Temperatures rise in the ocean

AUTHOR

Karin Bodtker, MRM, Manager, Coastal Ocean Health Initiative, Coastal Ocean Research Institute

REVIEWER

Peter Chandler, Fisheries & Oceans Canada, Institute of Ocean Sciences, Sidney, B.C.

What is happening?

Lately, we are setting new global temperature records each year. 2015 was the hottest year on record based on land and ocean temperatures (Figure 1), and 2014 had the same notoriety until records were compiled for 2015. Judging by land and ocean temperature or by ocean temperature alone, 2016 is shaping up to set another record.[1] Looking back 135 years, the 16 warmest years have all occurred since 1998, and that's only 18 years ago.[2]

In the region closer to home (i.e., a 5 degree latitude by 5 degree longitude area that includes Howe Sound, Vancouver, Victoria, and Seattle), a study of recent temperatures compared to a 30-year average for 1981 to 2010 still highlights 2014 as well above average and 2015 as extreme, more than 1.4 degrees Celsius above the 30-year average (Figure 2).[3]

In coastal B.C., sea surface conditions measured at 12 shore stations (mostly at light stations, part of the Fisheries and Oceans Canada Shore Station Oceanographic program) and 12 Environment Canada weather buoys show that average daily sea surface temperature (SST) at all locations was warmer by about 0.8 degrees Celsius in 2015 compared to 2014.[4] In particular, SST at shore stations was warmer by 1.1 degrees Celsius in 2015 than the 30-year average (1980-2010) and buoy locations were warmer by 1.2 degrees Celsius in 2015 than a 22-year average for 1989-2010.[5] None of these stations is in Howe Sound; the closest being a buoy at Halibut Bank in the Strait of Georgia.

