Off Denmark, a Drawn-Out War Against Hypoxia

The first signs of a problem in the Kattegat strait between Denmark and Sweden surfaced in the late 1970s, when Danish coastal officials chronicled a series of fish kills, plankton blooms, and low oxygen readings. The hypoxic conditions suggested that fertilizer runoff from farm fields might be the culprit, but the threat didn't register with the public until a lobster die-off in 1986 in the southern Kattegat.

An intense lobbying campaign led by the Danish Society for the Conservation of Nature persuaded the government to draw up an Action Plan on the Aquatic Environment. After a series of false starts, the plan, enacted in 1987, finally appears to be paying dividends.

The plan called for halving the release of nitrogen from all major sources—agriculture, industry, and sewage treatment plants—and cutting the release of phosphorus by 80% within 6 years. The $24 million a year plan doled out money for steps such as upgrading wastewater treatment plants, paying farmers to plant winter wheat to soak up excess nitrogen from the soil during the fall and winter, and limiting the amount of manure that farmers could dump on their fields.

By 1991, it had become clear that the agricultural measures were having no effect—or were even exacerbating the problem. Planting winter wheat, for example, had led to an increase in nitrogen fertilizer use—farmers had begun applying extra fertilizer in the fall to maximize yields, according to Daniel Conley, a marine ecologist with Denmark's National Environmental Research Institute.

Danish lawmakers tightened restrictions by requiring farmers to account for all fertilizer and manure they applied to their fields (they had not been required to report this before) and extended until 2000 the deadline for achieving nutrient reductions. In 1998, when monitoring again showed scant nitrogen reductions, Action Plan II was trotted out. The government began buying land from farmers to reestablish wetlands and forests, and paying farmers to use less than optimal amounts of fertilizer.

Far greater success was achieved, meanwhile, through regulations to reduce phosphorus emissions, mainly from wastewater treatment plants and industry. Over the last 14 years, phosphorus levels have fallen 80%; today, plankton growth in some coastal areas is limited by the available phosphorus, says Peter Bondo Christensen, a biologist with the National Environmental Research Institute. Although Danish scientists have never compiled a map of the dead zone in the Kattegat strait, their measurements show that oxygen levels are on the rise in open water.

Unlike the situation in the United States, the two constituencies most threatened by Denmark's dead zone are neighbors: "We're such a small country that the farmer lives next to the fisherman," says Christensen. And that means they have to get along to solve the problem, or else be at each other's throats.

–JOHN S. MACNEIL

John S. MacNeil, a former *Science* intern, is a staff writer for GenomeWeb in New York City.

the Mississippi. In response, the EPA held a conference and in 1997 established a task force of state and federal officials to recommend a course of action.

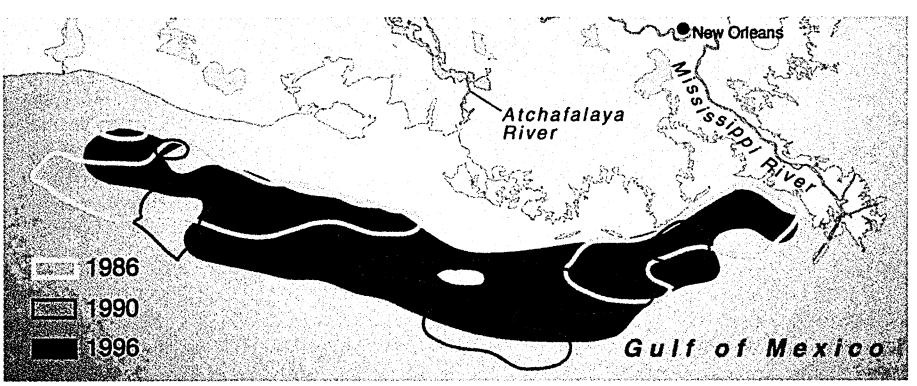
While the EPA's committee deliberated, the Clinton Administration took a baby step toward helping the gulf, proposing $117 million in new funds in 1998 to study runoff and harmful algal blooms, including those linked to the gulf's dead zone. Later that year, Clinton signed into law a measure requiring a White House advisory body, the Committee on the Environment and Natural Resources (CENR), to prepare a report on the dead zone's causes, consequences, and possible fixes. The law also called for the White House to develop an action plan to fix the dead zone by 31 March 2000—a task it entrusted to the EPA-led task force.

In May 1999, the CENR released a set of scientific reports backing the conclusion that chemical fertilizers are the main culprit. They offered several lines of evidence. In the Mississippi River, levels of nitrate—which leaches out of fertilizer-saturated soils—are three times higher now than they were in the 1950s; over the same period, chemical fertilizer use in the Midwest also tripled.

Forging a link between nitrogen levels and hypoxia are studies on sediment cores, which give clues to the gulf's past health. