November 27, 2011

From: Dr. Corey Goodman, elected member, National Academy of Sciences, and
David Lewis, Director, U.C. Cooperative Extension Marin County

To: Steve Kinsey, Supervisor, Marin County Board of Supervisors

Re: I. Marine Mammal Commission Drakes Estero Report acceptance of NPS correlation of harbor seals with oyster activity in Becker 2011 paper

Dear Supervisor Kinsey,

You asked us to examine the NPS science concerning the oyster farm in Drakes Estero, with particular reference to the potential impact of the oyster farm on the harbor seals. Beginning in April of 2007, you were told that the Park Service had overwhelming evidence of harm to the harbor seals by the oyster farm. The first three generations of NPS claims of harm to the harbor seals fell by the wayside, but in April of this year, NPS scientists published a new paper (Becker, Press, and Allen, 2011; herein called Becker 2011) using statistical analysis to provide evidence for long-term spatial displacement of harbor seals and their pups caused by the oyster farm.

Over the past few months, we worked to understand and analyze the NPS Becker 2011 paper. As reported earlier, we concluded that the NPS assertion of long-term spatial displacement of harbor seals out of Drakes Estero attributed to oyster farm activity was incorrect. Our review of NPS data indicated that a short-term spatial displacement of harbor seals into Drakes Estero had occurred, caused by a rogue elephant seal at Double Point in 2003 (documented by NPS). Superimposed on this stochastic (random) event was a second influence – the ebb and flow of the total regional seal population. We showed that NPS incorrectly ascribed to the oyster farm the movement of harbor seals – movements that were into Drakes Estero -- caused by natural forces along the coast.

We report here on our analysis of the Marine Mammal Commission Report with a focus on one key conclusion of the Report: <u>the MMC accepted the Becker 2011 conclusion that there is a correlation between harbor seals vs. oyster farm activity</u>.

How did the MMC and we come to such different conclusions? Here we describe that the MMC made a series of errors in accepting the NPS correlation. In brief, the NPS data are so thin, and so highly influenced by a stochastic event in 2003, that they cannot possibly be used to conclude any correlation with oyster farm activity.

The November 22, 2011 MMC Drakes Estero Report accepted the National Park Service's correlation, as found in the Becker et al. 2011 paper, that as oyster activity increases, the number of harbor seals in Drakes Estero decreases. The MMC stated:

> *"The Marine Mammal Commission believes that the data supporting the above analyses are scant and have been stretched to their limit. Nevertheless, the analyses in Becker et al. (2011) provide some support for the conclusion that harbor seal habitat-use patterns and mariculture activities in Drakes Estero are at least correlated. However, the data and analyses are not sufficient to demonstrate a causal relationship. Additional, carefully guided study would be required to determine if the apparent relationship is one of cause and effect."*

Although concluding that the NPS data was "*scant*" "*stretched to their limit*," and "*not* *sufficient to demonstrate a causal relationship*," the MMC nevertheless concluded there was "*some support*" for the NPS correlation that oyster activity and harbor seals have an inverse relationship. We conclude that the NPS correlation is statistically flawed, and that the MMC mistakenly accepted that flawed relationship.

While the MMC Report accepted the NPS correlation in Becker 2011, the MMC panel members, as represented in their own reports, were more critical. In the MMC Panel Member's Report appended to the MMC Report (appendix F), Dr. Peter Boveng (National Marine Mammal Laboratory, NOAA, Seattle, WA) wrote:

> *"The statistical challenges are great, the data are marginal for that purpose, and as everyone now knows the stakes are very high (or at least perceived to be very high by many parties). Consequently, if the numbers continue to be used in an adversarial manner rather than to inform a collaborative approach, there should be yet another review, starting with a diagnostic exploration of the data (i.e., sampling properties, any inherent structure that could compromise analysis, evidence of insufficient QA/QC, etc)."*

We conducted such a "*diagnostic exploration of the data*" as recommended by MMC panel member Boveng, but the MMC and NPS both declined to do so. Correlations, especially ones based on thin data, are highly sensitive to statistical outliers -- influential observations that can lead to false conclusions about the model. The NPS correlation, based on fifteen data points, is just such a case. The NPS correlation is highly leveraged (i.e., unduly influenced) by a single outlier data point. That influential outlier is a major lethal event that took place in 2003 and led to a dramatic and transient displacement of harbor seals into Drakes Estero. The MMC correctly concluded that NPS used a "*scant*" dataset that was "*stretched to the limit*." The MMC, however, failed to acknowledge that as a result of the limited dataset, a single outlier data point could leverage – or unduly influence – a correlation that was not present in the remaining years. As a result, the MMC failed to recognize that the NPS dataset is highly leveraged by a stochastic (random) event that did not involve the oyster farm.

A single stochastic (i.e., random) event in 2003 at Double Point drove hundreds of harbor seals and pups into Drakes Estero. This highly leveraged outlier (i.e., an event that had undo influence on the NPS correlation) occurred during the same period in which the NPS models categorized (incorrectly) oyster activity at a low point. This drove an artificial correlation between low oyster activity vs. high harbor seal numbers.

Had the event at Double Point occurred from 1982-1999, or from 2005-2009, it would have driven exactly the opposite correlation in the NPS model, but by circumstances, the random Double Point event occurred when the NPS model categorized oyster activity as low. The NPS correlation was unduly influenced by this single stochastic event, leading to an unsupported correlation of harbor seals and oyster activity.

The NPS correlation of oyster activity with harbor seals is supported only by the lethal 2003 event, with some carryover into 2004, after which levels return to pre-2003 observations. According to statisticians, if a supposed relationship is correct, then removing a single observation should not destroy the claimed relationship. In this case, removing a single observation does indeed destroy the relationship. The MMC, however, reported that they did not even ask NPS to conduct this key diagnostic outlier test to address this issue, notwithstanding requests from Congress and DBOC to do so.

[As discussed later, MMC did ask NPS, and NPS did conduct a version of this test, notwithstanding MMC's assertion that they did not.]

The MMC compounded their first decision – rejecting the diagnostic test for a highly leveraged outlier – by their second decision to accept the wrong diagnostic experiment from NPS in support of the NPS correlation. In trying to account for the impact of the lethal event in 2003 on their model, the NPS was allowed to "double down" – in effect, to mistakenly add 2 + 2 = 4 when they should have subtracted 2 - 2 = 0. The NPS did not eliminate the 2003 event from their model, but rather they compounded the impact of the 2003 event in their analysis. This will be explained below.

We have discussed our analysis with the statistics professors that we previously consulted at Stanford and U.C. Davis, and with another faculty at U.C. Davis. All concur with our analysis – the NPS data are too thin and the data too leveraged (i.e., unduly influenced) by the stochastic event in 2003 to be able to support any conclusion that establishes a correlation of harbor seals with oyster farm activity. All concur that the subsequent NPS analysis was fundamentally flawed by the doubling error. <u>We affirm that the NPS correlation at the regional level in Becker 2011 is entirely supported by the stochastic event in 2003. In summary, there is no statistically significant correlation at the regional level of harbor seals with oyster activity.</u>

We believe, as a result, that there are no scientific data – and no supported correlation – upon which to make a policy decision concerning the future of the oyster farm. There is no evidence for long-term displacement of seals from Drakes Estero that can be related to shellfish aquaculture. The MMC made a series of errors when they accepted the NPS correlation.

To resolve this issue, we recommend the following: Interested parties (e.g., elected officials, agency or committee staff, and the press) can verify our analysis by consulting with independent statisticians – independent of us, the NPS, the marine mammal community, and NGOs. Any professional statistician (e.g., the American Statistical Association) could help resolve this issue. We welcome such an independent analysis.

Overview

The NPS has fifteen years of data, with one data point per year, available for its regional scale analysis (i.e., the movement of seals between Drakes Estero and the coastal haul-out sites). NPS examined a correlation using these fifteen data points. The analysis of what MMC called "*scant*" data led to a correlation between a dependent variable (the proportion of pups in Drakes Estero) and an independent variable (a categorical measure of oyster farm activity in Drakes Estero: OYST Hi/Low). The NPS analysis led to a correlation that is just barely statistically significant.

Dr. Goodman initially examined the NPS analysis and observed that the NPS correlation appeared to be driven (or was highly leveraged) by a single influential stochastic event that took place in 2003. In 2003, according to NPS records, a single rogue (or lethal) elephant seal at Double Point (a coastal haul-out site) killed ~ 40 harbor seals and drove ~ 300 harbor seals into Drakes Estero, thus dramatically increasing the proportion of pups in Drakes Estero for 2003 (and with a residual decay in 2004). The proportion returned to baseline in 2005.

Goodman and Lewis evaluated the NPS correlation by eliminating the influential outlier year (2003) and determined that this single data point leveraged the published correlation -- the correlation was no longer statistically significant ($P > 0.1$). There was a residual impact of the 2003 event in 2004, and thus eliminating this year also led (to a lesser extent) to a decrease in statistical significance. However, we showed that the other thirteen data points, when eliminated one at a time, did not significantly lower the statistical significance of the relationship. We concluded that the influential outlier year (2003) had a disproportionate influence on the NPS correlation, and that the main independent variable used by the NPS (oyster farm activity) did not correlate with the dependent variable (number of harbor seals) when the stochastic event was removed.

