March 2018

To My Salmon Fishing Friends:

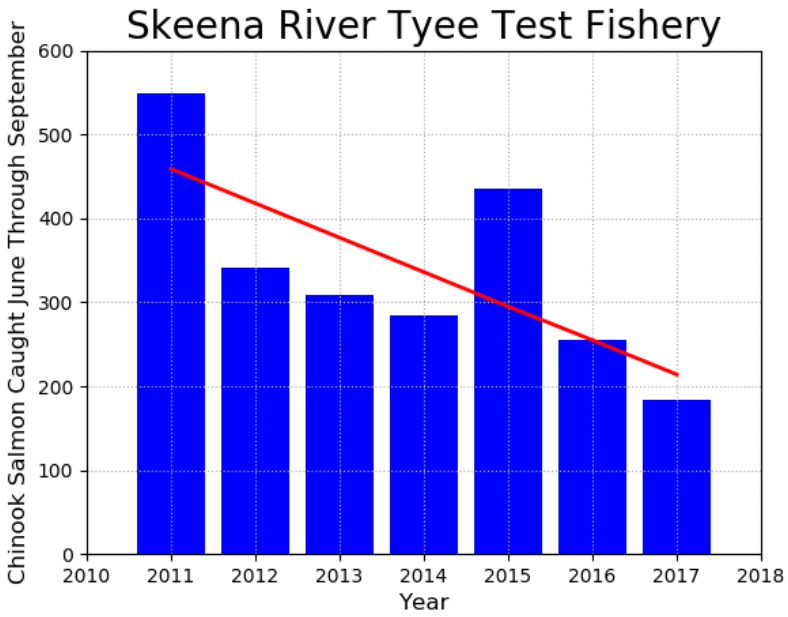
I did not guide last summer and spent less time salmon fishing than previous years: one trip to the BC central coast in late July followed by two months (August and September) of day fishing near my home in the Vancouver area. My personal experience was that the fishing on the central coast was quite good for coho and small chinook, and later in the summer I was able to find a few chinook in the ocean near the mouth of the Fraser River. Overall, though, it was a very difficult year for the salmon.

West Coast Salmon Runs

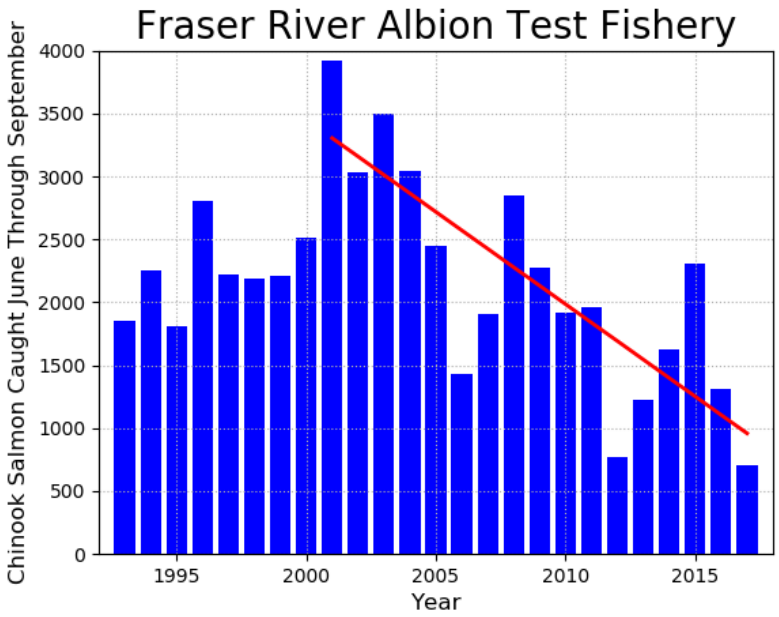
On May 29, 2017 the Alaska Fish and Game closed the southeastern Alaska chinook salmon commercial troll fishery due to record low returns. Then on August 10 they also closed the chinook salmon sport fishery, an unprecedented move. In comparison 2017 was a good year for Alaskan coho salmon.

In British Columbia the Fraser River is the largest producer of chinook salmon, with more than thirty different chinook runs which enter the river from May through September. The Skeena river comes a close second. Last summer Fisheries and Oceans Canada (DFO) closed both rivers to commercial and recreational salmon fishing (all salmon, not just chinook), another unprecedented move. Recreational salmon fishing in these rivers was only opened again after the main salmon runs had passed.

The DFO has a test fishery at Tyee, about twenty-five miles upstream from the mouth of the Skeena River (in 1967 as a university student I spent the summer working for DFO and living in a small cabin in a gravel pit at Tyee, a very interesting experience). In the test fishery a gillnet is set for one hour each daylight slack tide during the season. The graph below shows the number of chinook salmon caught from June through September. Unfortunately DFO only provides data going back to 2011.



As can be seen from the above graph the Skeena River chinook salmon runs are in decline, and the test fishery catch last summer was low despite the river being closed to commercial and recreational fishing.



The DFO has a similar test fishery at Albion on the Fraser River, and the graph above shows the number of chinook salmon caught from June through September going back twenty-five years. Last year's chinook runs were the lowest on record, despite the river being closed to commercial and recreational fishing.

Note that the Albion graph shows a cyclic structure between 2006 and 2011 which is repeated from 2012 through 2017. This structure is caused by ocean conditions, La Nina's and El Nino's, which have an approximate five year cycle. Unfortunately the chinook salmon runs are only partially recovering after each cycle.

I fitted the red lines to the data using the method of least squares. Both graphs show a decline of approximately 50% since 2011, as measured by the slope of the red line.

Last summer I did some salmon fishing in Washington State area 7, which includes the San Juan Islands and Point Roberts (just south of Vancouver). In this area recreational salmon fishing was permitted from July through September but the daily possession limit was only one chinook, and at the end of September the area was closed.

Although the Fraser River itself was closed to salmon fishing during the summer, there was one postage stamp size spot (area 29-3) in the Strait of Georgia off the mouth of the river which was open. Fishing there was a very social experience (a mild form of combat fishing), and although the weather was very nice through most of the summer the actual catching was slow enough to discourage all but the incurable optimists from doing it again next year (more on that later).

