

"Two Thousand Years of Sardines:

sardinops sagax returns to BC"

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This is one of a series of occasional papers outlining some issues in the development of the sardine fisheries of BC. Readers can provide comment and feedback to: dapepper@shaw.ca

All comments will be acknowledged and may be incorporated into the final draft of a paper from the Pacific Sardine Association entitled:

*"A Management and Development Plan
For the Sardine Fisheries of BC".*

This paper is provided for discussion purposes only.
The views expressed herein are those of the author only
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A Fable about Reality and Experts

A certain man was believed to have died. Not knowing what to do his relatives called in experts. They came and they pronounced him dead. He was being prepared for burial, when he revived. He sat up, but he was so shocked at the scene of all the experts surrounding him that he fainted.

He was put in a coffin and the funeral party, including the experts, set off for the cemetery. Just as they arrived at the grave, he regained consciousness, lifted the coffin lid, and cried out for help.

'It is not possible that he has revived', said the mourners, 'because he has been certified dead by competent experts'.

'But I am alive!', shouted the man.

He appealed to the well-known senior and impartial scientist who was present. 'Just a moment', said the senior scientist. The senior scientist then turned to the mourners, counting them. 'Now we have heard what the alleged deceased has had to say. I want you ten experts to tell me what you regard as the truth'.

'He is dead', said the experts, 'we have decided so'.

'Bury him', said the senior scientist.

And so he was buried.

Sufic parable from the 11th century.

"Sounds like fisheries experts to me", Charles Barnwell, sage.

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ONE: Introduction - how many fish are there?

Managing fisheries is always a difficult job for a simple reason. It is difficult to know at any given time how many fish exist at any time and place. This puts scientists and fisherman (and others) at odds with each other. Fishermen, practical men of affairs, believe that they know how many fish there are, because they are on the fishing grounds. Scientists, on the other hand, have their data and their models, and they also believe they know how many fish there are. The two estimates are usually highly different. Unfortunately, no one really knows, so the debate goes on.

This is exactly the current situation in the sardine fisheries: how many fish are there? No one knows. This paper explores that problem in detail to allow the ordinary person to form their own judgments and to let them try their hand at prediction. To do so we examine 2,000 years of data and review the science relating to sardines. We finally make some recommendations for the fishing of sardines in BC. We review three major papers: 1) Baumgartner, 2) Conser, Hill and 3) Ware.

While the papers are sometimes highly technical they will reward the diligent reader. The reward is an understanding of the science of estimating sardine populations with the bonus that the reader will be able to make his own predictions, based upon good science.

TWO: Baumgartner's Analysis

We want to know many fish there are and how many there will be. History can provide us with some clues about the performance of sardine populations in North America. We have 2,000 years of data. This comes about from an unusual occurrence. While drilling for oil off the California coast geologists found something unusual. They use the core samples they get to determine geologic formations in an area and from this make estimates of the probability of finding oil. While examining the many core samples off the California coast they found that they did not contain the usual rock and sand. Rather, they contained fish scales, in particular scales from sardines. Obviously, this meant that the sardines had died there. The scales did not decompose because of a lack of oxygen at the lower depths of the ocean. This unusual situation led a researcher, Tim Baumgartner and others (known as et al.) to analyze the core samples with the fish scales in them. It is all contained in Baumgartner, et al.'s paper. The results are interesting as a piece of scientific detective work and for our purposes in predicting the rise and fall of sardine populations.

What Baumgartner did was take almost 2000 years of data with a crucial choice of assumptions and from this make some estimates of sardine populations over time. The process, at first blush, was relatively simple: lots of fish scales meant to lots of fish, very few fish scales meant no great amount of fish during that time. While a simple process, the results of the analysis were profound. He found that there were definite cycles of relative abundance and cycles of relative scarcity. His first major conclusion was that sardines are cyclical, populations rise and then fall and the overall variation in population size is great. Roughly, from about 400 thousand tons of biomass to over ten times that amount, around 4.2 million tons. How did he get these conclusions? We shall examine his method and the results.

His method was to select the amount of scales ("SDR" = Sardine Deposition Rates), construct an index of these amounts and attribute to them an equivalent biomass. Thus, an SDR index greater than 5 means 4.2 million tons of biomass. An SDR index of 1 means 1.2 million tons of biomass. Less than an index of 1 means a very low biomass, around .4 million tons. Close examination of Figure 12 shows this method in detail. The bottom "step-function" shows three indexes with the various time periods. We have times of greater than an index of 5, indexes of 1-5 periods and those with less than 1. From this Baumgartner then calculated the intervals between these various periods. This is shown in the middle graphic as "Scale -deposition intervals". Those with an index greater than 5 and those with less than an index of 1 are shown. These numbers represent periods of recovery of the stock and periods of collapse. This graphic plots periods of great abundance and then periods of collapse. This is then represented again in the top graphic. Those above the centerline are periods of recoveries (an index of less than 1 to greater than 5) and collapses (where the index fell from greater than 5 to less than 1).

What did he find? Starting about the Year 300 he found sardines were abundant for about 30 years. Then he found a period where the fish stocks were more or less collapsing. Then appeared a period of recovery, a collapse, recovery, collapse, recovery and so forth. The result is he was able then to model the rise and fall of sardine populations over almost 2000 years. An elegant method, with a profound result.

A close review of Baumgartner's data shows that there were nine periods of recoveries and collapses. All this over almost 2,000 years, technically from about the year 300 onwards. More recent events are interesting, from about the year 1800 there were 70 years with lots of fish, then there were 30 years of a collapse, then a 30 year recovery and another period of 30 years of collapse. This brings us to the present. In our own time we can see one rise in the and then a collapse. We know that there were a lot of fish in BC and in California in the 1920's and 30's and then the collapse at the end of the '40's. In BC we had about 20 years of fish from about 1924 to 1944. And we find that we had 50

years (1945 to 1995) of no fish and then the recent comeback. This data is contained in Tables 1 and 2. If we look at Baumgartner's nine periods of recovery and collapse we can derive a "rule of thumb". Recoveries are around 30 years long. Further, collapses are also around 30 years long. Except for the two periods around the year 700 to 900 and from 1500 to 1800 you could say "30 years of plenty, followed by 30 years of famine". History isn't always that neat as the present situation for BC in recent time was for 20 years of plenty followed by 50 years of famine. Currently, we're into a period of abundance again and depending upon your preference you could say we may have another 30 years of fish or we may have another 60 years of plenty. Equally, we may not. This is by applying the "rule of thumb" from Baumgartner. It is difficult to argue with 2,000 years of data.

How reliable is Baumgartner's analysis? While it is difficult to say definitively we first of all we have to consider the model itself. In it he has assumptions about the periods and amount of scale deposition to derive his cyclical variations. You may quarrel with the model but the data speak for themselves. The tricky part is estimating or predicting the future. However, one fundamental conclusion follows from Baumgartner's analysis. Whether the stocks are fished or not, (historically, not) there will be millions of tons of fish and then the stock will collapse. Then after a suitable time the stock will recover. This has a profound implication for current fisheries management. Even if it is not fished it will ultimately collapse of its own accord. Similarly, even if it fished it will collapse. *But in both cases it will recover.* We shall have more to say about the impact of fishing on the stocks.

We can make some conclusions about sardine stocks from Baumgartner's analysis:

- b) With or without fishing, sardines stocks will fluctuate by an order of magnitude, from 400 thousand tons to over 4.2 million tons;
- c) Over 1,700 years there have been nine periods of recovery and nine periods of collapse;
- d) These periods of recovery and collapse are generally about 30 years with a low of 20 and a high of 70 years;
- e) Recent (since 1800) cycles have been 70 years of abundance, followed immediately by three periods of collapse, recovery and collapse of about 30 years each.