The MMC examined the NPS analysis, and worked with NPS to redo their analysis, but refused to ask NPS to properly test their model by removing the single outlier as requested by Congress and DBOC. Dr. Tim Ragen, Executive Director, MMC, wrote to Kevin Lunny on November 17, just a few days before releasing the MMC Report:

> "*I did not ask the Service to run its analyses without the 2003 and 2004 data points, as I do not believe anyone has provided legitimate justification for doing so. You can go through any statistically significant relationship and pick out certain data points that, if removed, would reduce the significance of the relationship. However, if there is not a specific reason for doing so, then that is cherry picking*."

We disagree. There is a "*legitimate justification*." First, if one compares Figure 5 in the MMC Report (below) with the May 2007 figure from Koenen and Allen NPS Research Project Summary Report (next page), it is clear that a stochastic event at Double Point in 2003 had a major influence on seals and pups in Drakes Estero in 2003 & 2004.

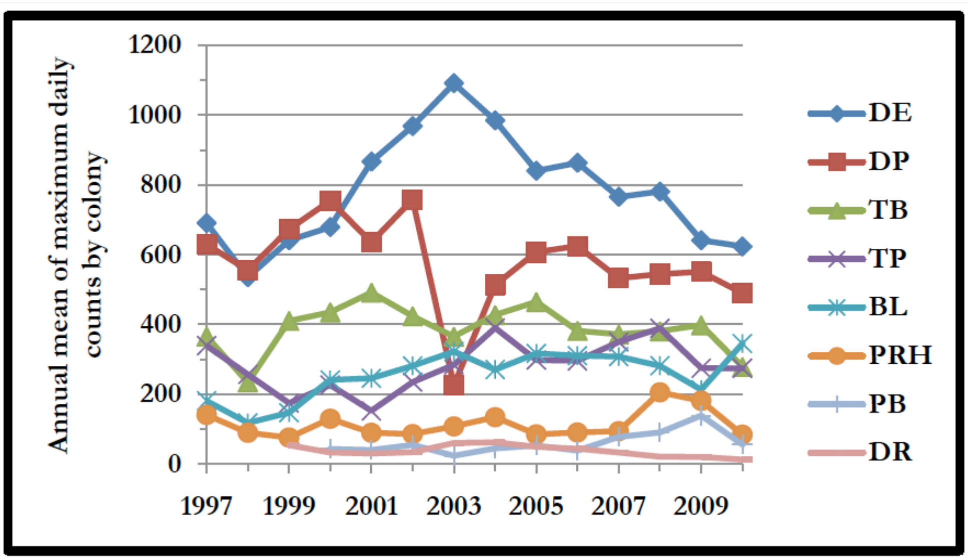
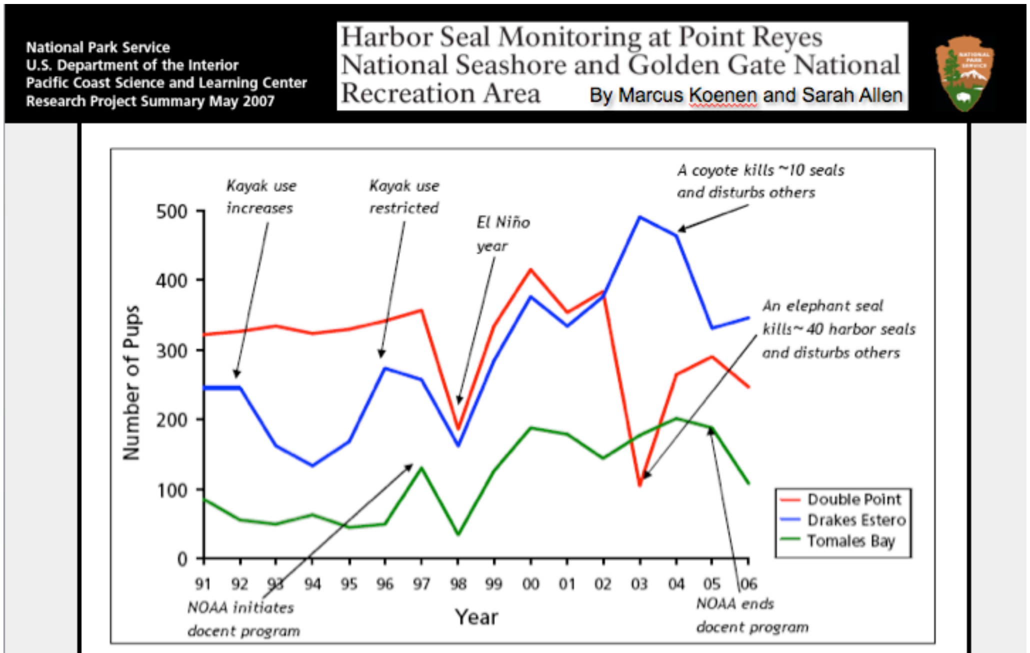


Figure 5. Annual mean of maximum daily counts (adults and pups) by colony and during the full year (left axis), and total of those counts (right axis). Colonies are Drake's Estero (DE), Double Point (DP), Tomales Bay (TB), Tomales Point (TP), Bolinas Lagoon (BL), Point Reyes Headland (PRH), Point Bonita (PB), and Duxbury Reef (DR) (data from National Park Service)



The harbor seal pup population is sensitive to human disturbance, climate variability and interactions with other species. Different management approaches also affect the seal population.

Second, the MMC acknowledged that there was a legitimate justification to test the impact of the stochastic event in 2003, they just objected to our diagnostic test. Third, according to statisticians, it is common in regression analysis to determine if one point highly leverages a correlation. Such an analysis was particularly critical in this case since the NPS correlation was based upon such thin (or "*scant*") data that a stochastic event could have led to a false conclusion.

Statistics textbooks (see below) recommend checking for influential points, particularly points that are so unduly influential that they support the entirety of a supposed relationship. In a case such as this in which the outlier point is caused by an unrelated stochastic event (i.e., the cause is known), it is common to diagnose whether that stochastic event unduly influences the correlation by eliminating the highly leveraged data point and then testing the significance and coefficient of the remaining data.

Our analysis concluded that the NPS correlation is leveraged by a single data point (the 2003 event). This brings both the NPS correlation and the MMC acceptance of that correlation into question. The data are simply too thin to draw any conclusion.

We present our reasoning below why (i) it was legitimate to test the NPS correlation by eliminating the stochastic 2003 event; (ii) it was a mistake for MMC to reject the request by Congress and DBOC to ask NPS to test the NPS model by eliminating 2003; and (iii) it was a mistake for the MMC to allow NPS to substitute a different test that did not assess whether 2003 leveraged the NPS oyster activity model. NPS added another independent variable leveraged by the same event. This revealed the importance of the 2003 event, but failed to test its influence on the oyster activity variable.

Thus, we agree with the MMC that the NPS data are "*scant*" and "*stretched to the limit*." However, we disagree with the MMC acceptance of the NPS correlation. The NPS data are so thin that a single stochastic event in 2003 unduly influenced the NPS correlation. The NPS data do not support the NPS correlation – the scant data do not permit any conclusion about harbor seals and oyster activity, and certainly present no scientific evidence on which to base either a scientific conclusion or a resulting policy decision.

The NPS Becker, Press, and Allen 2011 paper

In April 2011, NPS Dr. Becker, Mr. Press, and Dr. Allen published a peer-reviewed paper claiming to have evidence showing long-term spatial displacement of harbor seals (and in particular mothers and their pups) out of Drakes Estero with increased oyster activity. The NPS paper was based in part upon a statistical analysis at the regional scale using a General Linear Model (GLM using AIC analysis) of fifteen data points (one per year: 1982-1983, 1997-2009).

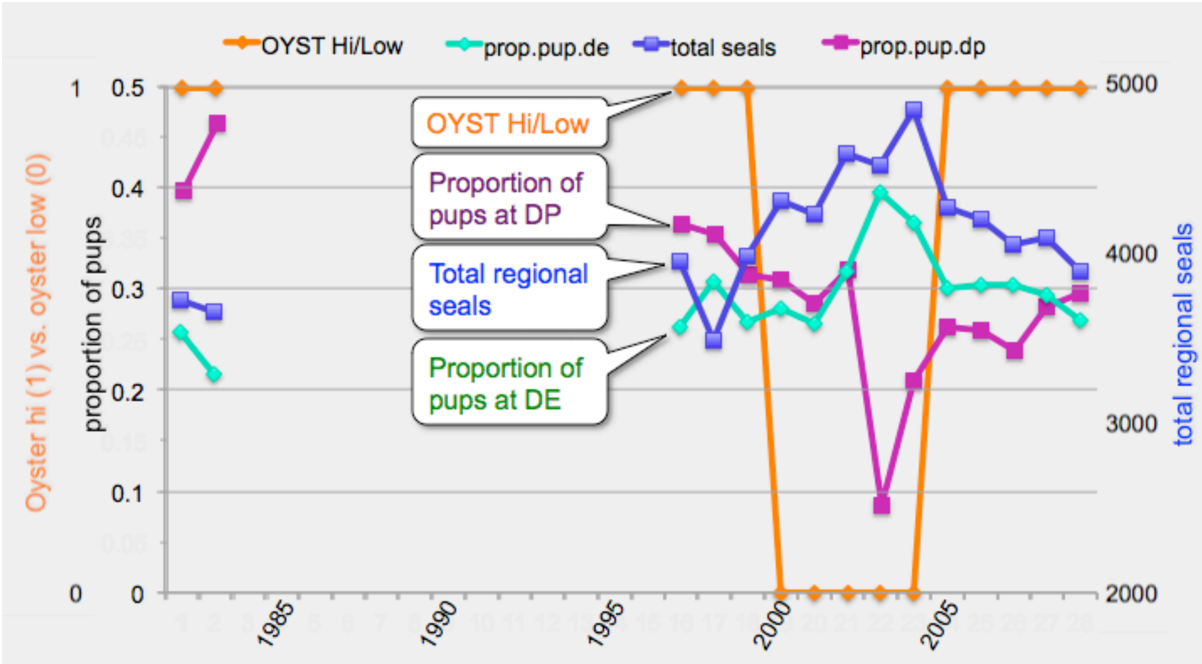
NPS used a Hi/Low categorical designation as a measure of oyster activity to correlate with the proportion of seals and pups in Drakes Estero. The OYST Hi/Low designation had "high" activity in ten years (1982-1983, 1997-1999, 2005-2009) and "low" activity in five intervening years (2000-2004) at sandbars UEN and OB (the oyster bag beds closest to the seal haul-out sites) during pupping season (March to May). We do not agree with the high vs. low categorical designation, but our analysis below accepts the (incorrect) designation and tests whether it correlates with seals and pups. In a separate document we will return to the issue of MMC accepting this categorical designation.

Dr. Goodman's analysis

At the invitation of the MMC, Dr. Goodman submitted a detailed review of the Becker 2011 paper on August 29. Goodman was struck by what the NPS data showed, namely, that the number of harbor seals (and in particular mothers and their pups) went up transiently in Drakes Estero in 2003, partially dropped back down in 2004, and returned to baseline in 2005. There did not appear to be a long-term movement of seals and pups **out** of Drakes Estero, but rather a short-term movement of seals **into** Drakes Estero.

What caused this transient spike in seals and pups into Drakes Estero? The answer was found in additional NPS records documenting a rogue – or lethal – elephant seal in 2003 at Double Point, one of the major harbor seal (and shared elephant seal) haul-out sites along the Point Reyes coast. According to a 2007 NPS document, in 2003, this single elephant seal killed ~ 40 harbor seals and chased ~ 600 seals and pups away from Double Point. The numbers from that year, and historical trends, suggest that ~ 300 of those seals and pups (~ 50% of them) were displaced **into** Drakes Estero. The traumatized harbor seals apparently had a decaying memory of the 2003 event, and thus there was a residual impact on seal distribution (between Double Point and Drakes Estero) the following year (2004), returning to baseline in 2005.

In brief, in 2003, there was a precipitous decrease in seals and pups at Double Point with a concomitant dramatic increase in seals and pups in Drakes Estero, all apparently caused by a stochastic event – a single lethal elephant seal. Thus, 2003 was an outlier data point (with a residual impact in 2004) that unduly influenced the fifteen-year correlation between oyster activity and harbor seals.



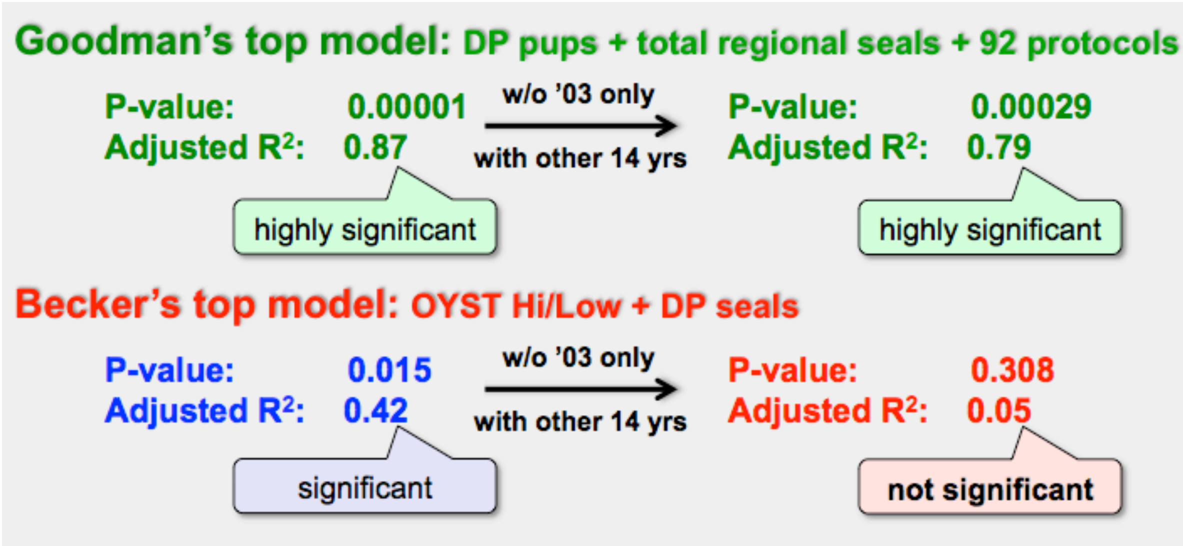
Dr. Goodman's August 29 analysis was based upon a statistical analysis using Multiple Linear Regression (MLR using adjusted R squared) of the same fifteen data points as in the Becker 2011 paper. As a diagnostic tool, given that 2003 appeared to be an outlier data point (with a residual impact in 2004), Dr. Goodman deleted 2003 and 2004 and tested the remaining thirteen years. He showed that when 2003 and 2004 were eliminated, the remaining years had no statistical significance in the relationship between oyster activity and harbor seals – the relationship was effectively flat-lined.

Goodman and Lewis supplemental analysis

In response to a critique from Dr. Dominique Richard, Goodman and Lewis provided MMC with further analyses on October 23 to supplement Goodman's August 29 analysis. Richard was critical of Goodman for using a different statistical method than Becker 2011. Richard did not know (and evidently MMC had not provided) that Goodman had already reported to MMC the answer to that issue. Lewis had repeated Goodman's analysis with the same statistical method as used in the Becker 2011 paper (GLM using AIC) and derived the same conclusions: the NPS correlation with oyster activity was leveraged by the stochastic event at Double Point in 2003. Both analyses reached the same conclusion: the NPS correlation was leveraged by the 2003 event.

Goodman and Lewis made two further additions to Goodman's initial analysis in their October 23 supplemental analysis. First, they tested the "outlier hypothesis" by scanning all fifteen years one at a time. In his August 29 report, Goodman had eliminated both years impacted by the stochastic event at Double Point: 2003 and 2004. We went a step further by showing that when 2003 alone was eliminated from the analysis, the remaining fourteen years had no statistical significance in the relationship between oyster activity and harbor seals. In addition, we did this diagnostic test – the elimination of 2003 alone – using both statistical methods head-to-head (i.e., GLM using

AIC vs. MLR using R squared) and derived the same conclusion.

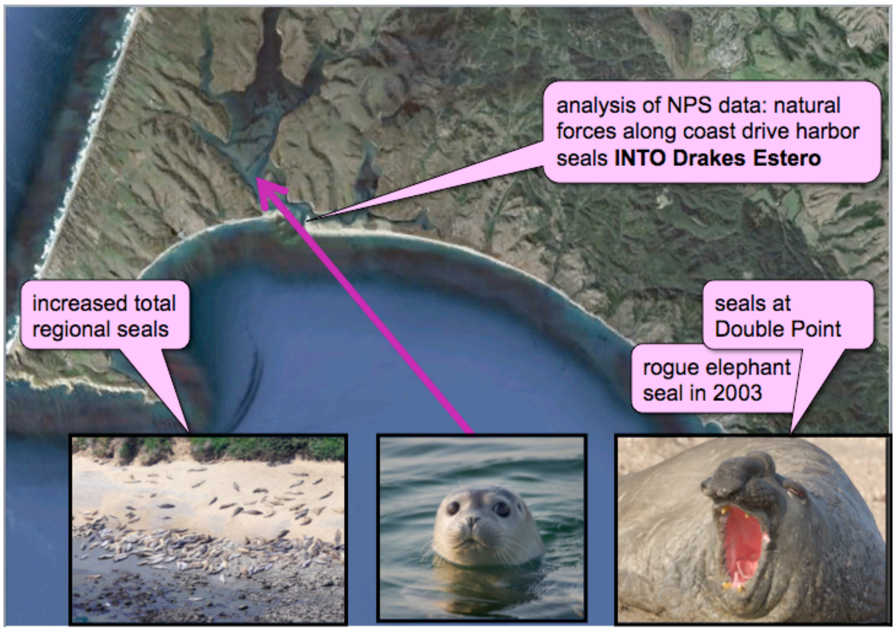


Significant = green; not significant = red		
ANALYSIS WITH 2003	**Multiple Linear Regression P-values**	**Generalized Linear Model P-values**
Goodman's Top Model:	0.00001	
DP pups	0.00005	< 0.0001
Total regional seals	0.00014	0.0002
92 protocols	0.01579	0.0127
Becker's Top Model:	0.01474	
OYST Hi/Low	0.00842	0.011
Double Point seals	0.03463	0.0463
ANALYSIS WITHOUT 2003	**Multiple Linear Regression P-values**	**Generalized Linear Model P-values**
Goodman's Top Model:	0.00029	
DP pups	0.00229	0.0024
Total regional seals	0.00080	0.0008
92 protocols	0.02054	0.0163
Becker's Top Model:	0.87444	
OYST Hi/Low	0.68948	0.1581
Double Point seals	0.91052	0.4774

We concluded that the NPS correlation was leveraged (i.e., unduly influenced) by an outlier data point – a lethal event in 2003. When 2003 alone was eliminated, NPS Becker's best model was no longer statistically significant. We concluded that what was called a long-term displacement OUT of Drakes Estero was actually a short-term displacement INTO Drakes Estero caused by the lethal event at Double Point.

Note: concerning Goodman's top model shown above (DP pups + total regional seals + 92 protocols), the MMC Report criticized it because of a built-in dependency: the "total regional seals" independent variable contained within it "Drakes Estero pups" also found in the dependent variable. In response, we re-ran our analysis using a modified version of Goodman's model (DP pups + total regional adults + 92 protocols) and obtained the same result. This modified model, either alone or when 2003 is eliminated, remains three orders of magnitude more significant than Becker's best model.

DP pups + total regional seals + 92 prot. (original) adj $R^2 = 0.87$ P-value = 0.00001
DP pups + total regional adults + 92 protocols (new) adj $R^2 = 0.86$ P-value = 0.00001
DP pups + total regional adults + 92 protocols (-2003) adj $R^2 = 0.80$ P-value = 0.0002



Marine Mammal Commission response to Goodman's analysis

Kevin Lunny wrote to Dr. Ragen, Executive Director, MMC, on September 12 and asked a series of seven questions intended for NPS Dr. Ben Becker. Lunny wrote:

> *"Is your OYST independent variable on its own, when run against the proportion of pups in Drakes Estero, still statistically significant when you exclude the years … 2003 and 2004?"*

Lunny submitted this question before we submitted to Ragen on October 23 that the NPS correlation was no longer significant when 2003 alone was eliminated. Thus, Lunny requested elimination of both 2003 and 2004, when elimination of 2003 alone was sufficient. Ragen responded to Lunny over two months later on November 17:

> *"I did not ask the Service to run its analyses without the 2003 and 2004 data points, as I do not believe anyone has provided legitimate justification for doing so. You can go though any statistically significant relationship and pick out certain data points that, if removed, would reduce the significance of the relationship. However, if there is not a specific reason for doing so, then that is cherry picking. The better way to handle a situation like this is to make sure that you are using a statistical model that accurately represents the relationship being*

> *depicted. In this case, I believe that Dr. Harwood provided the best guidance for how to model the influence of the 2003 Double Point event, and that was by modeling it as an abrupt change that rapidly (exponentially or logarithmically) dissipates. With that in mind, I did ask the Service to run the analysis modeling Double Point as suggested by Dr. Harwood. See the attachments."*

This email to Lunny forms the basis of the reasoning behind the MMC acceptance of the NPS correlation (see page 54 and 55 of the MMC report). There are two key points to Ragen's comment and Becker's additional analysis: first, he contended that there was no "*legitimate justification*" for eliminating 2003 and 2004 (or 2003 alone) and thus he did not ask NPS to do so; and second, he instead asked NPS to do what Harwood had suggested, namely, to model the 2003 event as either an exponential or logarithmic decay. Below we deal with each of these points.

It was legitimate to test the NPS model by eliminating single data points

Dr. Ragen argued that he had been provided with no legitimate justification for testing the NPS Becker correlation by eliminating 2003 and 2004 (or 2003 alone), and thus did not ask NPS to do so (this statement was not accurate as the MMC actually had asked NPS to do this test – see below). Yet, a few sentences later in the same paragraph, he contradicted his argument by agreeing that there was indeed a special stochastic event in 2003 at Double Point, and that is was worth modeling the influence of that event.

Clearly, Ragen considered the lethal 2003 event at Double Point to be a legitimate reason to add an additional independent variable, so it is difficult to understand why it was not equally legitimate to consider eliminating the data point as a diagnostic test of whether it highly leveraged (i.e., unduly influenced) the OYST Hi/Low variable. Ragen considered it legitimate to remove 1982 and 1983 in another part of the MMC report (thus accepting this diagnostic method). Thus, why was it not equally legitimate to eliminate 2003 and 2004, or 2003 alone as we submitted to him on October 23?

It is common in regression analysis to determine if one data point leverages (or unduly influences) the correlation (or relationship) in a dataset. Is the relationship "real" and based upon the majority of data points? Or is the relationship unduly influenced by a single data point? That is a standard question in statistics that textbooks and lectures deal with, and that confronts all regression – or correlation – analysis. The issue is particularly acute with the NPS correlation because the data are so limited.

Statistics textbooks recommend checking for influential data points. If the correlation is leveraged by a single point, it brings the correlation into question. In this case, testing 2003 was justified – it is an outlier based upon the rogue (or lethal) elephant seal at Double Point that caused a lethal event. A few examples are provided below.

The Rockefeller lecture "*Regression Diagnostics*" states:

> "*Outliers can sometimes cause problems with regression results*." The problem is when "*one observation is allowed to have too much influence over the regression (and any research or policy conclusions that flow from it). One solution is to report findings with and without outliers so that fair readers can make up their own minds*."

In "*A Review of Statistical Outlier Methods*" from 2006, Steven Walfish wrote:

> *"An outlier has a low probability that it originates from the same statistical distribution as the other observations in the data set. … Once an observation is identified—by means of graphical or visual inspection—as a potential outlier, root cause analysis should begin to determine whether an assignable cause can be found for the spurious result."*
>
> *"Outliers in regression can overstate the coefficient of determination (R^2), give erroneous values for the slope and intercept, and in many cases lead to false conclusions about the model. Outliers in regression usually are detected with graphical methods such as residual plots including deleted residuals."*
>
> *"When performing regression analysis, always review residual plots to ensure no outliers are affecting the model coefficients and inflating the R^2 value."*

In "*The power of outliers (and why researchers should ALWAYS check for them)*" from 2004, Jason Osborne and Amy Overbay from North Carolina State University wrote:

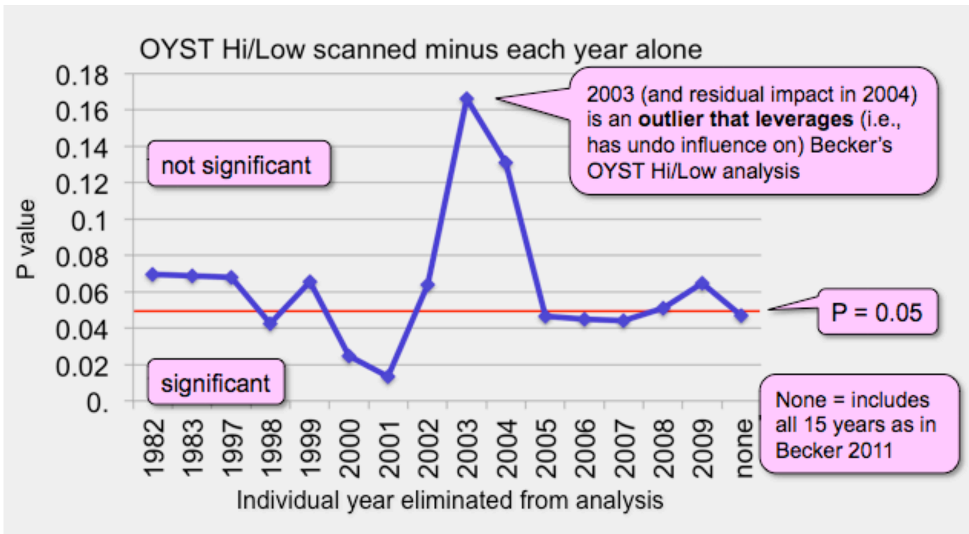
> *"Conceptually, there are strong arguments for removal or alteration of outliers. The analyses reported in this paper also empirically demonstrate the benefits of outlier removal. Both correlations and t-tests tended to show significant changes in statistics as a function of removal of outliers, and in the overwhelming majority of analyses accuracy of estimates were enhanced. In most cases errors of inference were significantly reduced, a prime argument for screening and removal of outliers."*

In the UCLA online statistics book "*Regression Diagnostics*" the authors wrote:

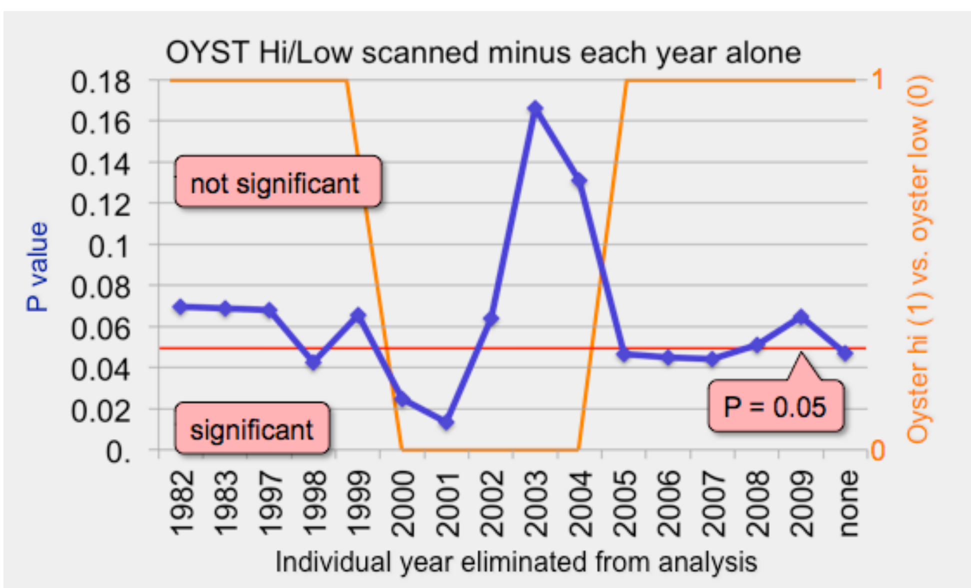
> *"A single observation that is substantially different from all other observations can make a large difference in the results of your regression analysis. If a single observation (or small group of observations) substantially changes your results, you would want to know about this and investigate further. There are three ways that an observation can be unusual.*
>
> *Outliers: In linear regression, an outlier is an observation with large residual. In other words, it is an observation whose dependent-variable value is unusual given its values on the predictor variables. An outlier may indicate a sample peculiarity or may indicate a data entry error or other problem.*
>
> *Leverage: An observation with an extreme value on a predictor variable is called a point with high leverage. Leverage is a measure of how far an observation deviates from the mean of that variable. These leverage points can have an effect on the estimate of regression coefficients.*
>
> *Influence: An observation is said to be influential if removing the observation substantially changes the estimate of coefficients. Influence can be thought of as the product of leverage and outlierness."*

In conclusion, to determine the integrity of a correlation, it is accepted to diagnostically test whether a single observation (or small group of observations) substantially leverages the relationship. Given the thin data used to determine the NPS correlation, it is particularly important to determine if the stochastic event in 2003 had undo influence on the NPS correlation. We concluded that it did.