2017 was expected to be a big year for Fraser River pink salmon – the average run in an odd year is 12 million salmon. Based on poor ocean conditions DFO made a 2017 pre-season forecast of 8.7 million pink salmon. That's low but still a lot of salmon. I expected that during August and September there would be some days that I would be unable to keep my lines in the water long enough to catch a chinook, and running flashers with small bait would be particularly difficult. It turned out not to be a problem – in 24 days of fishing near Vancouver I caught only three pinks, which I released. At the end of the season DFO estimated the actual return at less than 3.6 million pinks with a fry to adult survival rate of 1.6 percent, which is much lower than normal. All I can say is that if there were 3.6 million pinks swimming past they didn't show much interest in my gear.

DFO forecast a Fraser River sockeye run of 4.4 million salmon, and at the end of the season calculated the actual return to be 1.5 million sockeye. To put this in perspective, in 2010 (a peak year in the four year sockeye cycle) the return was 32 million salmon. This coming summer (2018) is another peak year and it will be interesting to see how strong (or weak) the return is.

The 2017 Fraser River coho run was expected to be poor. Fishing near the mouth of the river I caught only two coho salmon during August and September and released both.

Later in the fall my friend Chuck visited the Sechelt salmon hatchery and learned that only seven salmon had shown up in the traps – five coho and two springs. This was not enough to retain eggs and propagate either run (ten years previously he had made a morning visit to the same hatchery and had seen twenty salmon including a 40 lb spring in the trap).

And on Feb 14, 2018 the Vancouver Sun newspaper reported that only 57 steelhead had reached the spawning grounds of the Chilcotin River, and 177 on the Thompson River. These are tiny returns for two legendary British Columbia steelhead streams. The Committee on the Status of Endangered Wildlife in Canada has recommended an emergency listing order under the federal Species at Risk Act.

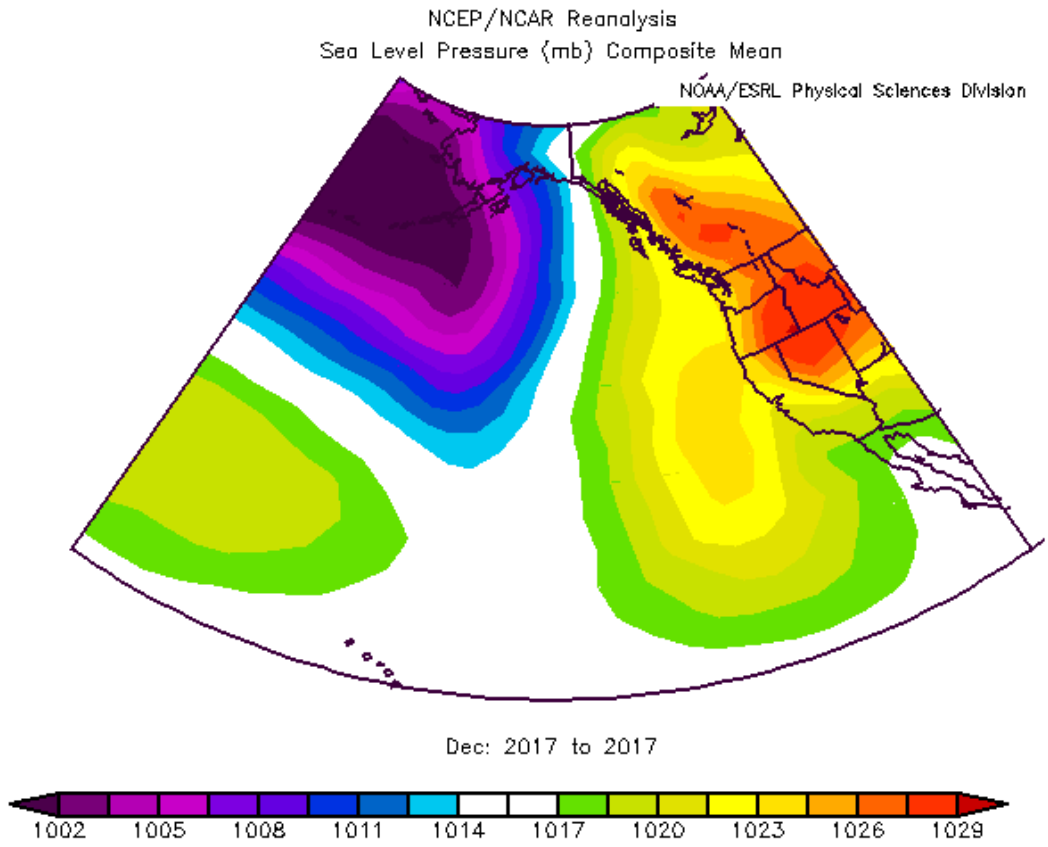
Summary: Despite very poor salmon and steelhead returns in 2017, ocean conditions off the BC coast are now changing for the better. Last spring I thought this change had taken place a year earlier, and would be reflected in stronger coho and pink salmon runs last summer due to their shorter life cycles. I also thought the chinook and sockeye runs (with longer life cycles) would suffer, which they did. Still it turned out to be much worse than I had expected.

"The Blob" and El Nino

By the summer of 2016 most of the "blob" was gone, or at least had settled lower in the water column where it was not visible in satellite imagery. However as the "blob" settled the El Nino which was underway pushed warm subtropical water north along the west coast into the Gulf of Alaska. This subtropical water had been depleted of nutrients long before it arrived in the Gulf of Alaska, and also contained southern zooplankton species which have less food value to the juvenile salmon. Essentially the "blob" followed by the El Nino subtropical water made up a "one-two" punch that dramatically reduced juvenile salmon survival during their critical first winter in the ocean.