We can now look at more recent history in detail.

THREE. The present state of sardines US analysis- Cosner, Kevin Hill, et al.

After the collapse of the California sardine fisheries in the 1950s the various US agencies formed a body to monitor the situation. Thus was formed the CalCOFI organization, formally known as the California Current Organization for Fisheries Investigation. They are charged with monitoring the sardine stocks, amongst other objectives. They provide the data for the information which is referred to the Pacific Fishery Management Council (PFMC) which sets the TACs for the US fisheries from his data.

In a paper prepared by Conser, Hill et al. for the PFMC one finds a clear summary of the present situation and the methods used to estimate the stocks of sardines. Simply put, they use an age-structured model (CANSAR) to derive estimates of population abundance and age-specific mortality rates. They use various indices of spawn abundance, egg abundance (Daily Egg Production Method), aerial surveys and time series of temperatures. We can examine some of these indices. As a summary, Figure 3 shows the index of relative abundance, which is rising. It has an "exponent of 0.3547". This is a fancy way of saying the stock is growing at a rate of 35.47 per cent year. Figure 4 shows the "Spawning Area Index". It is rising also and the numbers are perhaps staggering. In 1998 there was over 50,000 square miles of spawning! Figure 6 shows the index of the number of eggs from their surveys. (They use a big pump to process eggs out of the water.) Again lots of eggs, especially in 1998. The aerial spotter index fell (Figure 5) because fewer airplanes were used. Finally, the temperature index shows that temperature at the Scripps Pier fell in 1999, from 18.4 C in 1998 to 18.0C in 1999. This is important as it is one indicator that is significantly used in setting the TAC. All these indices are summarized in Table 2.

All this data and the various indices are used to construct Table 3. Two estimates are made 1) Stock biomass for the "inside" surveyed area with Upper and Lower Confidence Intervals (CI) and 2) recruitment rates in numbers of fish. The biomass size is used in estimating the current TAC and the recruitment numbers give an idea of future fisheries (look at 1998 data) and the health of the stock. Currently the biomass is estimated at 1.1 million tons. There was strong recruitment in 1998 and only "good" in 1999 and 2000.

The application of these indices is used in the Amendment 8 Harvest Guideline. This is a US guideline used by the PFMC. This formula is used to prevent the sardines from being over-fished and "maintain relatively high and consistent catch levels over a long-term horizon". The Harvest Guideline for the year 2001 was derived as follows:

Step One: take the estimate of the Total Area biomass, in this case 1,182,465 tons.

Step Two: apply a "CUT-OFF ". This is an amount below which the stock should never fall. In this case, 150,000 tons. Formally, "the lowest level of estimated biomass at which harvest is allowed".

Step Three: use a "FRACTION" which is a control rule for Pacific sardines which is a proxy for the MSY of the stock. Some heavy lifting was done to get the fraction. It uses the running average of temperatures at the Scripps Pier plus a "suitable number". The actual formula is:

$$\text{FRACTION} = 0.248649805(T^2) - 8.190043975(T) + 67.4558328$$

Where T is the average sea temperature.
This gives a FRACTION of 15%.

Step Four: apply the estimated US DISTRIBUTION of the stocks which is estimated at 87 per cent.

Thus:

TAC = BIOMASS minus CUTOFF times FRACTION (15 %) times US DISTRIBUTION (87%).

Applying the formula gives 134,737 tons of TAC or "Harvest Guideline". This is shown in table 4.

This amount is then divided up between the various states, California, Oregon and Washington. *In 2000 the US fisheries took less than 33 per cent of the fish available to them.*

The obvious question is: how good is the model? The answer cannot be given here but it is apparent that the stock is expanding and the US scientists have a good database upon which to estimate stock sizes. The poker game may be crooked but it is the only game in town. We now turn to the BC situation.

Four: The BC Situation - Ware

The sardines come from California. How many and under what conditions they come to BC is important. Examination of the historical data shows that they came most years when the stocks were good but occasionally they did not come to BC (see Table 1). In an interesting paper prepared for DFO Ware has analyzed the data and prepared some conclusions. In his review of the historical data he found the mean (average) age of fish in BC during 1924-45 was highly variable (Figure 9) but significantly most were older fish, except in 1942. Five, six and seven-year-old fish were the norm. Currently, however, the biomass is made up of several year classes with the younger fish predominating as is normal in a recovering stock. The 1998 spawners (year 2 class) is large and a focus of our analysis. Ware concludes:

" If the northern stock distributes itself along the west coast of North America in a similar pattern today as it did in the past, then roughly 8% to 9 % of the age 2 plus bio-mass is forecast to migrate to BC in the summer..."

Using the estimates prepared by Cosner et al. (noted previously) Ware estimates about 25% of the biomass is year 2 plus fish. This is about 300,00 tons. If sea surface temperatures are normal (above 12C at Amphitrite Point in July) then between 18,000 to 45,000 tons are expected in BC in 2001. Historically, Ware estimates that between 139-164,000 tons were in BC waters during 1926-46. Finally, he notes that there is another factor besides stock size that determines the amount of sardines in BC. It is temperature. Variations in stock size determine how *many* will arrive but as Ware notes:

"Variations in ocean conditions along the west coast of North America in the winter and spring will determine *when* the migratory component of the Northern sardine population will arrive in BC".

When sardines arrive in BC is easily calculated under Ware's analysis. If the Amphitrite Point temperature is greater than 12C in mid July, the sardines (have) arrived in mid-June. Lower temperatures mean they arrive later, in mid-July.

We now have the tools with which to start calculating and estimating the amount and timing of sardines in BC. We now have to determine how many we should catch. This leads us to PSARC or more formally, the Pacific Science Advisory Research Committee.

PSARC

PSARC is the body that sets the allowable catches for a variety of species. Their website is: <http://www.pac.dfo-mpo.gc.ca/sci/psarc/Default.htm>

Technically, it supplies recommendations to the DFO Regional Management Committee but it is here that the biologists do their work. How it functions and its term of reference are available at its website. The last time it formally reviewed sardines was in November 1999. D. M. Ware presented a paper: "Life History of the Pacific sardine and a suggested framework for determining a BC catch quota". It was reviewed by the Committee. Following the review the Committee made the following recommendations:

One. Calculation of the harvestable biomass in Canadian waters should be based upon the use of the US pre-season estimates of biomass less the cutoff.

Two. Based upon historic catch rates, until better information is available, it will be assumed that no more than 10% of the total stock is likely to migrate into Canadian waters.

Three. The catch ceiling in any year should be based upon a harvest rate not greater than the US Fmsy, which could range from 5% to 15%, depending upon the sea surface temperatures. Until more scientific information is available the Canadian harvest ceiling should be 5% of the projected biomass in Canadian waters.

Four. The use of in-season assessments to determine in-shore catchability.

Five. The continued use of offshore trawl assessments to improve our biological knowledge of the species.

SIX. Advice with respect to harvest rates and potential Canadian catches should be used as a ceiling, NOT as a target harvest rate or catch.

Seven. In season management should be used to balance catch among areas to allow for a pre cautionary treatment of potential ecosystems impacts.

Eight. The use of on-board Observers should continue.

The full report is available as " Report of the PSARC Pelagic Sub-committee Meeting November 16, 1999".

Five: PSARC's approach

Ware's Analysis

In a paper prepared for DFO Ware has an approach similar to the US model in setting a TAC for sardines in BC. In it he uses a "cut-off" and an assumption about migration into BC waters. It is not reviewed here.

Some applications of available data provided some hard numbers. If the US sets the total catch in 2001 at 134,000 tons, one approach is to merely set the Canadian TAC at 10 per cent of this at 13,400 tons. The logic is that on average 10% of the stock comes to BC. Allowing some sort of precautionary estimate would lower a TAC to perhaps 9,000 tons. This uses the US methodology and has a certain simplicity.

Another alternative, as suggested by a PSARC method is to take the total biomass (1,896,204 tons in 2000), assume 10% comes to BC, so there is 189,620 tons here. At a 5% exploitation rate (the lower end) we get 9,048 tons as the TAC for BC, remarkably close to the other "rule of thumb" approach. If BC went to the US harvest rate of 15%; the TAC for BC would be 27,000 tons.

One problem is the amount of fish that comes to BC is temperature dependent. An El Nino year would push more fish here, and cold years would mean less would come. Another problem is the distribution of fish in BC waters. While they do currently range as far north as Millbanke Sound (and up to Alaska) we can assume that most of the fish will be off the West Coast of Vancouver Island and in the inlets. Amounts available will vary with climatic conditions. In any case, an expansion from the current 1,600 tons TAC to 9,000 tons has considerable merit.

One must also keep in mind that the US is perhaps not capable of catching its TAC. Out of a quota of 186,791 tons in 2000 the US was only able to catch less than half this leaving over 80,000 tons in the water! One US scientist noted that if BC took every last fish in BC that we would have almost no impact on the stock. In fact, we would be over the TAC, but taking 80,000 tons in BC would still be under the total TAC for the stock, assuming the US would take about 90,000 tons again.

We can make some conclusions from this analysis:

ONE. We can take 9,000 tons in BC under the precautionary approach and a 5% harvest guideline.

TWO. The harvest guideline can range from 5% to 15%.

THREE. Because the US is not able to catch all of it TAC there is some logic that BC could take more than the estimates provided by the "rule of thumb (10% of the US TAC)" or under the PSARC analysis.

A Fly in the Ointment

There is another actor in the drama. Environment Canada has an advisory committee (COSEWIC) that maintains a list of endangered species. (Their website is : <http://www.cosewic.gc.ca/COSEWIC/Default.cfm>)

Formally, there are five categories:

- a) extinct
- b) extirpated
- c) endangered species
- d) threatened and
- e) species of special concern.

Somehow or other sardines are on the "species of special concern" list. It appears DFO scientists have been loathe to expand the TAC for sardines because the "optics are bad" (direct quote). The process to get sardines off the list is possibly underway but until DFO assumes responsibility for the science and the setting of a TAC the fate of the sardine fishery lies in the hands of a mysterious committee and unknown process located somewhere in Ottawa.

Policy for TAC

What should the BC TAC for sardines be? This depends upon the mechanism for setting it. Assuming the COSEWIC committee takes sardines off their list or alternatively, DFO assumes responsibility then the choice of methods and assumptions will determine the setting of the TAC.

A good policy is wide, deep and flexible. Wide to encompass most variables, deep to deal with fundamental issues, and flexible to adapt to a dynamic situation. Somewhat of a tall order. Obviously, DFO will follow the precautionary principle in the end, which merely means it will be conservative. Second, it will rely upon the US science and analysis. However, the choice of some crucial assumptions will determine the final result. They are worth noting:

- a) the acceptance of the US analysis;
- b) the assumed migration amount in BC waters;
- c) the exploitation or harvest rate, (5% to 15%).

Some further considerations may be important. Can in-season adjustments be made in an El Nino year (bringing more than the average) or when the sardines do not appear? This relates to the flexibility of the policy. The sardine situation is unique and will demand that the scientists apply some new thinking in developing the final policy. Ultimately, it is all about fish. How many are there and how many should we catch?

Conclusions:

From the foregoing it is possible to make some conclusions. The major ones are:

- the sardines stocks have recovered and are in a period of expansion, currently at a rate of over 30% per year.
- the existing biomass is about 1.4 million tons, the lower end of a recovered stock under Baumgartner's analysis.
- sardines will migrate in BC waters and the rate will depend upon the temperature.
- historically , about 10% of the biomass migrated into BC waters and catches were at that rate.
- US catches are seriously below the allowable TAC, providing a surplus in the overall stock.
- Canada could take up to 13,000 metric tons under the US assumptions and historical performance.

BIBLIOGRAPHY

Below is a select bibliography and some websites for material noted in the text.

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Websites:

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FIS: <http://www.fis.com/>

Pacific Sardine Association: <http://www.bcsardines.ca>

US HARVEST GUIDELINE FOR 2001

NMFS has published the harvest guideline for Pacific sardine in the Federal Register (65 FR 81766, December 27, 2000) for the fishing season beginning January 1, 2001. A harvest guideline of 134,737 metric tons (mt) is established for Pacific sardine based on a biomass estimate of 1,182,465 mt. The harvest guideline is allocated for Subarea A, which is north of 35° 40' N. latitude (Pt. Piedras Blancas) to the Canadian border, and for Subarea B, which is south of 35° 40' N. latitude to the Mexican border. Any unused resource in either area will be reallocated between areas to help ensure that optimum yield will be achieved. The northern allocation is 44,912 mt; the southern allocation is 89,825 mt. The sardine harvest guideline is in effect until December 31, 2001, or until it is reached and the fishery closed.

This harvest guideline has been calculated according to the formula in the Coastal Pelagic Species Fishery Management Plan (FMP) and in compliance with its implementing regulations. Information on this fishery and other fisheries may be obtained at the Southwest Region Website at:

<http://swr.nmfs.noaa.gov/>.

PACIFIC SARDINES: Stock Biomass and Recruitment

Biomass= (in metric tons) CI=Confidence Interval
 >age1 (in ,000) 95%
 Recruitment=age 0

YEAR	Area1	STOCK BIOMASS (MT)	
		Total Area	Lower CI Upper CI
83	5,056	5,056	2,957 10,099
84	12,816	12,878	9,063 21,181
85	20,961	21,439	15,573 33,385
86	29,917	31,484	24,446 44,926
87	72,083	75,573	59,772 108,304
88	105,088	114,408	94,477 152,212
89	160,457	178,912	148,464 239,814
90	175,762	208,108	173,068 282,917
91	222,968	258,856	198,733 394,671
92	331,202	416,435	308,879 643,578
93	482,639	438,385	336,054 655,658
94	511,541	635,350	511,046 912,435
95	537,008	720,733	580,872 1,013,478
96	483,698	789,746	654,219 1,076,120
97	435,700	765,450	644,562 1,032,142
98	693,865	738,098	601,127 1,030,048
99	693,865	1,084,814	818,716 1,654,253
2000	718,662	1,182,465	934,879 1,896,204
2001			

US Model for TAC

BIOMASS	CUTOFF	FRACTION(%)	US DIST	HARVEST GUIDELINE (mt)
1,182,465	150,000	15%	87%	134,737

Total Area	RECRUITMENT (numbers)	
	Lower CI	Upper CI
141,403	88,847	246,958
226,169	147,229	371,294
219,856	155,365	352,332
846,294	615,775	1,287,227
832,040	617,653	1,190,540
1,461,068	1,063,523	2,219,947
1,158,867	810,564	1,894,887
4,709,570	3,090,489	8,018,753
5,902,130	3,685,261	10,226,905
4,105,231	2,593,962	7,299,626
8,927,805	6,324,826	14,328,381
10,906,645	7,633,095	16,934,560
6,785,885	4,781,041	10,792,603
5,565,890	3,820,403	9,088,025
8,135,807	5,105,778	13,574,897
19,021,736	12,389,294	3,311,696
11,581,850	6,558,572	22,728,400
13,584,794	6,940,772	28,942,209

METRIC TONNE = 2206.4 POUNDS