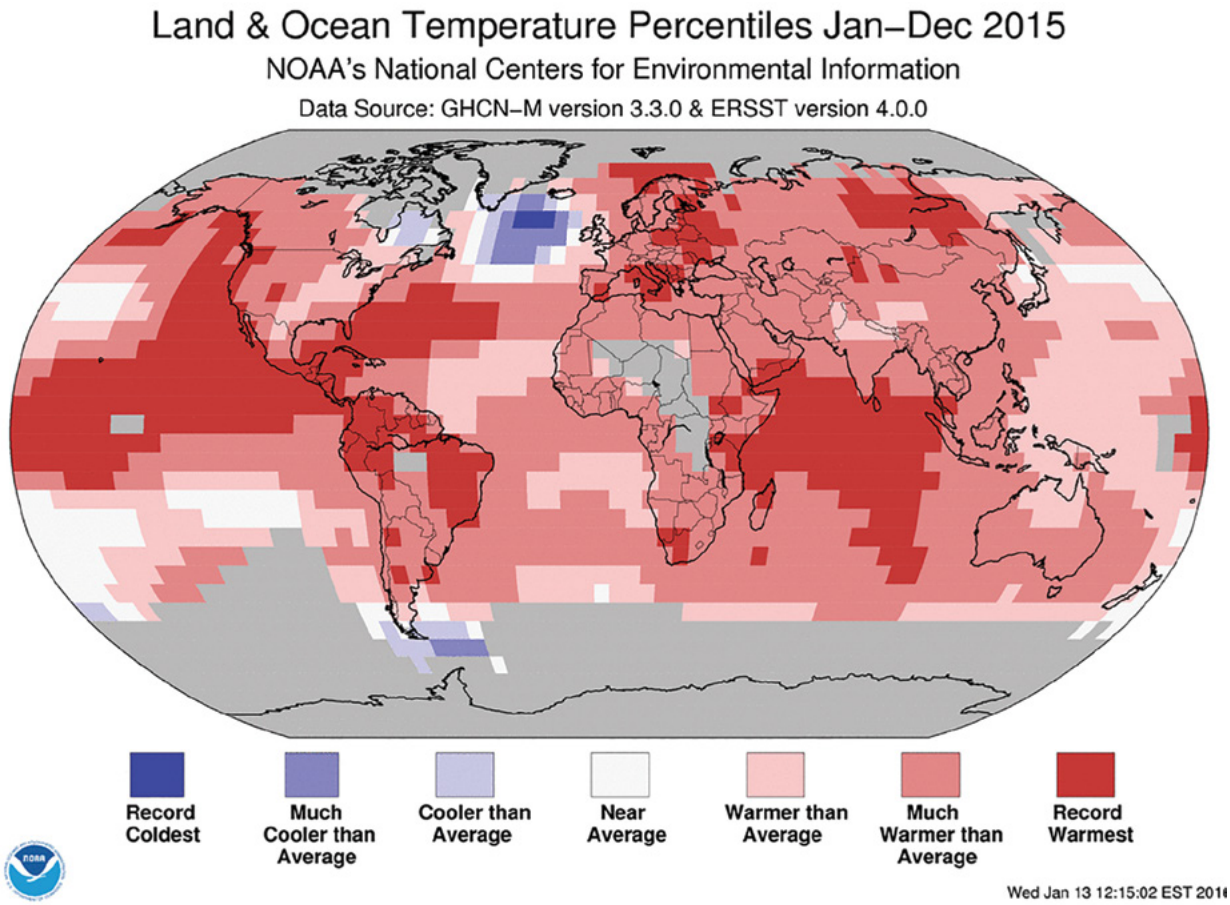

Figure 1. Land and ocean temperature percentiles for January to December 2015, compared to averages for the 20th century. Source: NOAA National Centers for Environmental Information.

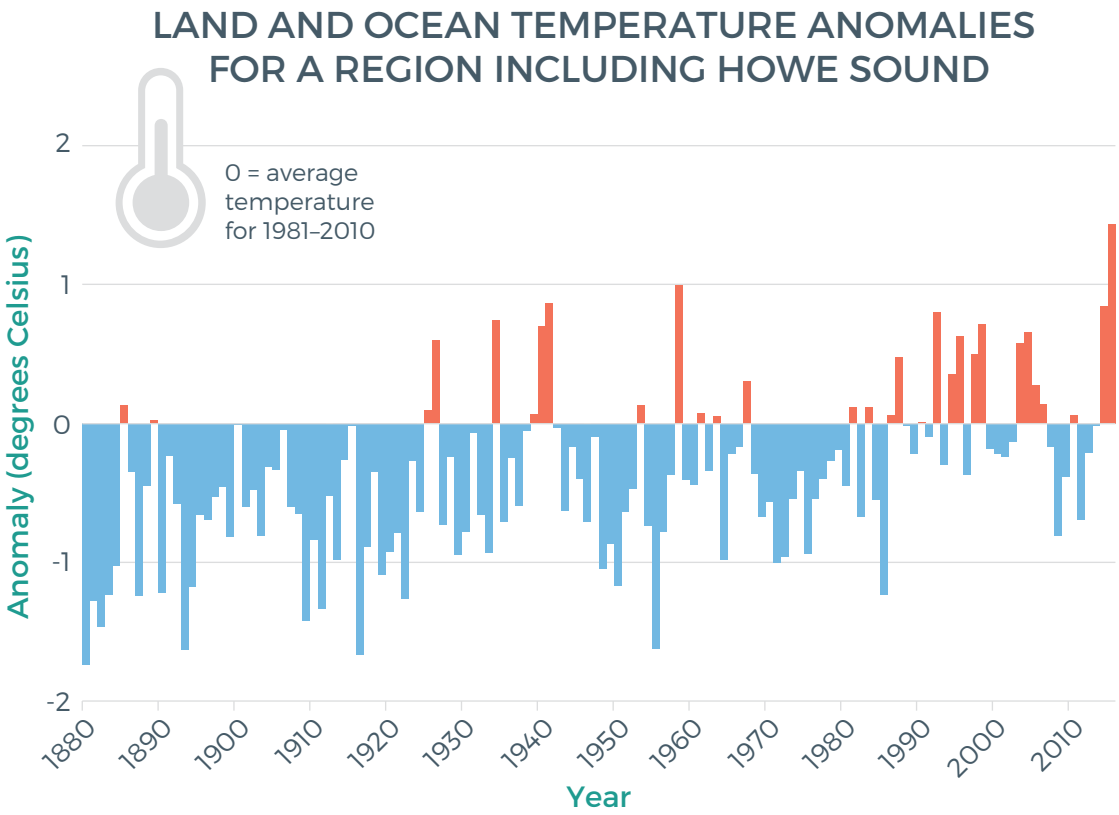

Figure 2. Annual land and ocean temperature anomalies (deviation of average annual temperature compared to the 1981–2010 average) for a 5 degree by 5 degree area that includes Howe Sound, Vancouver, Victoria, and Seattle. Source: NOAA National Centers for Environmental Information.

Why is it important?

Ocean temperature, salinity, and chemical properties like pH, a measure of acidity, tell us about the climate of the ocean. Species have long adapted to ocean climates that are typical for the region where they live. Changes to ocean climate that are outside of the historical range of variability can affect species and predator-prey relationships in various ways. Species ranges may migrate with temperature changes, generally moving north to stay within a preferred thermal zone, or species may suffer or adapt to warmer temperatures. Range shifts and adaptation will vary among species and other factors such as coastal development, management patterns, or even population specific adaptation may play a role. Salmon, for example, in fresh water temperatures above 18 degrees Celsius show signs of decreased swimming performance while temperatures above 20 degrees Celsius can result in disease, poor egg quality, and even mortality, but different populations may be able to adapt to changing conditions better than others.[6] Predator-prey relationships are vulnerable to changes in ocean climate from both a timing and abundance perspective. Preferred prey species may be less abundant due to warming conditions or may become un-

available at the time they are sought. For example, as a consequence of shifts in timing of the spring bloom and the cascade of productivity that results, plankton and zooplankton may not be present when salmon fry emerge and migrate to nearshore habitats.

Warmer ocean temperatures have a direct effect on sea level because as water warms the volume increases. This means sea level is rising in relation to temperature, no matter how much sea ice is melting and adding volume. Increases in sea level[7] will amplify the risk of coastal flooding (see flood hazard management article).

The timing of biological events can be altered by warming and other effects of climate change like changing freshwater flow patterns and the risk is that critical biological interactions become out of synch. A prime example here is the timing of salmon spawning runs.[8] If, for example, juvenile salmon migrated to saltwater at a time when the plankton they feed on was unavailable, they would need to adapt to another food source or suffer. At the same time, changes in temperature and salinity patterns will affect ocean currents and, in turn, upwelling processes and cycles of productivity may be altered. Although some study is occurring, projections of changes to circulation patterns and upwelling are not conclusive.[9]

What is the current state?

Sea surface temperature in 2015 was the warmest on record globally and in the Strait of Georgia, but we have no direct observations for Howe Sound. Some of the projected effects of a warmer ocean are being witnessed locally, regionally, and in the Northeast Pacific. The context of Howe Sound's location is important to consider. The oceanography of the Strait of Georgia, the hydrodynamic connections to the Pacific, and the

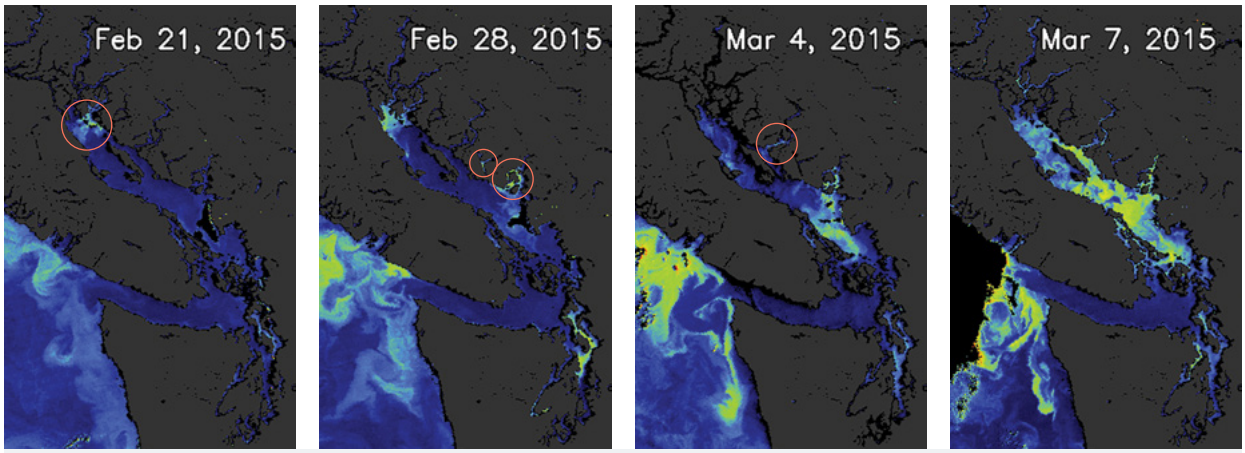

Figure 3. NASA MODIS Aqua fluorescence images for three days leading up to the main spring bloom in the Strait of Georgia (left three panels). Red circles indicate areas where blooms in inlets occur before high chlorophyll values are observed in adjacent areas of the Strait of Georgia. The MODIS image on March 7 (right panel) shows the bloom covering almost the entire Strait. (Figure provided by S. King, Sea This Consulting)

proximity of the Fraser River and the city of Vancouver, will all play a role in local changes observed in Howe Sound.

