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To All Interested Parties:

Sometime after 2014 NMFS/Kodiak made major changes to the long-term database relied upon during the pre-collapse years (1975-1981) to set harvest quotas and, during the years since, to analyze the effects of fishing on Bristol Bay red king crab (BBRKC). The attached white paper explains some of the ripple effects of these revisions and how they are likely to change perceptions as to whether or not the pre-collapse stock was overfished.

The prevailing theory, held by managers responsible for the sustainability of the BBRKC resource, is that the stock was *not* overfished. Instead, managers believe the crab succumbed to a 1976-1977 climatological regime shift, which is theorized to have killed tens of millions of adult crab and somehow decimated the productivity (reproductive success, growth, etc.) of the stricken population's remaining crab. Other than the catastrophic loss and continuing absence of the crab themselves — which logically could be interpreted as symptoms of overfishing — there is little or no data-based evidence to support the regime-shift theory.

That such consequential revisions to long-standing, official survey results were necessary is a worrisome aspect of this story. In 1979 the original population estimate provided by NMFS/Kodiak to Industry and to the North Pacific Fisheries Management Council was 86% higher than the revised estimate nearly 40 years later. That is, the original estimate implied that there were 20.3 million more legal crab on the grounds than did the much-belated revised estimate. For scale, the 1979 estimate *overage* of 20.3 million legal crabs is equivalent to 1980's all-time, record-breaking harvest of 130 million pounds. A similar trend of inflated estimates was observed in 1977 (over by 4%) and 1978 (over by 21%). Thus, during the three years immediately preceding the onset of the collapse, spurious over-estimates were stimulating the industry to a fever pitch. But the crab weren't there, and increasing efforts to find them were sending fishing mortality rates through the roof. The accompanying paper goes into some detail about how the early NMFS/Kodiak population estimates were inflated by 1) unauthorized prospecting tows and 2) the exclusion of 0-catches from average catch-per-unit area (CPUA) values.

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The Crabs That Never Were

> *"What we should wonder about is not so much that the abundance of king crabs declined but that they ever reached such a high abundance level in the first place".* Bradley G. Stevens, King Crabs of the World, p. 588.

Re-writing history is an enterprise fraught with peril. This is especially true when altering and reconstructing historical data closely associated with the catastrophic collapse of Alaska's king crab during the early 1980s.

Understanding that a trusting body of scientists and members of the public have relied on NMFS' deceptive data for nearly 40 years, revisionists are now faced with the following obligations:

1. Revisionists should acknowledge that the original data are wrong, present the magnitude of the error, and explain why the data are wrong (e.g., computer programming error, survey error, analysis error, incompetence, data fabrication, a typo, etc.).

2. Revisionists should acknowledge that theories (e.g., regime-shift induced reduction in stock productivity theory) and conclusions based on the original data are suspect or wrong.

3. Revisionists should reconsider their decision to include only post-collapse years (1984 to present) in the computation of the Minimum Stock Size Threshold (MSST).

4. Rather than to quietly alter the data, revisionists should also formally alter and publish major changes to their theories and conclusions as to causative factors of the collapse (or whether there was really a "collapse" at all). It is no longer reasonable to invoke a "regime shift" to account for the disappearance of crab that may never have existed.

Major Revision

Recently (circa 2015-2017) the NMFS' 1975-1983 legal-male population estimates used to set annual, pre-collapse Guideline Harvest Levels underwent major revision under the supervision of the NMFS/Kodiak facility. As part of the revision process, a great deal of trawl data (several hundred tows) included in earlier estimates were discarded.

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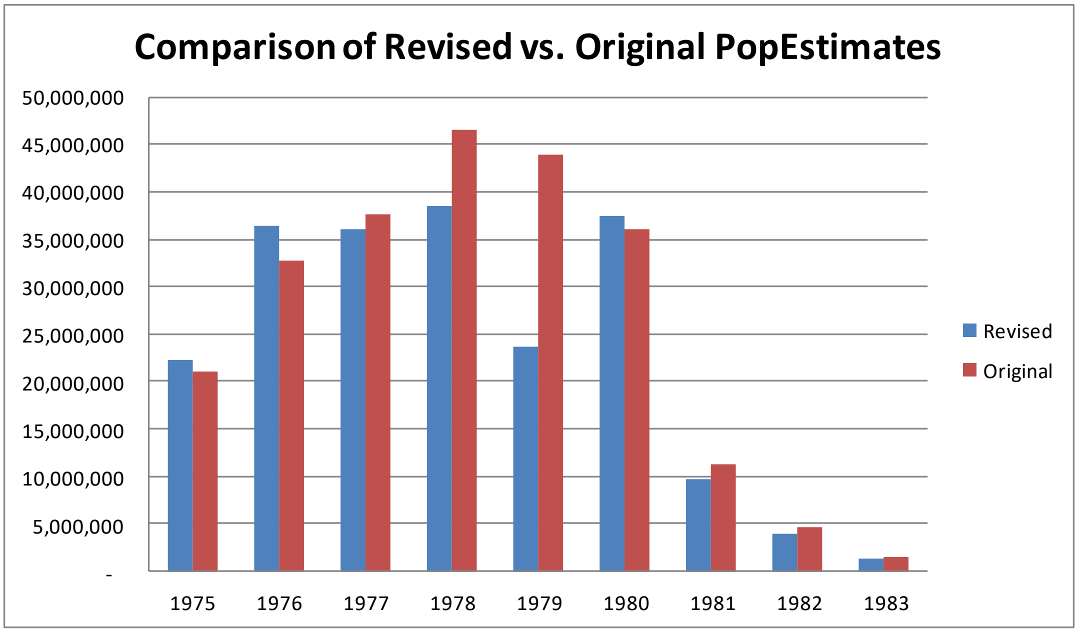
Figure 1.



Details of the revisions and, more importantly, their effect on previous management decisions and theories, are lacking. Examination of Fig.1 shows that the greatest differences between the revised and the original estimates occurred in 1978 and 1979. In 1979 the original estimate (43.9 million legal males), which was used to set the harvest quota for that year, is 86% greater than the newly revised estimate (23.6 million legal males). It should be obvious that such substantial revisions would have a similarly large effect on conclusions as to whether harvest overfishing occurred during the years preceding the collapse.

A first step in the re-evaluation of fishing effects is to reduce the June survey population estimates by 4/12 year to account for natural mortality (M = 0.18) between the survey and the October beginning of the fishing season. Given the original 1979 population estimate (reduced to 43.9*E^(-0.18*4/12) = 41.3 million), and a legal-male harvest of 16.8 million, the original 1979 exploitation rate was u = 16.8/41.3 = 41%, which is below today's overfishing limit of u = 0.50.

However, when we use the revised 1979 population estimate, we get an exploitation rate of u = 16.8/22.3 = 75%, which substantially exceeds the legal-male overfishing limit of u = 50%. If we do the same for 1980 and 1981, we get a three-year average exploitation rate of u = 64%. Therefore, using NMFS' revised estimates, overfishing was a constant feature of red king crab management for the three consecutive years (1979-1981) immediately preceding the collapse.

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	ORIGINAL Number of Legal Males (No)	Legals 4/12 Year Later (Nt)	Harvest (C)	Exploitation Rate (u = C/Nt)	Fishing Mortality Rate F = -Ln(1 - u)
1975	21,000,000	19,777,055	8,745,294	0.44	0.58
1976	32,700,000	30,795,700	10,603,367	0.34	0.42
1977	37,600,000	35,410,346	11,733,101	0.33	0.40
1978	46,600,000	43,886,227	14,745,709	0.34	0.41
1979	43,900,000	41,343,463	16,808,605	0.41	0.52
1980	36,100,000	33,997,700	20,845,350	0.61	0.95
1981	11,300,000	10,641,939	5,307,947	0.50	0.69
1982	4,700,000	4,426,293	541,006	0.12	0.13
1983	1,500,000	1,412,647	No Fishery	-	-

	REVISED Number of Legal Males (No)	Legals 4/12 Year Later (Nt)	Harvest (C)	Exploitation Rate (u = C/Nt)	Fishing Mortality Rate F = -Ln(1 - u)
1975	22,256,963	20,960,818	8,745,294	0.42	0.54
1976	36,352,392	34,235,393	10,603,367	0.31	0.37
1977	36,088,155	33,986,544	11,733,101	0.35	0.42
1978	38,527,112	36,283,468	14,745,709	0.41	0.52
1979	23,642,348	22,265,525	16,808,605	0.75	1.41
1980	37,479,518	35,296,881	20,845,350	0.59	0.89
1981	9,673,906	9,110,542	5,307,947	0.58	0.87
1982	4,002,738	3,769,637	541,006	0.14	0.15
1983	1,287,101	1,212,146	No Fishery	-	-

The maximum fishing mortality rate, Fmax, is another measure of overfishing. When the maximum allowable exploitation rate for legal males is u = 0.50, Fmax = -ln(1 – u) = 0.69. Using the 1979 NMFS-revised data, F = 1.41, or more than double Fmax. Given the 1979-1981 average u = 0.64, we get F = 1.03, defining a 3-year period of conspicuous overfishing leading up to the collapse.

Management By Regime Shift

For decades now, the movers and shakers in Bering Sea and Aleutian Island (BSAI) crab management have asserted that "… causes in declines of abundance are not related to fishing, and hence largely beyond control." (Otto 1986: 105). This denial has had a profound impact on Bristol Bay red king crab management.

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From Dew and McConnaughey (2005):

> *Managers have used the 1977 regime shift and its hypothetical effects on the environment and ecology of Bristol Bay to redefine the Bristol Bay red king crab population to be, in effect, a population with no history prior to 1984. In this way, the high-abundance years of 1975–1980, years in which the fishery extracted a total of more than 500 million pounds or 70–80 million legal-male red king crab from Bristol Bay, are not included in the baseline average used to evaluate whether the stock is overfished.*

From the BSAI Crab SAFE (2017):

> *If we believe that differences in productivity and other population characteristics before 1978 were caused by fishing, not by the regime shift, then we should use the recruitment from 1976-1983 … as the baseline to estimate $B_{35\%}$. If we believe that the regime shift during 1976/77 caused the productivity differences, then we should select the recruitments from period 1984-2015 as the baseline.*

One has to wonder: 1) why this important management dilemma is presented in the SAFE document as a belief system (more apropos of religion) rather than as evidence-based science; and 2) why there are no literature citations (pro and con) to support the managers' position (the regime shift did it) and to help readers make informed decisions as to whether the managers' position is reasonable..

The Crab Plan Team (CPT) responded:

> *Based on the author's discussion* [from the Crab SAFE, above] *regarding an apparent reduction in stock productivity associated with the well-known 1976/77 climate regime shift in the Eastern Bering Sea, the CPT continues to recommend computing average recruitment based on model recruitment using the time period 1984 … to the last year of the assessment.*

We have, then, a poorly defined (but "well-known") meteorological regime shift that, based on flimsy evidence, caused the disappearance of some 80 million (Loher and Armstrong 2005) adult red king crab (RKC). In addition, because this putative regime shift somehow has made it unlikely or impossible for the population to regain its former productivity and abundance, it is believed by managers that it would be unfair to include the relatively large, pre-collapse population estimates in the more recent, rather anemic baseline average used to quantify overfishing. In sum, it appears that managers believe the regime-shift effect on RKC is on a par with the Chicxulub event on the dinosaurs.

Now We Know Better

The problem is that, given the new, NMFS-revised population estimates, the regime-shift theory, which attributes the collapse to Mother Nature rather than to man's fishing, is no longer operative. We now know that for the years 1979-1981 BBRKC were being

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subjected to a regime of persistent overfishing, whereby 64% (58-76%) of the legal-male population was being killed annually in the directed (pot) fishery. This does not include the legal crab killed as bycatch in other fisheries, including the highly destructive bottom-trawl fishery, as shown below (Figure 7 from Dew and McConnaughey 2005).

Contents of a ''red bag'' delivered by a domestic trawler to the Soviet processor Chasovoy in late August 1981.

So Where Are The Millions Of Missing Crab?

> *"We will never know what caused the dramatic changes in the abundance of Bering Sea RKC after 1978"*. Bradley G. Stevens, King Crabs of the World, p. 589.

The precipitous collapse of Alaska's premier shellfish stock in the early 1980s was preceded by an equally baffling and spectacular increase in the stock's abundance. From 1972 to 1978, NMFS' rather precise survey estimates appeared to track a phenomenal (nearly 800%) increase in Bristol Bay legal-male abundance. For those familiar with the rudiments of population dynamics, this meteoric, 8- to 9-fold increase in a population of long-lived, late-maturing organisms should have been suspect.

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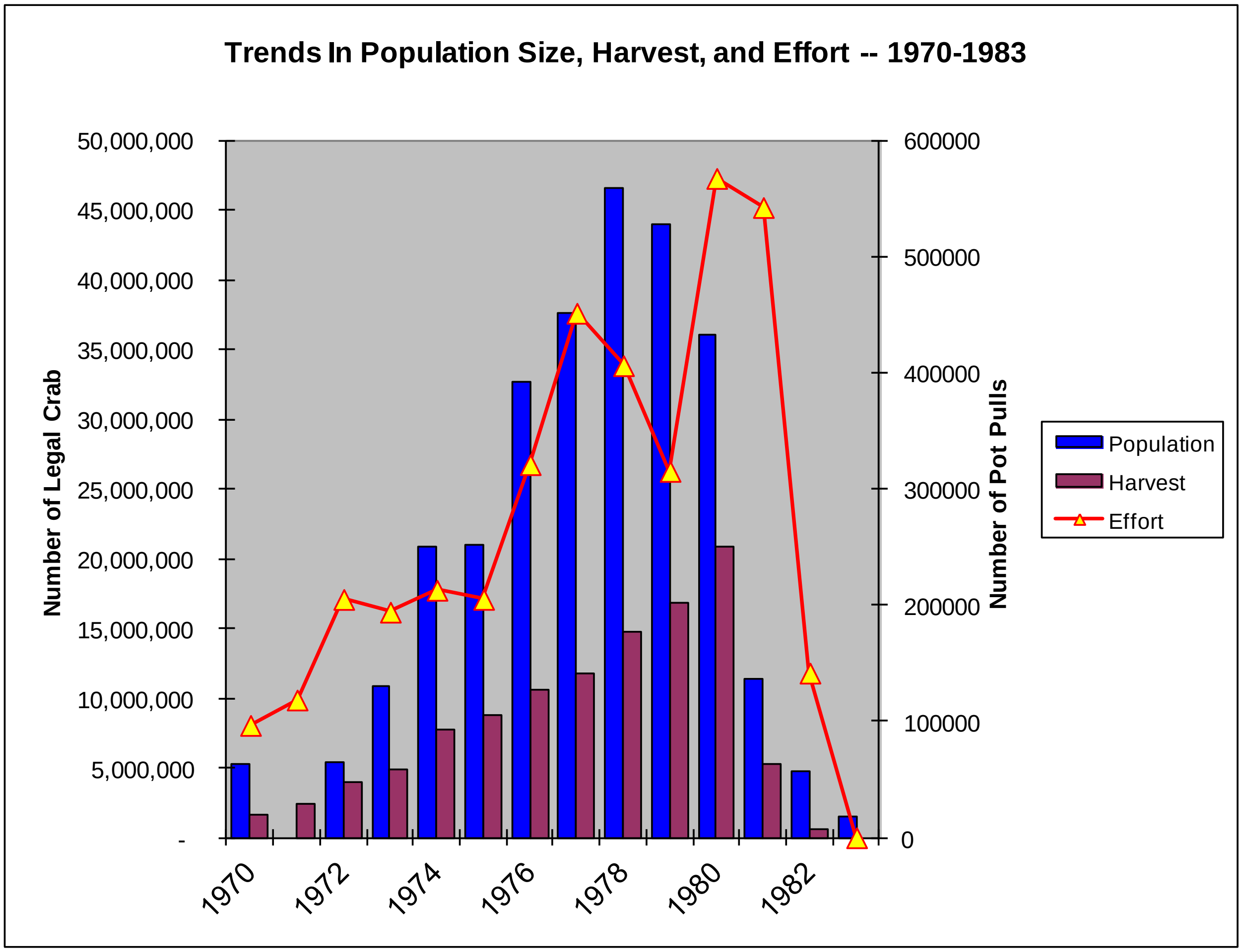
Overriding any such suspicion, however, was the euphoria of a lucrative harvest that had been doubling every 2.9 years since 1970 (Dew 2010, Figure 7).