Below is a test of the key NPS correlation in Becker 2011 (proportion of pups in Drakes Estero vs. OYST Hi/Low) with a scan in which each year was removed individually. Only elimination of 2003 & 2004 lead to significant decreases in the P value (remember that statistical significance is measured by P < 0.05). OYST Hi/Low is leveraged by 2003 & 2004. 2003 is the year of the rogue elephant seal at Double Point. The impact of this event persisted with decay into 2004. Thus, the request to test the NPS model without 2003 & 2004 (or 2003 alone) was justified. This diagnostic test showed that without the 2003 event, the NPS correlation was not statistically significant.



The NPS correlation was artificially driven because the 2003 stochastic event (the rogue elephant seal at Double Point) coincided with the (equally artificial) "low" oyster activity designation in the NPS model (see below). Notice the increase in statistical significance when 2000 and 2001 are removed, further suggesting that the OYST Hi/Low model is highly leveraged by the stochastic 2003 event at Double Point.



NPS improperly tested the NPS correlation by modeling the stochastic 2003 event as another independent variable

The MMC engaged Dr. Harwood from St. Andrews, Scotland, to review the Becker 2011 paper. Harwood, in his analysis of Becker 2011 for the MMC, also recognized that an unusual event in 2003 – the rogue elephant seal at Double Point – was likely to have leveraged much of Becker's analysis, although he did not know the full extent of the NPS data. After reading Goodman's analysis, Harwood wrote on September 2:

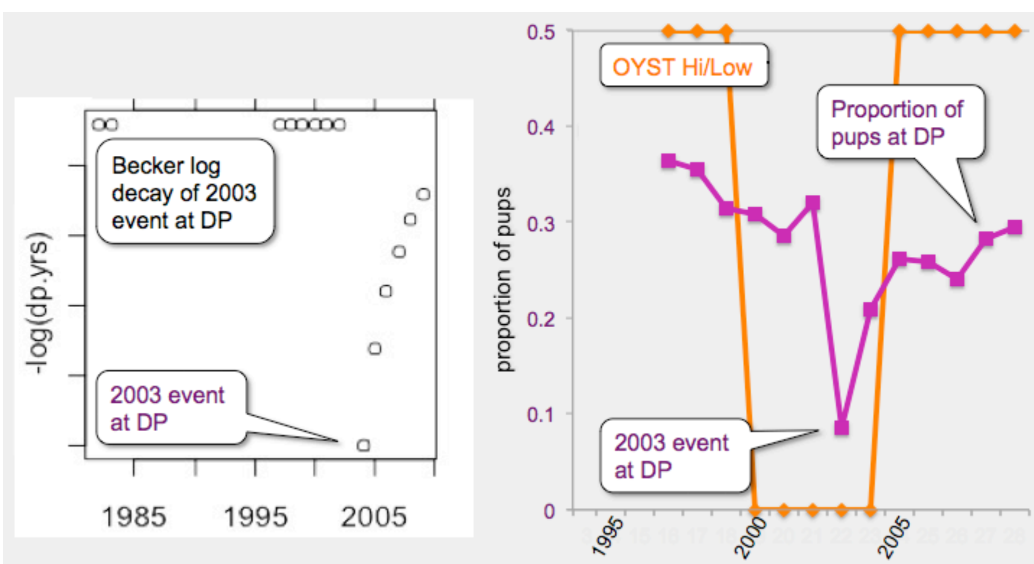
> *"[Goodman] also provides more detailed information about the impact of the "rogue" elephant seal at Double Point in 2003, which suggest that its impact was greater than described in Becker et al (they simply describe it as "aggressive", not lethal!) …"*

In his initial analysis of the Becker 2011 paper, Harwood wrote on August 29:

> *"The most likely explanation of these changes is that a large number of mothers and pups deserted Double Point in 2003, presumably because of the presence of the aggressive elephant seal, for other colonies, particularly Drakes Estero. These animals gradually returned to Double Point from 2004 onwards."*
>
> *"I think it would be more appropriate to model this disturbance in exactly the same way as the 1998 ENSO event: a fixed effect (whose size is estimated by the appropriate coefficient in the GLM) in 2003, whose influence declines exponentially over time."*

In the Becker 2011 paper, the NPS scientists tested the ENSO event in 1998 by modeling it as a fixed event whose influence declined exponentially over time. That would be an acceptable way of modeling the 2003 event, essentially accounting for the dramatic displacement of seals and pups into Drakes Estero in 2003, with a residual impact (modeled as an exponential or logarithmic decay) in 2004. [Some scientists would prefer to model the event using the raw data rather than a best-fit curve.]

Below is shown Becker's logarithmic model for the 2003 event, a mathematical model that is a good best-fit curve for the proportion of pups at Double Point.



To add another independent variable with the 2003 event [as Becker did with *exp(double point event.yrs)* or *log(double point event.yrs)*] does not test whether the OYST Hi/Low independent variable is highly leveraged by the 2003 event. Rather, Becker's introduction of a new independent variable (not in Becker 2011) doubles down on the 2003 event – it creates a new independent variable that by definition is leveraged to model the 2003 event.

Becker used different parameters for the dependent variable than in Becker 2011 (see discussion below), Becker then showed the following R^2 values:

OYST Hi/Low + log(Double Point.yrs)	$R^2 = 0.83$
log(Double Point.yrs)	$R^2 = 0.72$
OYST Hi/Low	$R^2 = 0.42$

By doubling down on the 2003 event, the R^2 value doubled. In Table 9 (next page) in the MMC Report these numbers are not put side-by-side to show that log (Double Point) as a single variable is superior to OYST Hi/Low suggesting that the 2003 event at Double Point predicted 72% of the variability in the harbor seal counts. The Best-fit curve for the 2003 event (modeled with a log decay) was clearly the best single model.

Table 9. QAICc ranking of models with exponentially decaying function for Double Point

Model	QAICc	ΔQAICc	r^2
Oyster (High/Low) + log(Double Point.yrs)	81.3	0.0	0.83
Oyster (continuous)+ log(Double Point.yrs)	84.1	2.8	0.78
Log(Double Point.yrs)	84.7	3.4	0.72
Exp(Double Point.yrs)	88.2	6.9	0.67

The issue was to determine if the 2003 event had undo influence on the OYST Hi/Low analysis. MMC rejected (incorrectly) the diagnostic test of eliminating the 2003 event and testing the remaining years. NPS modeled the 2003 event at Double Point as an abrupt change with an exponential or logarithmic decay. That much was acceptable.

Becker however erred. Becker should have subtracted the change from his model OYST Hi/Low. Instead Becker added the 2003 event model as another independent covariate. If OYST Hi/Low was leveraged by 2003, as the Goodman and Lewis analysis indicated, then adding another 2003-leveraged covariate would not decrease the significance of the OYST Hi/Low covariate – it would simply add one to another – or in the gambler's bet – double down on the bet on the 2003 event.

If OYST Hi/Low is leveraged by 2003, then adding another term leveraged by that same year is not a proper test of the NPS model. In other words, whereas Becker effectively added 2 + 2 = 4 by adding the 2003 event as another independent variable, he should have effectively subtracted 2 – 2 = 0 by statistically removing 2003 (and the decay in 2004) from the OYST Hi/Low variable. Goodman and Lewis had already done so in the simplest way, by simply eliminating 2003 alone from the model (and thus eliminating the outlier point that was unduly influencing the correlation) and also by eliminating both 2003 and 2004. They scanned the correlation by removing each data point individually to look at the influence of each point on the statistical significance.

The MMC accepted Becker's analysis using the log(Double Point.yrs) independent variable as the test that Harwood recommended. Having had our request for open discussion with Harwood rejected by MMC in early September, and Harwood's

September 2 comments on our analysis not provided to us by MMC until November 4, we are left re-reading Harwood's August review, trying to determine in what context Harwood proposed this experiment. Keep in mind that Harwood wrote his suggestion before reading Goodman's analysis. Harwood's suggestion was an appropriate way to test the importance of the 2003 Double Point event as an independent variable. But it was not an appropriate way to diagnose if the OYST Hi/Low variable was unduly influenced by the 2003 event. We do not know how Harwood intended his suggestion to be used.