In Howe Sound, for example, northern anchovy, a species known to be highly responsive to shifts in ocean condition,[10] were observed in Howe Sound in both 2015 and 2016.[11] While anchovies have been fished on the West Coast of Vancouver Island and infrequently in the Strait of Georgia,[12] they are much more commonly found along the coast of California in warmer waters.

The timing of a spring phytoplankton bloom is not directly related to sea surface temperature, but the spring bloom in 2015 was earlier than usual off the west coast of Vancouver Island (February 23, as seen in satellite images) and in the Strait of Georgia, where it started in late February in Desolation Sound and Howe Sound (Figure 3).[13,14] This was the earliest spring bloom in the Strait of Georgia since 2005.[15]

Warmer water temperatures and increased stratification (i.e., when water masses with different properties form layers creating a barrier to mixing), both in the North Pacific Ocean and closer to home, have been projected to result in more frequent phytoplankton blooms, including more frequent and severe harmful algae blooms, and a longer season of blooms.[16] In mid November 2016, large schools of juvenile anchovy were observed again in Horseshoe Bay, suggesting that a late fall bloom supported another successful spawn event.[17]

In addition, ocean acidification, another effect of climate change, may increase the toxicity of some harmful algal blooms.[18] Exact cause and effect is hard to determine, but 2015 saw an unusually large bloom along the North American Coast, from California to Alaska, which was prolonged (May to August), and with a toxic (domoic acid) component, a type of harmful algal bloom (HAB).[19] Concentrations of domoic acid in seawater, some forage fish, and crab samples were among the highest ever reported for the region, including levels 10 to 30 times greater than normal in Monterey Bay California.[20] NOAA announced an Unusual Mortality Event for large whales in the western Gulf of Alaska, following the death of nearly 30 large whales since May 2015, and numerous fisheries were closed along the U.S. West Coast.[21] In early July 2015, the Canadian Food Inspection Agency (CFIA) detected toxin levels in shellfish above the Canadian safe allowable standards in three areas along northwest Vancouver Island during routine monitoring and these areas were closed to shellfish harvest as a result.[22] Canada does not have a HAB monitoring program in the Pacific region.

Finally, changes in productivity patterns due to reduced upwelling with warming waters are expected. Evidence of this was seen well offshore in 2015 in the northeast Pacific in the form of nutrient (nitrate) depletion and lower than usual chlorophyll concentrations.[23] (I.e., Nitrate is normally upwelled from deeper waters to feed chlorophyll, but a warmer surface layer prevented this from occurring in summer 2015.) Nutrient levels are also monitored in the Salish Sea by Fisheries and Oceans to continue to develop an understanding about nutrient supply conditions, changes in the Salish Sea and possible impacts on Howe Sound.

These reported unusual events and conditions in the region and beyond are linked to a warming ocean. We cannot report local events and conditions due to lack of data locally in Howe Sound.

What is being done?

Fisheries and Oceans Canada (DFO) has numerous scientists monitoring and reporting on ocean conditions, including physical and biological, and select fishery resources for the Canadian Pacific, with some focus on the Strait of Georgia or the Northern Shelf Bioregion, through the "State of the Pacific Ocean" workshop and report series.[24] DFO has carried out a Salish Sea monitoring survey over the past 15 years. A science research vessel is used to collect physical, chemical and biological data at about 80 stations over a one week period three to four times per year. Howe Sound and other unique inlets and fjords do not receive individual attention or regular monitoring and reporting with respect to sea surface temperature, chemical properties or plankton surveys.

The Pacific Salmon Foundation is involved in at least two citizen science supported projects in the Strait of Georgia. One uses a "mosquito fleet" of fishing vessels to do oceanographic surveys in nine overlapping areas to collect oceanographic data[25] and the other, in collaboration with University of Victoria, involves passengers on BC Ferries in the testing of a HydroColour App that may help turn photos of the sky and sea into useful measurements of ocean productivity.[26]

Two major groups in Oregon and Washington — the Oregon Climate Change Research Institute at Oregon State University and the Climate Impacts Group at University of Washington — are actively researching climate change in the Pacific Northwest. Among other things, they are looking at impacts on the oceans and coastal communities.