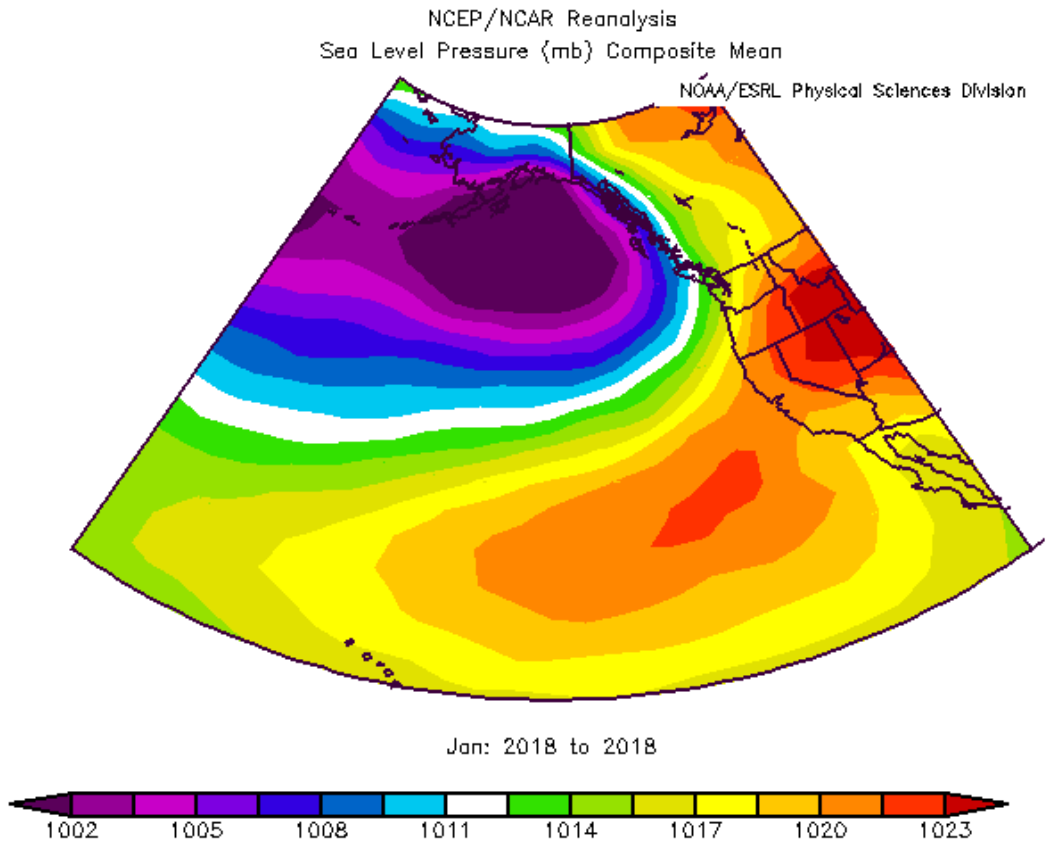
The El Nino ended during summer 2016 when we entered a mild La Nina period. The winter of 2016/2017 and the following winter of 2017/2018 were both relatively cold in British Columbia with strong winds, cold rain at sea level and excellent snow packs in the mountains. The strong winter winds in particular are important for mixing the ocean surface layer (to a depth of about 300 feet), bringing nutrients to the surface and setting the stage for the spring phytoplankton bloom. Summer 2017 should have been excellent conditions for the juvenile salmon entering the ocean, and survival during that first critical winter (2017/2018) should have been very good.

In the late fall as the Arctic Ocean freezes a high pressure region forms over the pole, representing very cold dry air which is sinking. This air flows south along the surface until it encounters open water, warms and rises, forming a low pressure region (the "Aleutian Low") which spins out winter storms. The Aleutian Low generally forms over the ocean near the edge of the land or ice.



The figure above shows sea level pressure averaged over the month of December 2017. Notice the low pressure region (the Aleutian Low) west of Alaska over the Bering Sea, and the ridge of high pressure located over the BC coast. The jet stream approximately follows the white gap between the low and the high, pushing moist air far to the north around the high pressure ridge. Essentially the ridge blocked the normal fall storms from reaching the west coast and California was in drought at this time. At sea level the winds approximately parallel the jet stream, pushing nutrient depleted subtropical water north into the Gulf of Alaska. This dynamic – the Aleutian Low sitting to the west over the Bering Sea, a strong high pressure ridge over the BC coast and winter drought in California generally means poor conditions for salmon in the Gulf of Alaska.

Last December the Bering Sea was ice free. This is the likely reason why the Aleutian Low was located above it. Thirty years ago the Bering Sea would have been solidly frozen over during December and the Aleutian Low would have been located further east in the Gulf of Alaska, as shown in the figure on the next page.

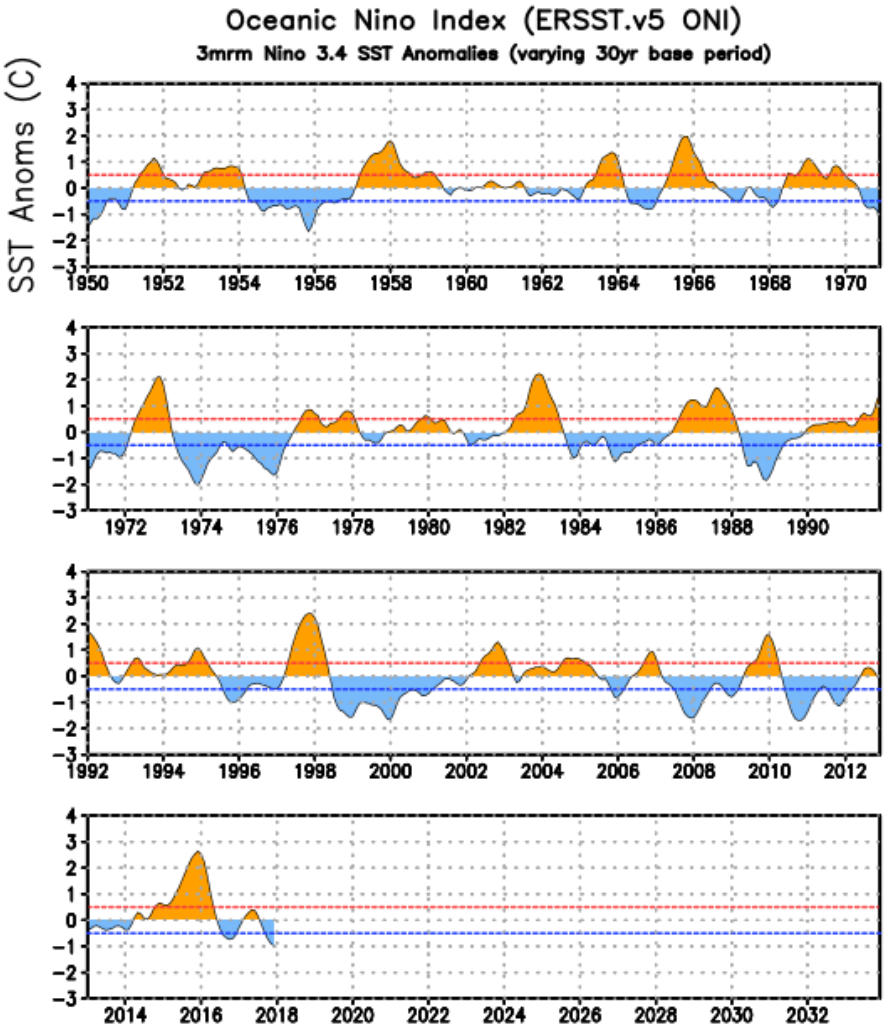


In this diagram, only a month later, the Aleutian Low has shifted east and is now over the Gulf of Alaska. The blocking high pressure ridge has moved south and although California is still in drought (except for the occasional “atmospheric river” event from the tropics) the main flow of winter storms (following the white band) is over Vancouver Island and into North America. The high pressure in the interior of the province shows cold polar air which is pushing south through Alberta into the mid-western United States – a serious blast of winter.