In essence, what Becker did was to take his OYST Hi/Low variable, which was already leveraged by the 2003 event, and add to it another independent variable that was entirely leveraged by the 2003 event (by definition of the best-fit curve). Thus, it is not surprising that he got a larger R squared. In fact, given the notion of the importance of the 2003 event, it would have been surprising if he had not. His two independent variables were different manifestations leveraged by the 2003 event at Double Point.

MMC did in fact ask NPS to run its analyses without 2003 and 2004

As mentioned above, on September 12, Kevin Lunny wrote to Dr. Ragen and asked a series of questions intended for NPS Dr. Ben Becker after NPS Superintendent Muldoon told Lunny that they would not answer questions directly, but would only respond to questions from the MMC. Ragen responded to Lunny over two months later on November 17 (and just a few days before the release of the MMC Report on November 22):

> *"I did not ask the Service to run its analyses without the 2003 and 2004 data points, as I do not believe anyone has provided legitimate justification for doing so. You can go though any statistically significant relationship and pick out certain data points that, if removed, would reduce the significance of the relationship. However, if there is not a specific reason for doing so, then that is cherry picking."*

During September and October, Lunny repeatedly asked Ragen whether he had submitted Lunny's questions to Becker. On September 19, Ragen answered:

> "*I'll let you know when I have sent them and have a response*."

On September 28, Ragen wrote:

> "*… I am not inclined to send anything until I am confident that I have everything as close to right as possible*."

Ragen wrote to Lunny on November 17 (just a few days before release of the MMC Report) and reversed himself and said that he had not asked the Park Service to do the experiment of eliminating 2003 and 2004. Ragen misled Lunny.

Six days after writing Lunny, on November 23 (a day after the release of the MMC Report), we obtained a copy of an undated report that Dr. Becker submitted to Dr. Ragen that contradicted Ragen's written statement to Lunny. It appears to have been prepared after August 29 and prior to Dr. Ragen's completion and release of the MMC report. Entitled "*Analysis of Drakes Estero Mean Seal Count Data without 2003 and 2004 data (with and without 1982-1983),*" in this report Becker analyzes the regional scale analysis of OYST Hi/Low without 2003 and 2004 that Ragen told Lunny on the 17th that he did not ask Becker to do. Becker wrote:

> "*prepared at the request of the Marine Mammal Commission*"

> "*… at the request of the MMC, we performed this analysis sans 2003-2004.*"

We do not know when Ragen asked Becker to do this experiment. Since Ragen told us that his report was nearly finished on November 1, we reasonably assume that he knew the results of all of the additional analyses by then. We were never informed about Becker's further analysis. We do not know why Ragen did not discuss this analysis with us in an open process. These results appear to confirm what Goodman and Lewis had concluded, namely, that the NPS correlation is highly leveraged by 2003 and 2004.

Becker argued that it was "*problematic to simply throw out data points*" and that he did "*not endorse the technique of throwing out data points*." As mentioned above, such a diagnostic test of influential outlier points is common in statistical analysis. Becker argued that Harwood's approach is better, but then Becker employed that approach inappropriately – adding an additional independent variable rather than testing if the 2003 event highly leveraged the OYST Hi/Low correlation.

For other analyses, such as exclusion of 2003 and 2004 while testing the NPS correlation at the colony scale, Becker provided both the coefficients and the P-values. But for his analysis in which he eliminated 2003 and 2004 while testing the NPS correlation at the regional scale, Becker did not provide the coefficients or P-values. It appears as if the P-values may no longer have been statistically significant. This is suggested by the low R^2 value. The R^2 value dropped from 0.42 to 0.13 when 2003 and 2004 were eliminated.

Concerning the analysis with the elimination of 2003 and 2004, Becker wrote:

> *"However, this analysis is certainly inferior to models explicitly accounting for a Double Point effect which have already been submitted to MMC."*

The difference is dramatic. When the 2003 event is eliminated from the OYST Hi/Low analysis by deleting 2003 and 2004, the R^2 value is 0.13. When the 2003 event is essentially duplicated in the OYST Hi/Low analysis by adding another independent variable entirely leveraged by that event (by definition), the R^2 value is 0.83. The R^2 value of the 2003 event [log(Double Point)] independent variable on its own is 0.72 (compared to 0.42 for the OYST Hi/Low variable on its own).

OYST Hi/Low + log(Double Point.yrs)	$R^2 = 0.83$	
log(Double Point.yrs)	$R^2 = 0.72$	
OYST Hi/Low (with new parameters)	$R^2 = 0.42$	in Becker 2011, $R^2 = 0.26$
OYST Hi/Low - 2003	$R^2 = 0.13$	

In the analysis in Becker 2011, the OYST Hi/Low model gave an R^2 value of 0.26. In Becker's new analysis, OYST Hi/Low gives an R^2 value of 0.42. What caused the 60% increase? The answer: Becker changed the parameters of his dependent variable, and as a result, included a greater influence of the changing total regional population.

Becker changed parameters compared to Becker 2011 and included more influence of the ebb and flow of the total regional seal population

Although the MMC Report implies that Becker's further analysis confirmed the Becker 2011 paper, in fact Becker changed virtually every parameter of the dependent variable (the measure of harbor seals in Drakes Estero) compared to what he published in Becker 2011. Whereas we analyzed Becker 2011, Becker provided a whole new analysis using new variables (Becker 2011 version 2.0). We believe that at least one of Becker's changed parameters artificially increased the NPS correlation by increasing the impact of the ebb and flow of the total regional population, something that was partly normalized in the original analysis. By changing most of the parameters of the dependent variable, Becker was no longer reviewing Becker 2011, but rather a modified Becker 2011 that undermined MMC's ability to conclude that Becker 2011 was affirmed.

Although Harwood suggested that NPS focus on pups and not seals, Becker did the opposite and focused his new analysis on seals and not pups. Becker changed from measuring the maximum (peak breeding season) harbor seal count to the mean count between April 15 and May 15. Because of what was contained in the NPS database, Becker measured the mean differently in different years, ranging from the mean of a collection of individual observation data points, to the mean of the weekly maximum count.

Becker changed from measuring the proportion of seals or pups in Drakes Estero to measuring the actual seal count level (which could be influenced by total regional population changes, see below). Finally, Becker added an additional year: 2010.

It is important to note that we do not have much of the data Becker relied upon for his new analysis. Neither NPS nor MMC provided it. While we requested and received the data used for Becker 2011, and were thus able to test the NPS models, we do not have the mean data or the 2010 data (or any other undisclosed data that might have been used in Becker's review).

Dependent variable & dataset	Becker, Press, Allen 2011 paper	Goodman & Lewis analysis	Becker November 7, 2011 response
Dependent variable: Pups?	Yes, pups and seals (pups larger impact)	Yes, focus on pups (but also did seals)	**No**, only seals
Dependent variable: Maximum?	Yes, maximum (peak breeding season)	Yes, maximum (peak breeding season)	**No**, mean (4/15-5/15, except '82-83, '97-99)
Dependent variable: Proportion?	Yes, proportion	Yes, proportion	**No**, total seal counts
Used 7/28/11 NPS "Becker 2011" data?	Yes	Yes	**No**
Data available for independent review?	Yes	Yes	**No**
Used same years as in Becker 2011?	Yes	Yes	**No** (added 2010)

Could Becker's changes in parameters have influenced the statistical outcome? The answer is yes. In particular, we are concerned about the shift from proportion of seals or pups in Drakes Estero to the absolute seal count number. When Becker 2011 defined the dependent variable as the proportion of seals or pups in Drakes Estero, he normalized for the impact per se of the total regional population by measuring changes according to proportion of seals or pups. This is important, because, as shown below, there was an increase in the total Point Reyes regional harbor seal population peaking around 2002-2004 and then dropping off ever since. That peak in the regional seal population artificially coincided with three of the "low" oyster farm activity years (as defined by the NPS designation).

When Becker converted from the proportion of seals or pups to the total Drakes Estero counts in his dependent variable, he introduced the impact of the peak regional population in 2002-2004 on the number of seals in Drakes Estero.

Several MMC panel members noted this dynamic in the regional population that coincided with the OYST Hi/Low designation (and thus might falsely drive a correlation). In the Panel Member's Report in Appendix F of the MMC Report, several of them asked that the total regional population be introduced as an independent variable (something we have done as part of our best models – see separate document on our response to the MMC Report criticism of our best models).

