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Ocean Acoustic Waveguide Remote Sensing (OAWRS) of Marine Ecosystems

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ABSTRACT

Ocean Acoustic Waveguide Remote Sensing (OAWRS) has been recently shown to be capable of instantaneously imaging and continuously monitoring fish populations over large continental shelf-scale areas at an areal rate of tens of thousands to millions of times greater than that of conventional methods. Here we discuss the fundamental principles of ocean waveguide propagation and scattering as well as the technology that makes OAWRS possible.

With the 'first look' of OAWRS on the New Jersey continental shelf in the spring of 2003, we were able to make a number of fundamental scientific discoveries about (1) the instantaneous horizontal structural characteristics, (2) temporal evolution and (3) propagation of information within very large fish shoals. These include the findings that; the instantaneous spatial distribution of fish observed follows a power law process, so that structural similarity exists at all scales from meters to tens of km (previously evidence for structural similarity existed only for small scales <100 m); large shoals are far more horizontally contiguous in 2D than was previously believed based on 1D line transect methods which sometimes inaccurately portray them as disjoint clusters and temporal autocorrelation scale of population change within a very large shoal is on the order of minutes; temporal fluctuations in shoal population also follow a power-law process, making the shoals far more predictable; and fish density waves regularly propagate information over km scales, 3 orders of magnitude larger than previously observed, at speeds ten times faster than fish can swim.

General predictions about animal group behaviour believed to apply in nature irrespective of species were confirmed by monitoring the Georges Bank marine ecosystem (Fig. 1A) with OAWRS in 2006. By quantifying the formation process of vast herring shoals (Fig. 1B) during spawning, it was shown that (1) a rapid transition from disordered to highly synchronized behaviour occurs as fish population density reaches a critical value; (2) organized group migration occurs after this transition; and (3) small sets of leaders significantly influence the actions of much larger groups. The spawning process was found to follow a regular diurnal pattern in space and time which proved to be difficult to detect without continuous wide-area sensing abilities.

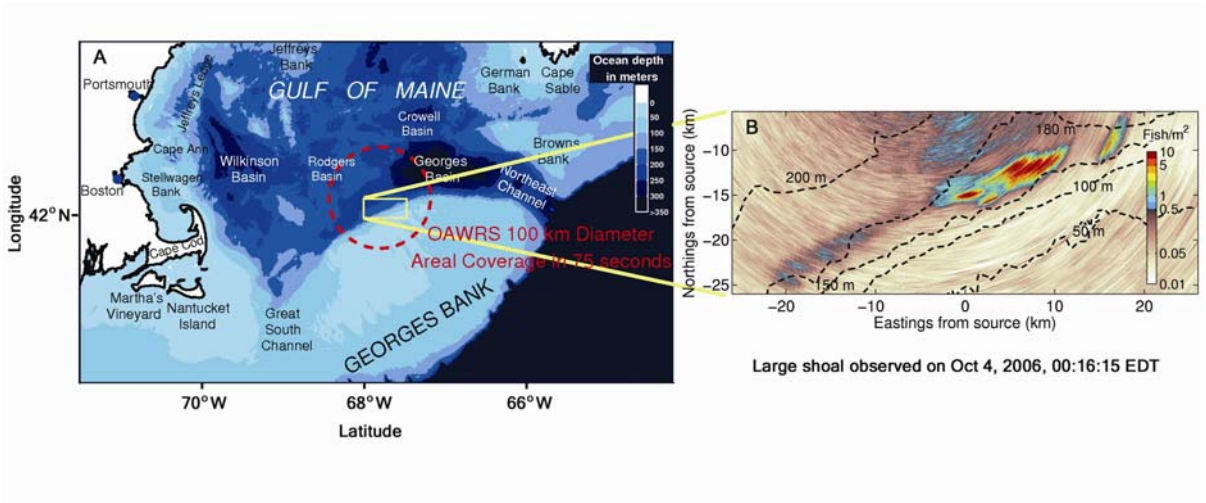

Figure 1. OAWRS survey of spawning herring in the Gulf of Maine, fall 2006. (A) Gulf of Maine bathymetry with circle showing OAWRS areal coverage in 75 seconds. (B) Zoom of large herring shoal containing roughly 250 million fish instantaneously imaged by OAWRS in boxed region shown in (A).