This January 2018 figure is similar to a normal winter forty or fifty years ago. Violent winter storms drive huge waves in the Gulf of Alaska which mix the surface layers to a depth of a hundred meters or more, bringing colder nutrient rich waters to the surface and setting the stage for the spring plankton bloom.

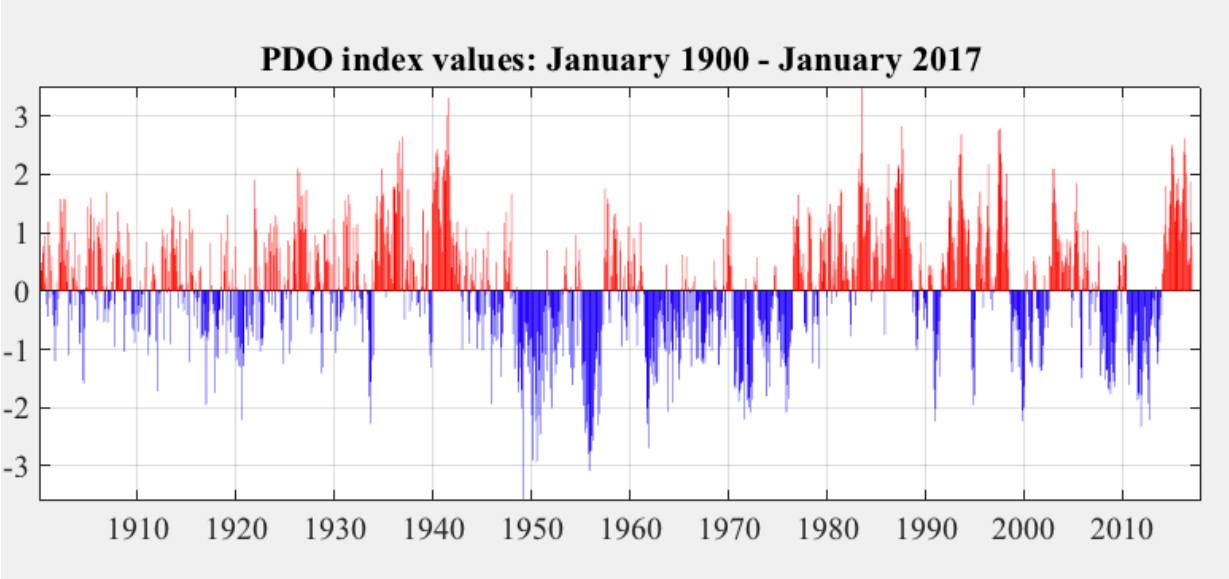
I believe that the biggest factor impacting our local winter weather over the past ten years has been the lack of ice cover in the Bering Sea, which results in the Aleutian Low shifting west so it sits over the Bering Sea instead of the Gulf of Alaska. This allows the blocking high pressure ridge to move north, causing drought in California and ocean winds which push nutrient poor subtropical water into the Gulf of Alaska.

For the latest update on the El Nino / La Nina Southern Oscillation see https://www.climate.gov/enso. We are presently in a mild La Nina phase but a transition to ENSO neutral is expected in the spring. The NOAA "expert discussion" is available here: http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/lanina/enso_evolution-status-fcsts-web.pdf.



Incidentally the severe hurricane season just experienced in the Caribbean is consistent with La Nina conditions. El Nino generally causes high altitude winds in the Atlantic which disrupt hurricane formation, so the southeastern US gets more hurricanes during La Nina years. Global warming results in higher surface water temperatures in the Caribbean making those hurricanes on average much stronger than in the past.

The Pacific Decadal Oscillation (PDO) index (https://www.nwfsc.noaa.gov/research/divisions/fe/estuarine/oeip/ca-pdo.cfm) is a measure of water temperature off the coast of Oregon. This index is positive during El Nino episodes (which are harmful to the salmon) and negative during periods of strong upwelling which are beneficial to the salmon. As can be seen from the diagram below the PDO has been strongly positive during the recent "blob" and El Nino events. It is still mildly positive, indicating poor ocean conditions for salmon.



A very useful measure of the health of the oceanic food chain leading directly to salmon is the date of biological spring transition (https://www.nwfsc.noaa.gov/research/divisions/fe/estuarine/oeip/ec-biological-spring-trans.cfm) measured by the Northwest Fisheries Science Center, which is based in Seattle.

During the winter months the current along the California, Oregon and Washington coasts flows north, pushing warm subtropical water and zooplankton with it. The subtropical water has been depleted of nutrients and the accompanying zooplankton species have low food value for salmon. This winter current is called the Davidson Current. Then the onset of sunny spring weather brings winds from the northwest which reverse the direction of the current, now called the California Current. These winds push cooler water from the north and cold water zooplankton species into the area and also cause upwelling along the California and Oregon coasts. The upwelling brings nutrient rich water to the surface which feeds and sustains the summer phytoplankton and zooplankton bloom.

The Northwest Fisheries Science Center measures the date of transition between the winter (warm water) and summer (cold water) copepod species. Several of the cold water copepod species are particularly high in lipids and Omega 3 acids, and when these copepods are plentiful the juvenile salmon grow rapidly and experience low winter mortality. The date of arrival of the cold water copepod

community and the number of days during the summer that they are present are two critical measures of ocean health off the California, Oregon and Washington coasts.