Concerning the issue of regional population, Dr. Sean Hayes (National Marine Fisheries Service, Southwest Fisheries Science Center) wrote (Appendix F, MMC Report):

> *"I am concerned that there were other unaccounted for variables in the population such as changing oceanographic conditions, and the larger California harbor seal population dynamic itself …"*
>
> *"Given the size of the Drakes Estero population (Becker et al. 2010) it is likely to respond to whatever large scale dynamics influence the California stock. … there were some results suggesting Drakes Estero population dynamic correlated with the regional population dynamic and all were declining somewhat during the period of increased mariculture activity."*

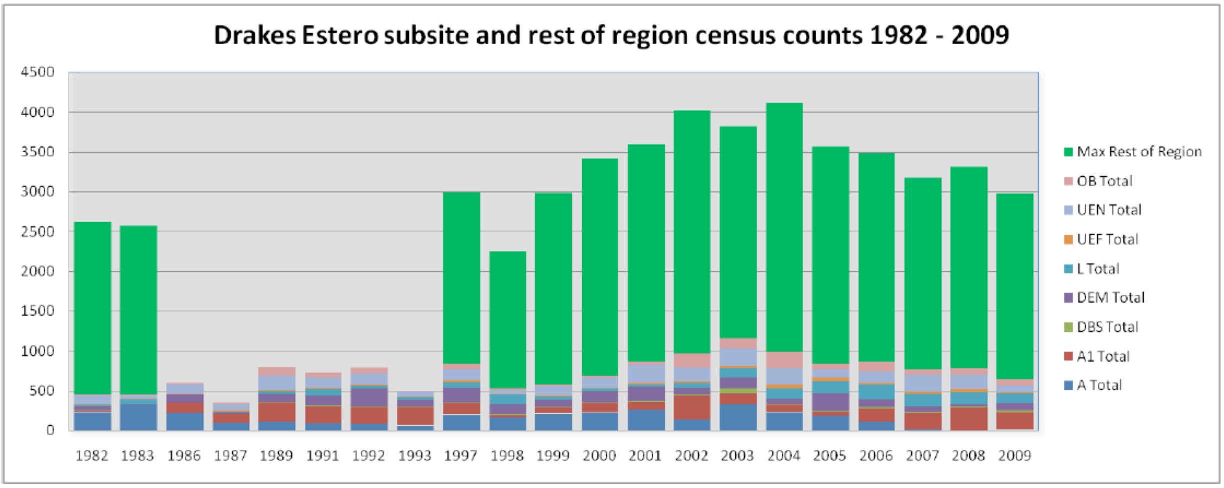
Dr. Steven Jeffries (Washington Department of Fisheries and Wildlife) wrote (Appendix F, MMC Report):

> *"The changing population dynamics that have occurred as regional harbor seal numbers have grown will contribute to why harbor seal use haulout sites in these esteros and adjacent areas and is influenced by natural density dependent factors affecting the overall harbor seal population."*
>
> *"I would like to see a new analysis by an applied biometrician with additional covariants used including: … overall population trends for the California harbor seal stock, California sea lions and elephants seals …"*

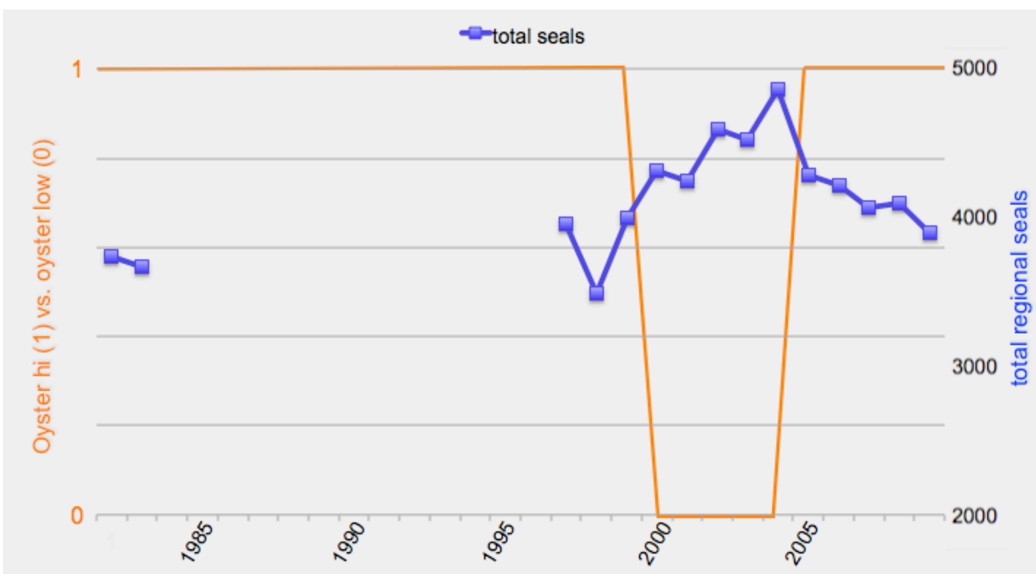
Dr. Brian Kingzett (Vancouver Island University) wrote (Appendix F, MMC Report):

> *"During discussion it was stated by panelists and others that the regional seal population, has been expanding over the long term and may have hit carrying capacity. This population is exposed to a variety of anthropogenic and natural phenomena that could affect behavior, survival and reproductive success. It would*

not be unlikely for this population to undergo trends both positive and negative and all possible factors should be assessed when looking for potential reasons to explain year to year variability." (the graph below is from Kingzett's report)



We agree, which is why we believe Becker should have continued with proportional counts (rather than switch to total counts) as in Becker 2011. The change of this parameter falsely increased the significance of the NPS correlation because of the coincidence of the regional population peak in 2002-2004.



The MMC Report was remiss for not including the total regional seal population in Figure 5 (next page). As shown above, including the total regional population allows the reader to observe that the decrease from the period 2002-2004 to 2010 at Drakes Estero is represented in the overall regional population trend and likely has nothing to do with the oyster farm. As Dr. Sean Hayes wrote, there was evidence that the "… *Drakes Estero population dynamic correlated with the regional population dynamic and all were declining somewhat during the period of increased mariculture activity."* Figure 5 in the MMC Report did not permit the reader to observe that relationship.

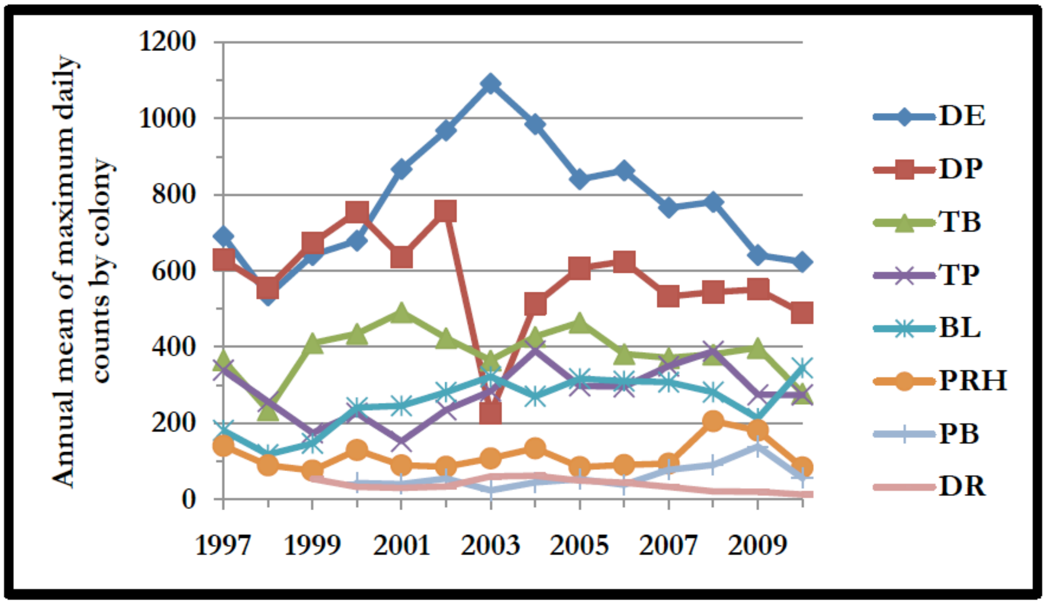


Figure 5. Annual mean of maximum daily counts (adults and pups) by colony and during the full year (left axis), and total of those counts (right axis). Colonies are Drake's Estero (DE), Double Point (DP), Tomales Bay (TB), Tomales Point (TP), Bolinas Lagoon (BL), Point Reyes Headland (PRH), Point Bonita (PB), and Duxbury Reef (DR) (data from National Park Service)

In the June 2011 draft version of the MMC Report (see below), Ragen included the curve for the total regional seal population for comparison to the curves for Drakes Estero and the other haul-out sites. We do not understand why the total population line was not included in the final version of the MMC Report in November 2011 (see above).

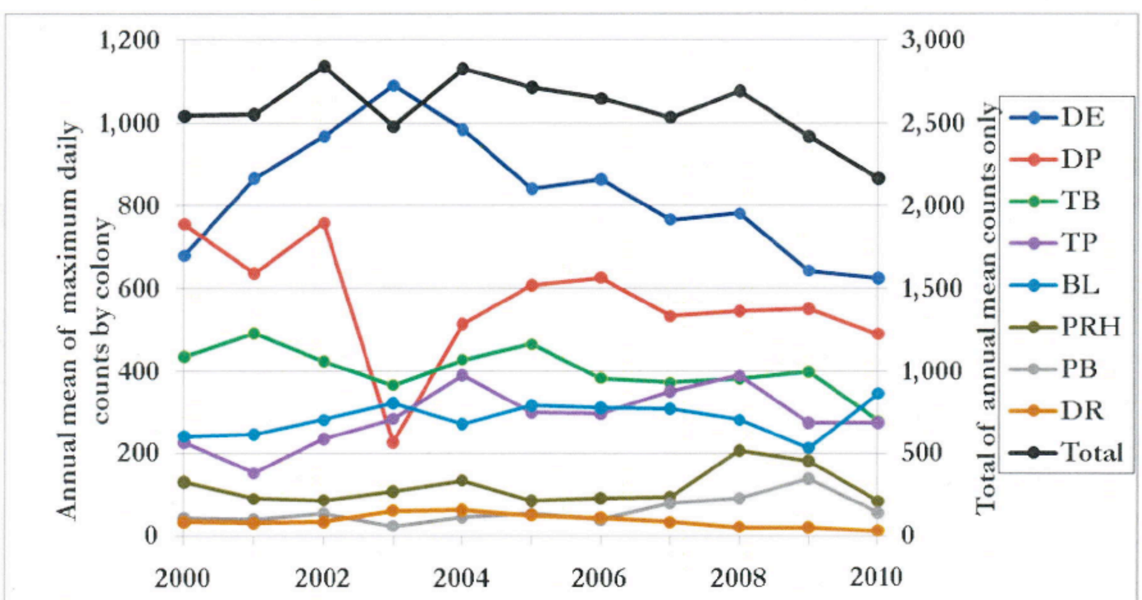


Figure 5. Annual mean of maximum daily counts by colony (left axis), and total of those counts (right axis). Colonies are Drake's Estero (DE), Double Point (DP), Tomales Bay (TB), Tomales Point (TP), Bolinas Lagoon (BL), Point Reyes Headland (PRH), Point Bonita (PB), and Duxbury Reef (DR). (Data from National Park Service.)

