts. Retrieved from https://oceanservice.noaa.gov/facts/upwelling.html

NOAA Fisheries (2017, January) *Killer Whale (Orcinus Orca).* Retrieved from http://www.nmfs.noaa.gov/pr/species/mammals/whales/killer-whale.html

NOAA Fisheries-Northwest Fisheries Science Center. (n.d.) *Coastal Upwelling*. In Northwest Fisheries Science Center. Retrieved on June 8, 2018 from https://www.nwfsc.noaa.gov/research/divisions/fe/estuarine/oeip/db-coastal-upwelling-index.cfm

Pacific Fisheries Environmental Laboratory. (n.d. a). *Monthly Upwelling Indices*. Retrieved June 11, 2018 from https://www.pfeg.noaa.gov/products/PFELData/upwell/monthly/upindex.mon

Pacific Fisheries Environmental Laboratory. (n.d. b). *North Pacific Upwelling Index Products-Map*. Retrieved June 10, 2018 from https://www.pfeg.noaa.gov/products/PFEL/modeled/indices/upwelling/NA/click_map.html

Pacific Fisheries Environmental Laboratory (n.d. c). *PFEL Coastal Upwelling Indices: How PFEL Determines the Upwelling Indices.* Retrieved June 19, 2018 from https://www.pfeg.noaa.gov/products/PFEL/modeled/indices/upwelling/NA/how_computed.html

Pitman, R. (2011). An Introduction to the World's Premier Predator. *Journal of the American Cetacean Society*, 40, 2-5. Retrieved from https://www.orcanetwork.org/Main/PDF/WhalewatcheVol40No12011.pdf