Year	Cold Water Copepod Start	Cold Water Copepod End	Length (Days)
1970	March 20	October 20	214
1971	March 20	6 November	231
1983	July 21	August 19	29
1996	July 3	October 31	120
1997	May 15	August 27	104
1998	September 20	September 24	4
1999	May 14	November 4	174
2000	April 6	October 23	200
2001	March 20	November 7	232
2002	April 18	November 1	197
2003	June 5	October 3	120
2004	May 11	October 14	156
2005	August 26	September 28	33
2006	June 29	October 31	124
2007	March 22	December 31	284
2008	March 4	October 27	237
2009	March 6	December 1	270
2010	June 18	November 24	159
2011	March 23	September 29	190
2012	May 4	October 25	174
2013	April 1	September 26	178
2014	June 11	September 25	106
2015	(did not arrive)		0
2016	(did not arrive)		0
2017	June 28		

After two disastrous seasons (2015 and 2016) the cold water zooplankton community did arrive in late June 2017. Hopefully the juvenile salmon will have had good winter survival.

Summary: The warm water of the "blob" followed by one of the strongest El Nino's on record made 2014 through 2016 very difficult years for the salmon, but ocean conditions off the BC coast have finally changed for the better. The salmon smolts that migrated down the rivers and entered the ocean in spring 2017 encountered excellent conditions and should have had high survival through this last winter, however it will be several years before these salmon return as adults. This summer chinook salmon are likely to be small and difficult to find, while coho runs on the central coast may be quite good. I'm not expecting much in the way of pink or chum salmon. It will be very interesting to see how many sockeye return to the Fraser River this summer – it's a peak year in the cycle and runs in the recent past have been huge (32 million in 2010), so this will be a good measure of ocean productivity.

DFO and the 2016 State of the Ocean Report

The Fisheries and Oceans Canada 2016 State of the Ocean report is now available at http://www.dfo-mpo.gc.ca/oceans/publications/soto-rceo/2016/index-eng.html. This report indicates that 2016 was the warmest year on record globally and sea surface temperatures in the northeastern Pacific Ocean were 1°C to 2°C warmer than average.

The 2017 State of the Ocean report should be available later this year.

Caamano Sound

In July my wife Kim and I made a trip to Bella Bella, where we joined Tom and Linda Millar on their boat Lindy Marine to fish the Caamano Sound area.

We spent the first couple of days just north of Borrowman Bay on Aristazabal Island and found the fishing to be relatively slow. There were a few coho in the area and we were able to find three chinook that had some weight to them, but were unable to get the salmon to the boat -- all I can say is that we were using spoons and the barbless hooks were quite slippery. Then we moved further north to Eclipse Point at the south end of Campania Island where we found the fishing to be much better.

Eclipse is an area of strong tides and abundant sand lance. The other boats fishing the area were using flasher and anchovy, spoons, and medium herring. We tried all of these methods and found that flasher and hootchie worked best for us. During low light conditions the red flasher with army truck hootchie produced well, and when the sun hit the water a purple haze flasher with Silver Horde Green Splatterback Ace Hi fly (#142) was the ticket. Lots of springs in the teens with the occasional salmon in the twenties (Tom's best was 29 lbs), a halibut in the low 20s and many, many coho. On our final morning in three hours of fishing Tom estimated that we had released thirty salmon (I had given up counting).

Summary: For sheer fishing action it is hard to beat flasher and hootchie, especially in an area that has a lot of sand lance. And thanks Tom and Linda for your gracious invitation and hospitality.

Black Boxes

My boat is a 17 ft Double Eagle which I have extensively modified for single handed fishing. One of the modifications is a Pro-Troll "black box", which allows me to set the voltage of the stainless steel downrigger cable on the starboard side. As a control I'm using braided Spectra downrigger cable (which does not conduct electricity) on the port side.

My experience during the summer was that the black box did not seem to make a difference and I caught approximately equal numbers of salmon on both sides, although my largest salmon (a 33 lb spring) was on the black box.

Daniel Nomura's Master's Thesis (UBC Zoology 1979) describes the use of black boxes in the commercial fishing industry. I've posted this document on my website http://www.thescienceofsalmonfishing.com/fishing_notes/fishing_notes.htm . It is very interesting reading.

Summary: Running stainless steel downrigger cables with a black box (or taking advantage of the natural voltage of a welded aluminum hull) might double your chances of success. That's not huge, but fishing is a game of probabilities and every little bit helps. I plan to continue the test this summer.

Islander Fishing Reels

I have a pair of gold anodized Islander MR2 fishing reels, and last summer used one Daiwa reel and one Islander reel while fishing Sand Heads at the mouth of the Fraser River.

One morning I arrived at Sand Heads at 7:30 am. I set up the port rod with the standard green onion flasher and glow/green anchovy teaser head at 47 ft (Daiwa reel) and the starboard rod with the same gear at 62 ft (Islander reel). Shortly after I got the second rod set up I noticed on the depth sounder a salmon trace at 60 ft, and it appeared to be following my gear. A minute later I looked over and the starboard rod was bent double with line screaming out (but very quietly, it was on the Islander reel). If I hadn't glanced over I would not have known that I had a salmon. Excellent fight and lots of fun, a 20 lb white spring.

Summary: The next day Kim bought me a second Daiwa M-One UTD 400 reel to replace the Islander. The Daiwa has a much louder clicker. Thanks, Kim -- I've now retired both Islander reels. They look great on the shelf at home but for fishing I prefer the Daiwa's.

Pro-Cure Brine'N Bite Chartreuse Glow

The Fraser River pushes out a plume of muddy water which reduces visibility in the Strait of Georgia. It also provides nutrients which maintain the spring plankton bloom through most of the summer. I found that it was important to use a flasher in the murky water, and my "go to" outfit was a Big Shooter Green Onion flasher with glow/green Rhys Davis teaser head. In local waters almost all of my salmon last summer were on this rig.

Typically I used anchovies, but later in the season I also used medium (nine inch, blue package) herring. In both cases I brined the bait with Pro-Cure Brine'N Bite chartreuse glow bait brine. This dyes the bait a very bright chartreuse green colour which stands out in the murky water, and also contains amino acids which are supposed to intensify scent and trigger strikes.

This stuff is serious dye so it's important to keep it off your clothes and other items on the boat. For a lodge trip I would not pack the liquid brine in my bag, for obvious reasons, however the same stuff is available in powdered form as Pro-Cure Brine'N Bite bait brine powder and Pro-Cure Bad Azz bait dye powder, which I believe would travel better.

Summary: I'm a convert. It worked well for me last summer and I plan to use it again this summer when the water is a murky green colour.

Fishing Sand Heads

In early August I moored my boat at the Point Roberts Marina (https://webapp.navionics.com/#boating@12&key=en%7CiHzrdnV) and fished both Point Roberts and Sand Heads (https://webapp.navionics.com/#boating@12&key=cetjHbgvoV) at the mouth of the Fraser River (the Navionics webapp provides a marine chart of the area -- use the mouse to zoom in and out and roam around).