Conclusions and recommendations

1) The elimination of the outlier data point (2003) to determine if this event highly leveraged (i.e., unduly influenced) the NPS correlation was a legitimate and appropriate diagnostic test. MMC was incorrect to reject this diagnostic test.
2) The Becker 2011 statistics are leveraged (i.e., unduly influenced) by a single stochastic (random) event -- the rogue elephant seal at Double Point in 2003: when 2003 alone is eliminated, Becker's best models are no longer significant.
3) The same conclusions are derived regardless of statistical method: Goodman and Lewis provided head-to-head comparison of GLM using AIC vs. MLR using R squared analysis, and derived the same conclusion: the NPS oyster activity model is entirely supported by the stochastic (and lethal) 2003 event.
4) Having rejected the request to ask NPS to do the outlier diagnostic test of their model, MMC instead accepted a different analysis from NPS that was purported to determine the leverage of the 2003 event on the NPS correlation. Rather than subtracting the 2003 event from their correlation, NPS instead added another independent variable that was leveraged by the 2003 event. Instead of effectively testing 2 – 2 = 0, NPS in essence tested 2 + 2 = 4. MMC accepted an incorrect test.
5) By adding another independent variable entirely leveraged by the lethal 2003 event, NPS essentially doubled down – they tested two variables that were both leveraged by the same event – and no surprise, found an increased R squared.
6) Although MMC stated to Kevin Lunny that it had not asked NPS to do the outlier diagnostic test, it actually had asked NPS to test their model without 2003 and 2004. In the absence of 2003, the NPS model was no longer significant.
7) The MMC mistakenly accepted the NPS correlation that was highly leveraged by the random 2003 event at Double Point. The MMC made two compounded errors. First, MMC did not request the outlier diagnostic test. Second, MMC allowed NPS to do an inappropriate test that added rather than subtracted the 2003 event and never determined whether it leveraged the oyster activity model.
8) The NPS data are too thin, and too highly leveraged by a stochastic event in 2003, to be able to support the NPS correlation between harbor seals and oyster activity. Moreover, the NPS data are inadequate for MMC to affirm the NPS claim of a correlation between harbor seals and oyster activity.
9) What was called a long-term displacement OUT of Drakes Estero was actually a short-term displacement INTO Drakes Estero caused by events at Double Point. There is no evidence for long-term spatial displacement of seals and pups OUT of Drakes Estero that can be related to shellfish aquaculture.
10) The MMC mistakes could have been avoided had the MMC proceeded with their original open process rather than the insular closed process they conducted. Open dialogue, open discussion, and open exchange could have helped avoid these mistakes. Unfortunately, the closed process led to a flawed MMC Report.

To resolve this issue, we recommend the following: Interested parties (e.g., elected officials, agency or committee staff, and the press) can verify our analysis by consulting with independent statisticians – independent of us, the NPS, marine mammal community, and NGOs. Any professional statistician (e.g., the American Statistical Association) could help resolve this issue. We welcome such an independent analysis.

Epilogue: using Becker's exponential model in a subtraction experiment to test whether the 2003 event at Double Point leveraged Becker's model

Several people have asked us if there might be another method – in addition to the diagnostic outlier test – to test whether Becker's OYST Hi/Low model was highly leveraged by the 2003 event at Double Point. One suggestion has been a variation on another experiment that Goodman did in his August 29 analysis. The notion is to leave all fifteen years, but to make an adjustment for the 2003 event by decreasing the number of pups in Drakes Estero according to the exponential decay.

In Goodman's August 29 report, he did a variation of this adjustment experiment using the following reasoning. The mean proportion of pups at Double Point (prop.pup.dp) for the fifteen-year study period was 0.296. In 2003, a rogue elephant seal killed ~ 40 seals and chased away ~ 600 seals from Double Point, leaving the prop.pup.dp at 0.085. Thus, the rogue elephant seal led to a decrease in the prop.pup.dp of 0.211 that equals 260 pups. Many of the pups chased away from Double Point went into Drakes Estero. Based upon NPS data, it is conservative to assume that ~ 50% of the pups from DP went into Drakes Estero (i.e., 130 pups). Goodman subtracted 130 pups from DE and recalculate the prop.pup.de to an adjusted value from 0.394 to 0.289. A similar adjustment for 2004 led to an adjusted prop.pup.de value of 0.321. That adjustment experiment led to an adjusted R^2 of – 0.0619 and a P value of 0.5943, indicating that the relationship of oyster activity (OYST Hi/Low) to harbor seal pups in Drakes Estero was no longer statistically significant. The relationship is best described as flat-lined.

What if we did this same adjustment experiment using Becker's exponential decay mathematical model for the 2003 event at Double Point to determine the adjustment of the pups in Drakes Estero? Whereas we could determine the numbers for Becker's exponential, we did not have the parameters for his log model. Both gave similar values, and to our eye, the exponential model appeared to provide a better curve-fit model for the changes in the proportion of pups at Double Point.

We ran the experiment conservatively, and then even more conservatively. In the first version, we used Becker's exponential model and assumed that 125 pups entered Drakes Estero in 2003 as a result of the rogue elephant seal at Double Point (the actual number is closer to 150). In the second more conservative model, we assumed that only 100 pups entered Drakes Estero as a result of the 2003 event at Double Point. In both cases, the adjustment number dropped off exponentially in each subsequent year as modeled by Becker. For example, in the first version, the adjustment number dropped from 125 pups in 2003, to 47 pups in 2004, to 19 pups in 2005, to 6 pups in 2006, to 2 pups in 2007, to 0 pups in 2008.

We adjusted the proportion of pups in Drakes Estero (prop.pup.de) using this exponential decay of the original value. The "125" vs. "100" in the definition of the models (below) defines the adjustment to the number of Drakes Estero pups in the starting year, 2003.

For Becker's OYST Hi/Low model, we obtained the following values:

OYST Hi/Low (Becker 2011, no adjustment)	adjusted R^2 = 0.21	P value = 0.0468
OYST Hi/Low (Becker exp decay, 100 pups)	adjusted R^2 = 0.13	P value = 0.1053
OYST Hi/Low (Becker exp decay, 125 pups)	adjusted R^2 = 0.08	P value = 0.1661

We then conducted the same experiment with Becker's top model from Becker 2011: OYST Hi/Low + DP seals. For Becker's best model, we obtained the following values:

OYST Hi/Low + DP seals (no adjustment) adjusted $R^2 = 0.42$ P-value = 0.01474
OYST Hi/Low + DP seals (exp decay, 100) adjusted $R^2 = 0.10$ P-value = 0.21526
OYST Hi/Low + DP seals (exp decay, 125) adjusted $R^2 = 0.00$ P-value = 0.38657

We then conducted the same experiment with Goodman's modified top model: DP pups + total regional adults + 92 protocols (see Goodman and Lewis part II for further details – this modified model has none of the dependencies criticized in the original model). For Goodman's modified best model, we obtained the following values (note – we have also included the model without the Double Point variable):

DP pups + total reg adults + 92 (no adjustment) adjusted $R^2 = 0.86$ P-value = 0.00001
DP pups + total reg adults + 92 (exp decay, 100) adjusted $R^2 = 0.71$ P-value = 0.00078
Total reg adults + 92 protocols (exp decay, 100) adjusted $R^2 = 0.63$ P-value = 0.00109
Total reg adults + 92 protocols (exp decay, 125) adjusted $R^2 = 0.58$ P-value = 0.00226
DP pups + total reg adults + 92 (exp decay, 125) adjusted $R^2 = 0.59$ P-value = 0.00469
Total reg adults + 92 protocols (no adjustment) adjusted $R^2 = 0.57$ P-value = 0.00264

Predictably, with both Becker's best model (OYST Hi/Low + DP seals) and Goodman's modified best model (DP pups + total regional adults + 92 protocols), the subtraction of Becker's exponential decay adjustment rendered the Double Point term of less statistical significance, particularly so in the version that adjusted Drakes Estero in 2003 by 125 pups.

Thus, when we used Becker's exponential decay mathematical model of the 2003 event as a subtraction experiment to determine if the 2003 event highly leveraged the OYST Hi/Low variable, we found that both the conservative and very conservative adjustments rendered Becker's model to be no longer statistically significant. In contrast, Goodman's modified best model retained its statistical significance.

We conclude from this adjustment experiment that the 2003 event highly leveraged the OYST Hi/Low variable and thus highly leveraged the NPS correlation of oyster activity with harbor seals. Goodman's best model (including the pups at Double Point + the total regional adult seal population + the 92 protocols) remained statistically significant under the adjustment conditions of this test. These results further confirm the diagnostic outlier test described in the main body of this report.