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Professor Elizabeth Wheatley
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Dear Professor Wheatley,

You wrote to me, inquiring about infrasound and low frequency noise (ILFN) impacts from a large array of wind turbines proposed for Lake Michigan. Impacts, that is, on people living on shore, some four miles away, and impacts on fish.

Your concerns are well-founded. First, a crash course on "noise." Noise propagation models are based on the spherical movement of sound waves and the dispersion of their power. In these models, sound loses its power rapidly.

Sound waves over water, however, present a special case. The issue over water is that instead of having an *absorptive* surface, the way trees and vegetation and houses might absorb sound—you now have a *reflective* surface. Basically, you're dealing with half of a sphere; the power of the sound is concentrated because the whole bottom of the sphere is reflected back into the top of the sphere.

The other thing that occurs over water is that there are different layers of air under different weather conditions (for instance, either cool & still over the water, or certain kinds of cloud cover). By "layered" I mean the air has different densities or temperatures or wind conditions. *The boundary between air layers* likewise acts as a reflective surface.

Hence, it is not uncommon to have the reflective surface of the water and a reflective surface of layered atmosphere above it (at the boundary of this layered atmosphere, such as cloud cover). *The upshot being that both of these reflective surfaces (the water and the air layer boundary) will reflect the sound back into the same layer where the sound travels.*

This means that sound energy, instead of dispersing in a *sphere*, disperses in a *flat layer*, more

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like a two-dimensional circle—a pancake or, if you prefer, a frisbee. Bottom line, the sound energy is heavily concentrated and travels much farther.

When you understand that infrasound and low frequency noise travel farther than higher frequency noise, this "channeling" of noise—reflective surface of the water below, air layer boundary above—becomes pronounced and, in this wind turbine case, alarming.

In summary, you are correct to be alarmed about ILFN reaching land from these lake-based turbines.

Now consider what happens under water. Sound propagates even more efficiently through water than through air. And water is, of course, defined by boundary conditions: (a) the surface between water and air is a boundary that tends to reflect sound back into water, and (b) different layers of water (varying in temperature, density, and current)—the boundaries between these different layers of water also act as reflective surfaces. Hence, you can get channels through water where ILFN travels very far, because it's concentrated by these two reflective surfaces.

By the way, everything I have said about noise propagation above and within fresh water is true, as well, for oceans, with the added element of salt. In oceans, layers are also defined by salinity, which of course affects water density.

What about the fish in Lake Michigan (or Nantucket Sound, for that matter)? Fish, we know, are acutely sensitive to infrasound and respond to it with fear and avoidance. Hence, the turbines and the noise they make have the potential to change patterns of (a) fish movement, (b) fish migration, and (c) breeding behavior.

If breeding behavior is changed, fish populations can crash. (My PhD is in population biology/behavioral ecology, from Princeton University.)

A few more words about ocean environments. Crustaceans also avoid ILFN. Whales are known to beach and die in response to Navy sonar—which by definition is in the ILFN range. And there is information about seal rookery problems—rookery failure—in the UK.

Birds. Birds on Lake Michigan and over the ocean are at risk insofar as they are not used to encountering obstacles as they fly over water. Turbines in the Great Lakes could have a disastrous impact on bird migrations when turbines are located within the great migratory highways (flyways).

On the matter of water-borne ILFN, keep in mind that we're talking about vibrations coming off the supporting structures under the water, propagated directly into the water, in addition to ILFN traveling above water. In other words, ILFN skimming across the surface and below the surface.

Lastly, it has been demonstrated that large turbines produce more ILFN than smaller ones. The bigger they are, the bigger the ILFN load. If you're talking about 5 and 10 MW turbines in Lake Michigan, this spells big trouble.

I hope this is helpful.

Sincerely,

Nina Pierpont

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