My wife claims that I am an incurable optimist – I keep expecting that one of these years the North Pacific will cool and more salmon will take the southern route through the Strait of Juan de Fuca and swim past Point Roberts, like they did fifty years ago. However 2017 was not the year. During August and September I fished eight days at Point Roberts, caught two chinook, and fished sixteen days at Sand Heads where I caught twelve chinook. Clearly most of the salmon are still taking the northern route.

	Point Roberts	**Sand Heads**	**Total**
days fished	8 days	16 days	24 days
hours fished	32 hours	64 hours	96 hours
rod-hours	37 rod-hours	127 rod-hours	164 rod-hours
chinook salmon caught	2	12	14
smallest chinook	15 lbs	12 lbs	12 lbs
largest chinook	17 lbs	33 lbs	33 lbs
average chinook			18 lbs
rod-hours per chinook	18.5 rod-hours	10.6 rod-hours	11.7 rod-hours
fishing hours per chinook	18.5 hours	5.3 hours	6.8 hours
average fishing hours to chinook after arrival (the days I caught chinook)	3.5 hours	1.5 hours	1.5 hours
days with chinook	2 days	10 days	12 days
days skunked (no chinook)	6 days	6 days	12 days

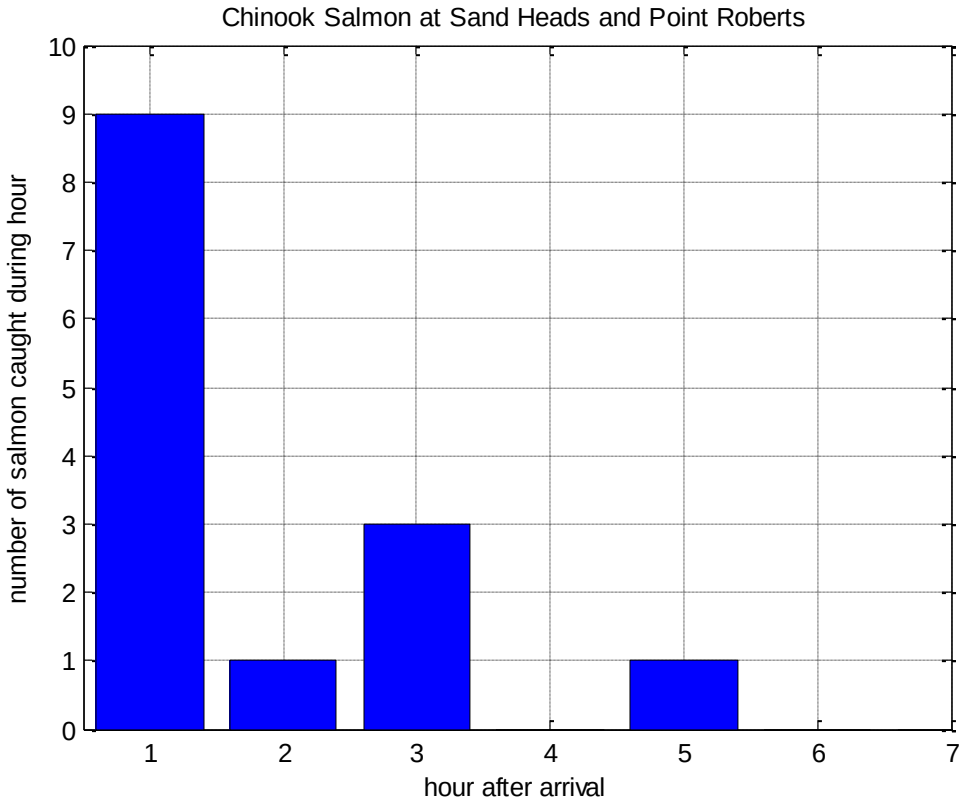
To put this in context a typical five day lodge fishing trip involves about 44 hours of fishing and the possession limit is four chinook salmon and four other salmon. This summer I was able to fill the freezer with chinook salmon (14 chinook with an average weight of 18 lbs) in 96 hours of fishing.

My general strategy was to leave the dock as early in the day as possible, which was often at dawn. On the days I fished Point Roberts it only took a few minutes to get past the marina breakwater to a spot

where I could begin fishing. The 15 nm run to Sand Heads took me about 45 minutes and since the area is very exposed I only made that trip when the weather forecast was favourable.

At Point Roberts if I was alone in the boat I was limited to fishing one rod (US regulations) while at Sand Heads I could fish two rods (Canadian regulations). I would fish until I caught one chinook then return home.

It is interesting that most of the chinook salmon were caught shortly after arrival, in fact nine of the fourteen salmon were caught in the first hour:

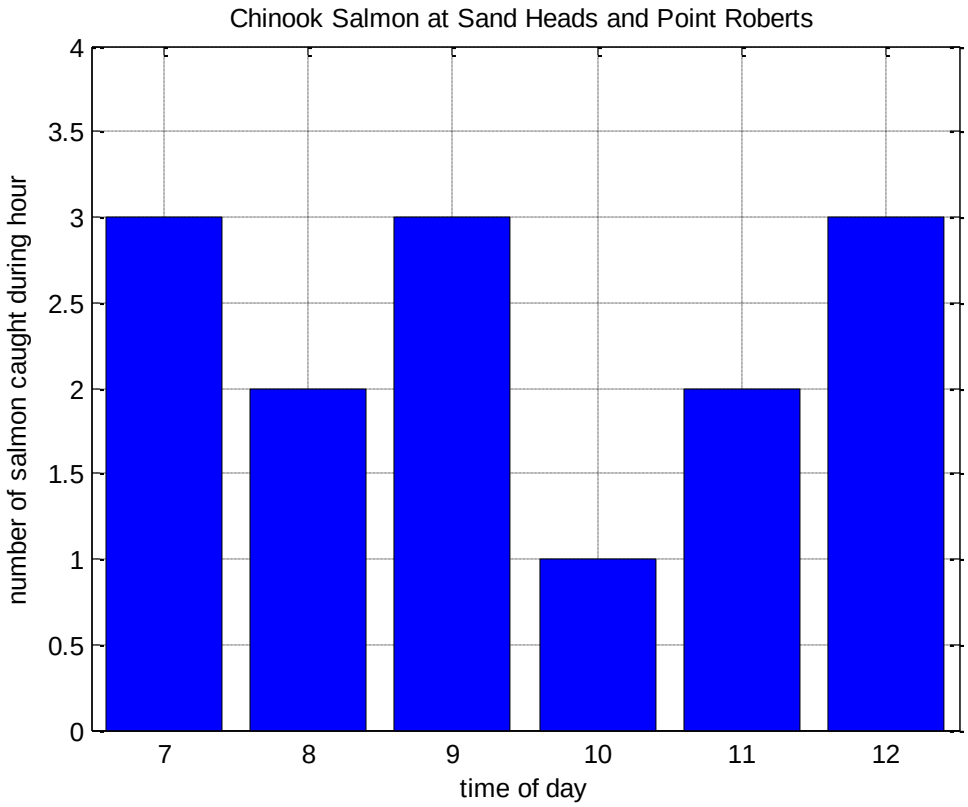


In general the longer I fished the lower the probability of catching anything (if the salmon weren't there, fishing longer didn't help). Since wind and wave conditions were my primary concern, I usually made the run to Sand Heads early in the morning and without considering the timing of the tides. I carefully recorded the time at which I caught salmon, but for the most part this didn't correlate with any stage of tide. I think I did a bit better during slack tide than when the current was running strong but likely because at slack tide it is easier to present the gear at the right speed. Fishing Sand Heads in a pack of fifty to sixty boats when a strong current is running can be difficult and frustrating.

I also noticed that fishing in local waters is very different from fishing on the BC central or north coast where there is more action. At Point Roberts or Sand Heads the fishing would typically be dead slow – nothing at all happening – then suddenly one of the rods would hammer down (a huge adrenaline rush),

ten minutes later I would have a nice salmon in the boat and then I would be on my way home. Very binary. Most days I only had the one strike (if I was lucky).

The figure below shows the time of day that the salmon were caught (on the x axis, “7” means the interval between 6:30 am and 7:30 am). From the graph it appears that time of day is not significant – again if the salmon were there I caught one, otherwise I was skunked.



A couple of days stand out:

Friday September 1, 2017. The previous two days I had fished hard without a touch, no action whatsoever. I needed a change of luck and asked Kim to fish with me today. We reached Sand Heads at 7:30 am. Beautiful morning, flat calm with 30 to 50 boats in the area.

At 10:35 am Kim hooked a 13 lb white spring (green onion flasher with glow/green anchovy teaser head at 47 ft), then at 11:45 am a 21 lb marbled spring. This second salmon went off on a screaming run directly across the bow of another boat and tangled in their downrigger cable. Fortunately it came clear

without cutting our line (I was using 50 lb Spectra braided line which is abrasion resistant). We headed home after landing it. By the way this is the first time I have ever had a salmon tangle in another boat's downrigger cable and not lost the salmon – a big benefit to running braided line. I checked the braid afterwards and there was no damage, it is very tough line.

Tuesday September 19, 2017. Up at 5:00 am, left the house at 6:00 am and at US immigration about 6:30 am. The immigration officer asked me where I was heading and I said "to the marina, to go fishing". It was pitch black and the rain was pounding down (our first rain after three months of drought). He paused, smiled at me then wished me luck. I've seen that smile before, he probably thought I was nuts. I arrived at Sand Heads and was fishing by 8:00 am. The water was pretty much flat with a light wind from the southeast but the rain was very heavy. There were only three other boats fishing the area.

I ran the green onion flasher with glow/green anchovy teaser head at 47 ft on the port side and a green onion flasher with glow/green herring teaser head (with medium herring) at 32 ft on the starboard side.

Shortly after I began fishing a humpback whale passed within a hundred meters of my boat and spent fifteen minutes working nearby. This is the first time I had seen a humpback whale near Vancouver.

After about 40 minutes I dropped the starboard line to 62 ft. It was still raining very heavily and I was soaked through. I can remember thinking that if I caught a salmon now I would be quite happy to go home. A few minutes later I had a solid hit on the starboard rod, set the hook (it was already off the release clip) and the salmon took off on a terrific run, taking me off the braid and into the mono main line. Fortunately there was only one other boat in the area and when I waved he changed course away from the salmon. While holding the rod in one hand to fight the salmon I brought in the other line and pulled up both cannonballs with the hand-crank downriggers, to clear the deck prior to netting the fish.