A clue to the mystery behind this apparent population increase lies in the many deviations from, and violations of, standard sampling protocol. In NMFS' Bristol Bay bottom-trawl survey, the sampling was designed to be distributed systematically (evenly) over a uniform grid of stations (typically one tow in the approximate middle of each 400 nm^2 grid square), thereby collecting a random sample from the crab population. However, beginning in 1976, the systematic sampling design was often unbalanced by ad hoc "prospecting" tows in areas thought to be prime legal-male crab habitat. Because of these ad hoc departures from the sampling design, the annual sample collected from the crab population was no longer random; instead, after 1975, it was increasingly biased toward greater numbers of legal males. Most importantly, the annual samples collected from Bristol Bay RKC habitat (Stations A04 through J16 + Z05), because of unequal and undocumented effort, were not comparable among years.

The number of unsanctioned extra samples, which were routinely included in NMFS' population estimates, was not inconsequential. In 1979, for example, 108 non-design-based prospecting tows (up to nine at a single station, E06) were conducted within 82 Bristol Bay grid squares — a 132% deviation from the standard-survey sampling effort (see Dew 2010, Table 1).

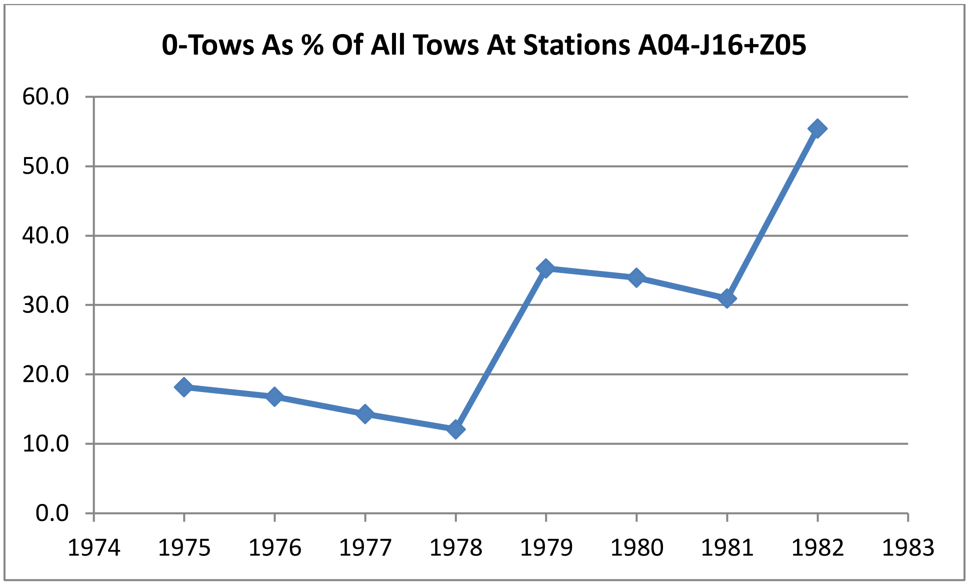
Extra sampling might not have biased the population estimates if some care had been taken to ensure that the sampling was random (it was not) and that equal effort was expended at all stations (it was not). But sampling bias was not the only problem: a more serious problem was caused by selection bias, whereby investigators selected for analysis only those tows that caught RKC. Tows that caught no RKC were not included in the station's average abundance. For example, at grid square E06 in 1979, ten tows (one standard tow and nine non-design-based extras) were conducted. Only three tows caught RKC and these three were the only tows used in calculating the average abundance at Station E06.