The Pacific Climate Impacts Consortium (PCIC) provides practical information on climate variability and impacts of climate change in our region. They released a "science brief" on simulated oceanic conditions along the B.C. continental shelf, which explains modeled projections in non-scientific language.[27]

The National Oceanic and Atmospheric Administration (NOAA) of the U.S. provides many online resources and tools. NOAA's National Centers for Environmental Information monitors and assesses the state of the Earth's climate in near real time and provides data and information on climate trends and variability including comparisons to the climate of the past.

What can you do?

SOME ACTIONS CONTRIBUTED BY CORI

Individual and Organization Actions:

- Help prevent climate change by producing fewer greenhouse gasses. Adopt policies and practices within your organization.
- Eat sustainable seafood to foster healthy and resilient fish populations.

Government Actions and Policy:

- Incorporate latest climate change hazard assessments into emergency response planning.
- Protect any cold water "refugia" within rivers. Strengthen regulations that protect riparian areas along streams to keep warming to a minimum.
- Acknowledge that diversity among salmon populations will be critical in helping salmon populations adapt to future climate conditions and develop policy to maintain the diversity.

Resources

NANOOS
The Northwest Association of Networked Ocean Observing Systems. NANOOS (nanoos.org) is part of IOOS (ioos.noaa.gov) and provides information and products related to weather and ocean data.

Pacific Climate Impacts Consortium
The Pacific Climate Impacts Consortium (PCIC - pacificclimate.org) is a regional climate service center at the University of Victoria that provides practical information on the physical impacts of climate variability and change in the Pacific and Yukon Region of Canada.

Climate Central
climatecentral.org
An independent organization (U.S.) of leading scientists and journalists researching and reporting facts about the changing climate and its impacts including on the ocean.

Preparing for Climate Change
wcel.org/sites/default/files/WCEL__climate__change__FINAL.pdf
An implementation guide for local governments in British Columbia.

NOAA: National Centers for Environmental Information
www.ncdc.noaa.gov/climate-monitoring/

Map of Shellfish Harvesting Status for B.C. showing biotoxin status and sanitary status
maps.bccdc.org/shellfish/

Footnotes

[1] NOAA National Centers for Environmental information, Climate at a Glance: Global Time Series, published September 2016, retrieved on October 5, 2016 from http://www.ncdc.noaa.gov/cag/

[2] See 135 years of global warming in less than 30 seconds; watch the video. https://www.theweathernetwork.com/news/articles/see-the-graphics-that-lock-2015-in-as-hottest-year-on-record/62607/

[3] NOAA National Centers for Environmental information, Climate at a Glance: Global Mapping, published September 2016, retrieved on October 5, 2016 from http://www.ncdc.noaa.gov/cag/

[4] Chandler, P. 2016. Sea surface temperature and salinity trends observed at lighthouses and weather buoys in British Columbia, 2015. In: Chandler, P.C., King, S.A., and Perry, R.I. (Eds.). 2016. State of the physical, biological and selected fishery resources of Pacific Canadian marine ecosystems in 2015. Can. Tech. Rep. Fish. Aquat. Sci. 3179: viii + 230 p. Available online: http://waves-vagues.dfo-mpo.gc.ca/Library/365564.pdf

[5] SSTs along the outer coast of B.C. were significantly influenced in 2014 and 2015 by the warm water anomaly known as "the Blob". These years are considered anomalous. See 2015 State of Pacific Ocean Report referenced above in footnote 4.

[6] Eliason, E.J., T.D. Clark, M.J. Hague, L.M. Hanson, Z.S. Gallagher, K.M. Jeffries, M.K. Gale, D.A. Patterson, S.G. Hinch and A.P. Farrell. 2011. Differences in thermal tolerance among sockeye salmon populations. Science 332(6025): 109-112

[7] Sea level will also be influenced by other changes associated with climate change, notably more intense storm events causing large storm surges.

[8] Mauger, G.S., J.H. Casola, H.A. Morgan, R.L. Strauch, B. Jones, B. Curry, T.M. Busch Isaksen, L. Whitely Binder, M.B. Krosby, and A.K. Snover, 2015. State of Knowledge: Climate Change in Puget Sound. Report prepared for the Puget Sound Partnership and the National Oceanic and Atmospheric Administration. Climate Impacts Group, University of Washington, Seattle. doi:10.7915/CIG93777D

[9] Ibid.