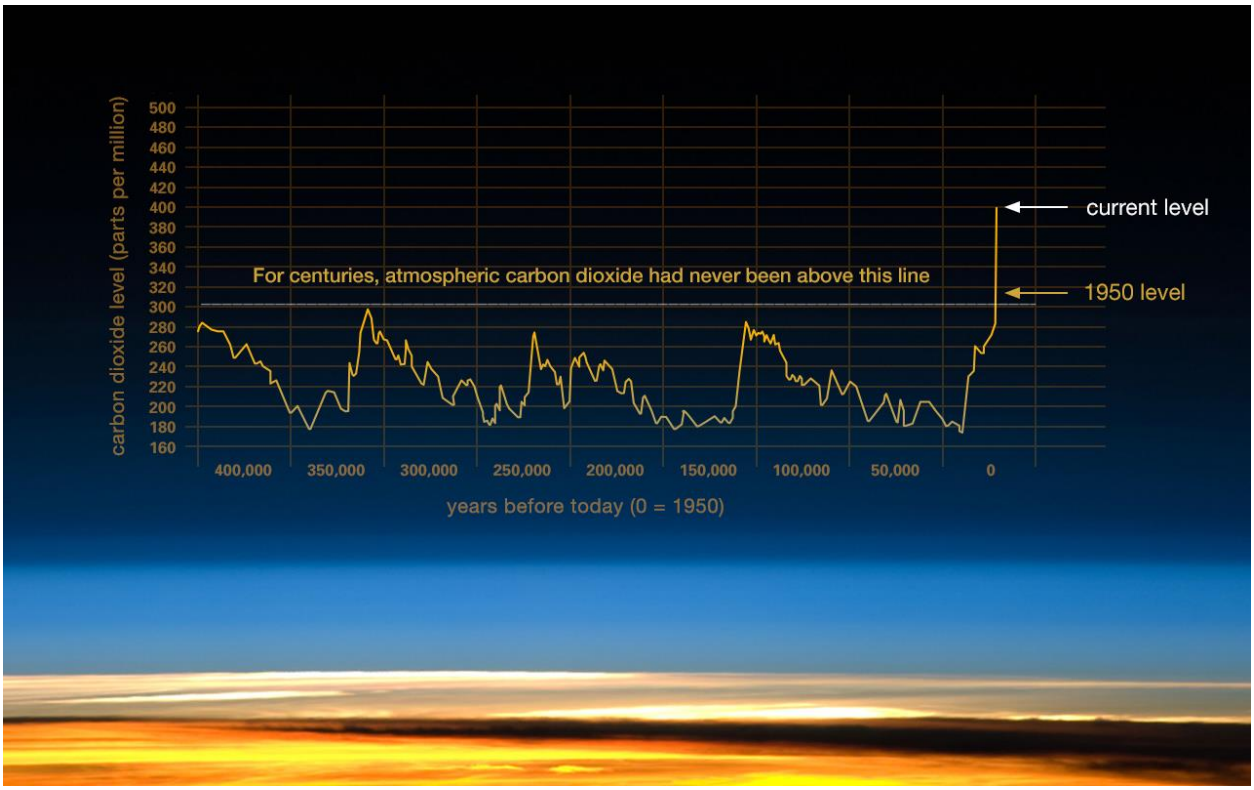
Bill with 33 lb Spring

A lovely white spring, 33 lbs, and the largest salmon I've caught in local waters in 60 years of salmon fishing (although I have caught larger salmon on the central coast). This was the first time this season that I had run a medium herring behind an inline flasher – I think it made a difference in the murky water at Sand Heads.

Global Warming and Salmon

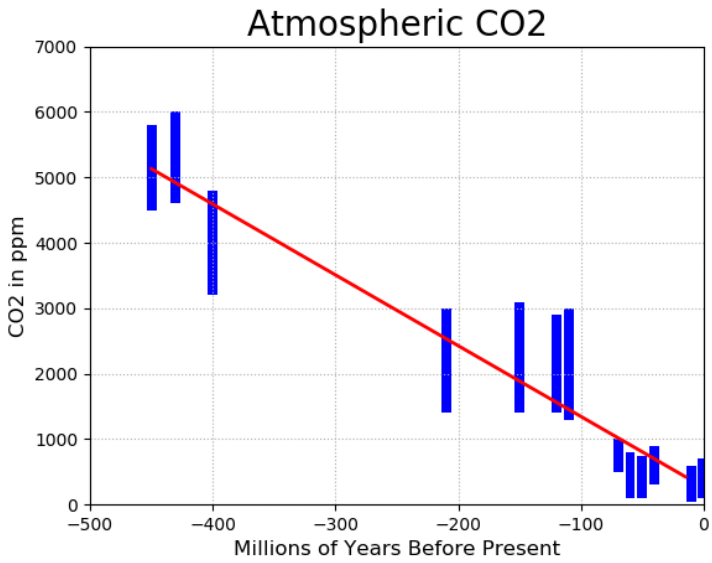
A couple of big events took place last year. First, in July 2017 a 5800 square kilometer block of ice broke free from the Larsen C ice shelf in Antarctica. This iceberg, now known as A-68, is pretty big -- it's similar in size to Delaware or roughly a quarter the size of Wales. It will drift around the southern ocean for a few years as it breaks up and melts, then the fresh water will sink slowly to the bottom of the ocean (because water has maximum density at 4°C) and join a series of deep ocean currents that will take it on a tour of the world's oceans for about a thousand years before finally pushing it back to the surface where it will mix with the salt water. The implication is that the climate consequences of this one event will take several thousand years to play out, the earth responds very slowly to change.

Second, in September the average carbon dioxide level in the atmosphere reached 403 ppm (parts per million), and is increasing at the rate of 2 ppm per year from human activities. To put this in context, for the past several million years the atmospheric CO_2 has cycled between 180 ppm during glaciation periods and 280 ppm during interglacials such as today, and in the year 1750 was at 280 ppm. An increase of 2 ppm per year is incredible. Not only are we at the highest atmospheric CO_2 level in approximately ten million years, but the rate at which we pump CO_2 into the atmosphere continues to accelerate.



The figure above is from the NASA website and shows atmospheric CO_2 over the past 400,000 years. The level has cycled between 180 ppm (at the coldest part of each ice age) and 280 ppm (at the end of each ice age) then since 1750 has climbed from 280 ppm to the present level of 403 ppm. These

measurements are made from gases trapped in glacial ice and are very accurate. I've seen similar graphs that go back 800,000 years. Beyond 800,000 years CO_2 levels can be estimated from fossilized leaves, by measuring the spacing of the stomata (little pores that exchange gases with the environment, which is how trees absorb CO_2). The next graph shows CO_2 levels which go back 450 million years (this data is taken from the IPCC 2001 report).



The blue vertical bars represent the range of the data measurements. I fitted the red line using the method of least squares, to estimate the rate at which the earth removes CO_2 from the atmosphere through natural processes. The slope of this line shows a reduction of 6 ppm every million years.

We are presently adding CO_2 to the atmosphere at the rate of about 2 ppm per year. The implication is that for every year forward, burning fossil fuels, it will take the earth about 330,000 years to recover.

Last year CO_2 emissions from China rose by 3.5%, mainly due to the use of coal fired power plants. China is responsible for about 29% of global CO_2 emissions, with the United States running second at 14%.

Summary: The earth removes about 6 ppm of carbon dioxide from the atmosphere every million years, through natural processes. We are presently adding about 2 ppm of carbon dioxide to the atmosphere *each year* and the rate is accelerating. The earth responds slowly and the warming that we see today is the earth's transient response – if we were to stop adding CO_2 to the atmosphere today the earth would continue to warm for several thousand years before it reached equilibrium. The last time atmospheric CO_2 was at 400 ppm was about ten million years ago, when beech trees were growing in Antarctica. At the time there were no permanent ice sheets anywhere on earth, including Antarctica. The average temperature was 3^{o}C warmer and sea levels were 25 meters (about 80 feet) higher than today. That is our future, if we stop adding CO_2 to the atmosphere today. Every year forward at this rate (2 ppm per year) will take the earth an additional 330,000 years to recover.

Ocean productivity declines dramatically as the earth warms – the greatest ocean productivity was during the coldest part of the ice ages, when diatoms in the southern ocean removed so much CO_2 from the atmosphere that levels dropped to 180 ppm, and whales and salmon thrived. A warm ocean means much less food for all of us.

My Website

I welcome you to visit my website (www.thescienceofsalmonfishing.com) where you can check out the book and read my fishing notes from previous years.

Jenny Lee

Have a great summer and I hope to see you on the water (that's my boat in the photo above).

Bill Haymond