LONG-TERM GOALS
The goal is to develop and test the hypothesis that certain paths associated with rays reflected from rippled surfaces enhance the backscattering of sound by small targets. The enhancement of the scattering by the small target should be important for targets situated close to a reflection caustic of the rippled surface. This is a “Graduate Traineeship Award in Ocean Acoustics.”

OBJECTIVES
The objective was to detect and model the enhancement as a function of target position including the complicated case of the “two-way” enhancement in which both the target illumination and the detected echo are reflected and focused by caustics.

APPROACH
In previous theoretical, computational, and experimental research [1-4], the fluctuations associated with caustics were studied for acoustic wavefields produced by reflection from rippled surfaces, including the case of a randomly rippled surface. The theory, numerical simulation, and experiments all support the existence of an enhancement in the amplitude received by a hydrophone positioned close to a simple Airy caustic. The amplitude increases with the frequency in proportion to $k^{1/6}$ where the wavenumber $k$ is proportional to the frequency. In the research supported by this grant the acoustic backscattering was measures and modeled for small targets situated in (or near) an Airy caustic. Professor Philip L. Marston directed the research (while receiving no financial support from this grant). Benjamin R. Dzikowicz was a graduate student supported by this grant at Washington State University.

WORK COMPLETED
Ben Dzikowicz completed his Ph. D. Thesis titled "Backscattering of Sound from Targets in an Airy Caustic Formed by a Curved Reflecting Surface." The thesis abstract is listed below under “RESULTS.”
The goal is to develop and test the hypothesis that certain paths associated with rays reflected from rippled surfaces enhance the backscattering of sound by small targets. The enhancement of the scattering by the small target should be important for targets situated close to a reflection caustic of the rippled surface. This is a Graduate Traineeship Award in Ocean Acoustics.
RESULTS

The focusing of the caustic associated with the reflection of a locally curved sea floor or surface affects
the scattering of sound by underwater targets. The most elementary caustic formed when sound
reflects off a naturally curved surface is an Airy caustic. The case of the spherical target is examined
here. With a point source acting also as a receiver, a point target lying in a shadow region returns only
one echo directly from the target. When the target is on the Airy caustic, there are two echoes: one
path is directly to the target and the other focuses off the curved surface. Echoes may be focused in
both directions, the doubly focused case being the largest and the latest echo. With the target in the lit
region, these different paths produce multiple echoes. For a finite sized sphere near an Airy caustic, all
these echoes are manifest, but they occur at shifted target positions. Echoes of tone bursts reflecting
only once overlap and interfere with each other, as do those reflecting twice.

Catastrophe theory is used to analyze the echo amplitudes arising from these overlaps. The echo
pressure for single reflections is shown to have a dependence on target position described by an Airy
function for both a point and a finite target. With double focusing, this dependence is the square of an
Airy function for a point target. With a finite sized target, (as in the experiment) this becomes a
hyperbolic umbilic catastrophe integral with symmetric arguments. The arguments of each of these
functions are derived from only the relative echo times of a transient pulse. Transient echo times are
calculated using a numerical ray finding technique. Experiment confirms the predicted merging of
transient echoes in the time domain, as well as the Airy and hyperbolic umbilic diffraction integral
amplitudes for a tone burst. This method allows targets to be observed at greater distances in the
presence of a focusing surface.

Comment (which is not part of the thesis abstract): While the wavefields associated with hyperbolic
umbilic catastrophes had been previously analyzed [4, 5], prior to this research there was no obvious
connection between hyperbolic umbilic singularities and the backscattering by small targets situated on
(or near) an Airy caustic.

IMPACT/APPLICATIONS

This improved understanding of the effects of focusing on scattering may allow targets to be observed
at greater distances in the presence of focusing caused by undulations of the upper sea surface or by
variations in the height of the sea bottom. Some of the results also apply to caustics caused by
refraction due to ripples in the sea bottom or by refraction due to long-range propagation in water.

TRANSITIONS

After completing and defending his Ph. D. Thesis, Ben Dzikowicz began research in a research staff
position at the Naval Coastal Systems Station (Panama City, FL). Among other responsibilities, he is
investigating how certain caustics may (or may not) contribute to the backscattering by certain
cylindrical targets. Ben now works with Raymond Lim.
REFERENCES


PUBLICATIONS


HONORS/AWARDS/PRIZES