The multiple-tow data (# legal males per tow) for the ten repeated tows at Station E06 in 1979 are: 0, 0, 0, 0, 0, 4, 0, 130, 0, 89. The legitimate arithmetic mean of these data is 22.3 (n = 10). But by omitting the seven 0-tows, as if they had never occurred, the average jumps to 74.3 (n = 3), more than a three-fold increase. In this way, the number of legal crab estimated for grid-square E06 in 1979 went from 1.1 million to 3.6 million, a spurious increase of more than 200%. In 1979, 34 0-tows at 17 stations were scrubbed from the data in order to come up with an inflated estimate of 43.9 million legal RKC. Using only one (the first) tow at each station, consistent with the EBS systematic survey as designed, 20.3 million non-existent legal males were eliminated to obtain the NMFS-revised estimate of 23.6 million vs. the NMFS-original estimate of 43.9 million.

Scientists Imitating Fishermen

Scientists are often reluctant to use commercial fisheries data for population-size assessment because of the catch-per-unit-effort (CPUE) or catch-per-unit-area (CPUA) trap, as described by Maunder et al. (2006) and Erisman et al. (2011). RKC form large aggregations, covering areas up to at least 100 nm^2 (Dew 2010), and competent fishermen are good at finding and staying on them. Because it is as easy to find these aggregations when population abundance is low as when it is high, CPUA can remain high despite declining population abundance. Thus, it is anathema for resource-assessment scientists to play fishermen and seek to maximize survey CPUA with exploratory tows in violation of the sampling design. Such transgressions become even worse when the zero catches from the exploratory tows are disregarded in the calculation of average CPUA-values — a practice that likely falls within the realm of scientific misconduct.

There have been at least two major harmful effects resulting from NMFS/Kodiak's statistically undisciplined, extra sampling. First, the extra sampling, and its inclusion (without the zero catches) in the computation of area averages, tended to replicate the problem often found in commercial fisheries data. Specifically, the extra tows provided investigators with non-random data, spatially biased toward high catches, and lacking any record of search time (which often increases as the target population declines). In this situation, search time could have been represented by efforts that resulted in zero catches. This information, had it been presented, could have provided a warning that the stock was being overfished after 1978.



Instead, the North Pacific Fisheries Management Council and others were presented with a misleading set of catch data, which was unfettered by any honest accounting of effort, and which implied that the stock was growing like kudzu.

There is a second facet of the unsanctioned, exploratory tows that has adversely affected the management process. That is, the string of expanding population estimates, from 5 million (1970) to 47 million (1978), attesting to a nearly order-of-magnitude increase in the Bristol Bay population of legal males over a period of eight years, was improbable to the point of being nonsensical. No wonder the Crab Plan Team and others have been reluctant to include this rather incredible string of estimates in their baseline used to calculate MSST. A stock is overfished, and a rebuilding plan must be prepared for the stock, if stock abundance falls below the MSST, defined as 50% of the baseline average stock size. Therefore, the higher the baseline average stock size (and it would be higher if abundance data from 1975-1980 were included), the more conservative (protective) is the MSST.

However, rather than subjecting the NMFS astounding numbers to verification, managers since 1983 seem to have been content to scapegoat Mother Nature, theorizing (with remarkably little evidence) that the red king crab, a highly successful species evolved over hundreds of thousands of years, suddenly died by the millions and, after 1983, lapsed into a new, low-productivity state because of a rather subtle 1976-1977 meteorological “regime shift”. This management story, although convenient for Alaskan and Seattle fishermen, represents a double whammy for the crab: 1) it avoids having to acknowledge that the population was overfished; 2) it obviates the need for a rebuilding plan. In view of the recently exposed numbers game, it might be time to re-evaluate this decision. Put another way,

> *In our opinion, resetting the historical baseline to include only the remnants of a population in the aftermath of a catastrophic collapse defeats the purpose of the guidelines under MSFCMA (Dew and McConnaughey 2005).*

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