[10] Horn, M., L.A. Allen and R.N. Lea. 2006. Biogeography. In: Allen, L.G., D.J. Pondella II and M.C. Horn (Eds) The Ecology of Marine Fishes California and Adjacent Waters. University of California Press. 660pp.

[11] Anchovy sighting data from Gibbs, D.M., C. Gibbs, and A. Lamb. Pacific Marine Life Surveys. Data accessed Sept 16, 2016. Opportunistic sightings are recorded, so the information is not from systematic surveys and anchovy may have present in years not recorded.

[12] Fisheries and Oceans Canada. 2002. Pacific Region 2002 Management Plan Anchovy. It is not clear in the management plan if any commercial fishery openings for anchovy did occur in 2002, but no management plan for Anchovy has been published since then.

[13] Gower, J. and S. King. 2016. Satellite and Buoy Observations of B.C. Waters. In: Chandler, P.C., King, S.A., and Perry, R.I. (Eds.). 2016. State of the physical, biological and selected fishery resources of Pacific Canadian marine ecosystems in 2015. Can. Tech. Rep. Fish. Aquat. Sci. 3179: viii + 230 p. Available online: http://waves-vagues.dfo-mpo.gc.ca/Library/365564.pdf

[14] Carswell, T., M. Costa, A. Hilborn and R. Sweeting. 2016. Chlorophyll Phenology in the Salish Sea: Spatial and Temporal Data from Ocean Colour Satellites Imagery. In: Chandler, P.C., King, S.A., and Perry, R.I. (Eds.). 2016. State of the physical, biological and selected fishery resources of Pacific Canadian marine ecosystems in 2015. Can. Tech. Rep. Fish. Aquat. Sci. 3179: viii + 230 p. Available online: http://waves-vagues.dfo-mpo.gc.ca/Library/365564.pdf

[15] Allen, S.E., D.J. Latornell, E. Olson and R. Pawlowicz. 2016. Timing of the spring phytoplankton bloom in the Strait of Georgia, 2015 AND 2016. In: Chandler, P.C., King, S.A., and Perry, R.I. (Eds.). 2016. State of the physical, biological and selected fishery resources of Pacific Canadian marine ecosystems in 2015. Can. Tech. Rep. Fish. Aquat. Sci. 3179: viii + 230 p. Available online: http://waves-vagues.dfo-mpo.gc.ca/Library/365564.pdf

[16] Integrated Ocean Observing System. 2016. Climate. Accessed Oct 6, 2016. http://www.nanoos.org/education/themes/climate.php

[17] Jeff Marliave (Senior Researcher, Vancouver Aquarium Marine Science Centre), discussion with K. Bodtker, Coastal Ocean Research Institute, Nov 15, 2016.

[18] Mauger et al. 2015.

[19] Trainer, V.L., McCabe, R. Hickey, B. and Kudela, R. 2015. The impacts of a massive harmful algal bloom along the US west coast in 2015. PICES 2015 Annual Meeting, Book of Abstracts, p. 130. Accessed Oct 7, 2016. http://www.pices.int/publications/book_of_abstracts/2015-PICES-Book-of-Abstracts.pdf

[20] Ibid.

[21] Ibid.

[22] Pena, A. and N. Nemcek. 2016. Phytoplankton in the Surface Waters along Line P and Off the West Coast of Vancouver Island. In: Chandler, P.C., King, S.A., and Perry, R.I. (Eds.). 2016. State of the physical, biological and selected fishery resources of Pacific Canadian marine ecosystems in 2015. Can. Tech. Rep. Fish. Aquat. Sci. 3179: viii + 230 p. Available online: http://waves-vagues.dfo-mpo.gc.ca/Library/365564.pdf

[23] Ibid.

[24] Fisheries and Oceans Canada. 2016. State of the Pacific Ocean, Technical Reports, Research Documents, Advisory Reports (Summary), and Reports. Accessed Oct 7, 2016. http://dfo-mpo.gc.ca/oceans/publications/index-eng.html#state-ocean

[25] https://www.psf.ca/blog/citizen-science-boats-are-coming-communities-near-you

[26] https://www.psf.ca/blog/citizen-science-bc-ferries

[27] https://www.pacificclimate.org/news-and-events/news/2014/new-pcic-science-brief-model-simulation-future-oceanic-conditions-along-british-columbia-continental