Addressing the criticisms of the paper

This paper had two reviewers. One thought that the paper was too erroneous, incomplete, and poorly written to be reviewed and the other thought that JASA was an appropriate journal for the paper but that more explanations were needed, and that the modeling was strong. The editor also described significant flaws of the paper such as the description of the experimental procedures and modeling, the only approximate calibration of the sound stimulus coupled with the curved nature of the vibrissae, the manner in which water loading was accomplished, the manner in which the results are presented, and the lack of any broad discussion concerning the impact of the major findings.

I will first attempt to address the editor’s criticisms.

**Flaws in description of the experimental procedures and modeling**

The paper has undergone extensive revisions to clarify the experimental procedures and modeling some of which are:

1. A clearer description (page 6) and picture (Figure 3) of the two modes of motion.
3. A section on the drag term (pages 11-12).
4. A more detailed description on the FEM (page 12).
5. An appendix which illustrates that the code of the FEM correctly matches the exact solution for the resonant frequencies of a cylinder. (Appendix A)

**The only approximate calibration of the sound stimulus coupled with the curved nature of the vibrissae**

This approximate calibration was used in (Shatz and Christensen 2008). In that paper it is described in more detail. That paper is now more explicitly referenced when describing the approximate calibration.

**Flaws in the manner in which water loading was accomplished**

As was previously mentioned, we now include the Stokes solution for the force and drag on an oscillating cylinder in linear fluid, and more explicitly describe the FEM procedure. The loading is accomplished in the same manner as in (Shatz and Christensen 2008), and that paper is more explicitly referenced when discussing the loading.

**Flaws in the manner in which the results are presented**

Several improvements have been made to improve the manner in which the results are presented. Some of the improvements are responses to Reviewer 2’s critiques and these are listed in the table below.

**The lack of any broad discussion concerning the impact of the major findings**
The section *Vibrissae Tuning and Seal Behavior* has been added discussing the impact of the findings on seal behavior.

The table below describes the reviewers’ specific criticisms and how they are addressed.

<table>
<thead>
<tr>
<th>Reviewer’s Criticism</th>
<th>How criticism is addressed in revised manuscript</th>
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</thead>
</table>
| Reviewer 1: The paper was too erroneous, incomplete, and poorly written to be reviewed | - The work has been gone over and a minor error in the code was found so that the Young’s modulus that best produces predictions to the data is closer to 2.9 GPa not the 2.8 GPa as in the original paper. All the results of the models are derived using 2.9 GPa (although the differences to the figures are barely noticeable).  
  - Several new sections (on the fluid modeling, the FEM, effect of clamping, the Q factor, seal behavior), have been added as well as an appendix that proves that the model works for a cylindrically shaped vibrissa, whose exact solution is known.  
  - The figures have been enhanced and a they, as well as their captions, are more descriptive.                                                                                                                                 |
| Reviewer 1: The y-axes of all of the response curves have no units. Presumably those numbers located below zero are negative, not positive as shown but what are the units? If they are dB then the experimental Qs cited by the authors are completely wrong and the theoretical curves make no sense whatever. | - The caption of new Figures 5, 10, 11, 12, and 13 now contain the sentence:  
  *The y-axis of the plot demonstrates the natural logarithm of the ratio of the maximum vibrissa displacement to the maximum air displacement.*  
  - The caption of new Figures 6, 7, 8, and 9 contain the sentence:  
  *The y-axis of each plot demonstrates the ratio of the maximum vibrissa displacement to the maximum air displacement.*  
  We’ve also expanded the description of the quality factors to clarify how these were calculated.                                                                                                                                 |
| Reviewer 2: All of the data plots have unexplained ordinates (y scales). The labels on the scales tell us we are looking at ratios, yet the numeric labels show what look like positive and negative values. (I assume the x in the box is some typographical error that should be interpreted as a negative sign). If this is the case, then the scales may be logarithmic. Is this true? If so, are they natural or common log values? Are these powers of ten? Whatever they |

We’ve also expanded the description of the quality factors to clarify how these were calculated.
are should be noted in the caption of each figure.

Reviewer 1: Saying that fluid loading is accounted for by some mysterious unspecified Z, which is incorporated into the finite element model in some mysterious unspecified way is not satisfactory. The effects of water loading appear to be much larger than one would expect.

I provided the expression for Z and described how it was incorporated into the finite element method. The effects of water loading are not larger than one would expect given that the mass density of water is 800x that of air and that its viscosity is 100x more.

This is borne out by plotting the amplitude of the fluid force on a 3.6 cm long vibrissa using the Stokes solution for fluid force of an oscillating cylinder given on page 11 of the revised paper. The ratio of the two cases is 100 at low frequencies where viscous forces dominate and is 800 at high frequencies where the inertia dominates:

<table>
<thead>
<tr>
<th>Frequency (Hz)</th>
<th>Force (N)</th>
</tr>
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<tbody>
<tr>
<td>1 x 10^{-5}</td>
<td>5 x 10^{-4}</td>
</tr>
<tr>
<td>2 x 10^{-5}</td>
<td>2 x 10^{-4}</td>
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<td>5 x 10^{-4}</td>
<td>1 x 10^{-5}</td>
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</tbody>
</table>

Reviewer 1: The nature of the finite element model needs to be specified. Fluid loading in finite element models is usually accounted for using finite or infinite

- I don’t believe the fluid loading is accounted in a questionable way. It was done like this in:

fluid elements. Why have the authors chosen to make up their own rather questionable way of accounting for it? (Actually, why use finite elements at all to find the frequencies in air? The Rayleigh Ritz method would give better results which could actually be verified by the reader and applied to other cases).


And in


- The FEM modeling focused on the mechanics of the vibrissa, not the fluid.
  To verify the FEM model, I’ve applied it to a cylindrical beam in Appendix A and compared the results to an exact solution


The reader can then verify the results himself.

Reviewer #2: The manuscript is too concise and is in need of more explanation. I’ve added more explanations throughout the paper.

Reviewer #2: Since there are many seals I would include the common name (and many genus and species) of the harp seal in the title.

The title now reads: The Frequency Response of the Vibrissae of Harp Seal, Pagophilus Groenlandicus, to Sound in Air and Water

Reviewer #2: The figures try to do too many things. One set of figures should be used to sketch out the effects of varied structure on the model predictions. A second set of figures could concentrate on the frequency ranges of the measurements.

Many of the data plots compare Figure 5 is used to show the general shape of the tuning curves over a large range of frequencies for a single vibrissa. The captions mention that the shapes of the vibrissae tuning curves are similar.

Figures 6 and 7 focus on two tuning curves, one with an excellent match between the model’s predictions and data and one with a weaker match. The caption to Figure 6 reads:

Tuning curve for the case where the model’s predictions best matched with the data. The y-axis of demonstrates the
model predictions with a (very) few measurement points. While we are told something about the variation in x and y of each of these points it is not at all clear why there are multiple points. We are told that the points represent some average of measurements from 13 vibrissae. Does each plot represent the measurements from a single vibrissa? How are the data points in each plot separated into different frequency bands? I can understand how the techniques allow the determination of a resonant frequency. How are the measurement frequencies that are greater or less than the resonant frequency selected? Are they 10 Hz below and above the resonant frequency? The methods say nothing about the display of measurements at other than resonant frequency.

The plots are very inefficient. Most of the plot space is spent looking at the model predictions, which, while shifted in frequency and varied in damping, look very similar. The general shapes of the model results and how they vary with damping and vibrissae dimensions could be displayed in a few plot panels. The comparisons of model and measurements would be much better served by

displacement. The points represent a single displacement measurement at a particular frequency with 10% error bars for the frequency measurements (x-axis) and a factor of two (100% and 50%) for displacement measurements. The error bars derive from redoing the experiment where the vibrissa is not in the exact same position in front of the speaker as when the measurements were taken originally. All of the model predictions fall within the error bars of the data.

And the captions to Figures 7-9 reference the appropriate information in Figure 6.

Figure 8 and Figure 9 contain the results of all the vibrissae, focusing just on the frequencies for which there is data, and the captions to these figures read

Motion of 13 vibrissae of various lengths for wide-side stimulation predicted by the model (curves) and measured (points). Each plot represents the tuning curve for a single vibrissa. The y-axis of each plot demonstrates the ratio of the maximum vibrissa displacement to the maximum air displacement. See Figure 6 for a description of the error bars.

In the text I added the sentence:

For each vibrissa, for each mode of motion, motion was recorded at its fundamental resonant frequency, at the highest and lowest frequencies for which motion was observable, and for a number of points in between those frequencies, if the range wasn’t too small (less than ~10% of the resonant frequency).

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1 Thin side for Figure 9
panels with highly restricted frequency ranges, where the reader can better see the quality of the fit of data points at multiple frequencies with the model predictions.

Reviewer #2: I find the phrase in the second paragraph on page 3 'Pinnipeds like seals' confusing. It either needs some commas 'Pinnipeds, like seals,' or better yet 'Pinnipeds, the taxonomic group that includes seals, sea lions and walruses.'

The sentence now reads: *Pinnipeds, the taxonomic group that includes seals, sea lions and walruses, use their vibrissae...*

Reviewer #2: Does the term 'sensor hair' (as it is used in the introduction) include stereocilia or kinocilia? If not, what are the sensor hairs in the vestibular system? If only kinocilia are included, than the auditory inner ears of many non-mammalian vertebrates (e.g. alligator lizards) also contain sensor hairs.

If stereocilia are included, why is there no mention of hearing in vertebrates?

The term sensor hair does include stereocilia and kinocilia. The first sentence mentions sound-induced motion so at to include them:

*Sensor hairs are found in hearing organs, lateral line organs of fish and amphibians and in spiders, crickets and cockroaches; these hairs are used to detect sound-induced or mechanically induced motion of the fluid surrounding the hairs.*

Reviewer #2: The degree of clamping of the vibrissae at their base could have a significant effect on the measured and predicted frequency response. What is known of the natural clamping condition? Is the hair really fixed in the skin? Or is there a compliant pivot?

I’ve added the section:

*The Effect of Clamping on Vibrissae Tuning*

Reviewer #2: What are a AND HR 120 and ER 120 A? Who makes them?

I’ve corrected the sentence to read:

*The masses of the vibrissae were measured with the A&D HR-120 and the A&D ER-120A balances accurate to ...*

Reviewer #2: What is a 100% I removed the error bars from the logarithm plots since...
error? Could a true response of 1, actually result in a measured response of 0 to 2? If this is the case, and the data are plotted on logarithmic scales, then the negative going error bars should go down a long way on that log scale. Do the authors mean a factor of 2 error, where the measured response might vary between 2 and 0.5? This would be consistent with their symmetric errors bars in what I assume is a log scaled y-axes.

The text now reads:

Error bars in the frequency measurements of 10% of the measured frequencies, and error bars equal to 100% and 50% of the displacement ratio are shown, the latter because results could differ by a factor of two when the experiment was repeated at another time, when the vibrissa was not in the exact same location in front of the speaker as before. This large variation is likely due to the large variation in air displacements due to non-uniform shape of the speaker; and the curved shape of the vibrissa which would result in varying magnitudes of air displacements along the vibrissae.  

Reviewer #2: What bearing do the results presented here have on the behavior of the harp seal? What is the behavioral impact of a sensitivity to the displacement of the water at 50 to 300 Hz? Does it help them feed? Or communicate?

I’ve added the section:

I’ve focused more attention on tuning in water and added the following section:

Vibrissae Tuning and Seal Behavior to address these questions.

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2 This variation also corresponds with the variation observed in the output of a velocity microphone in the vicinity of the vibrissa.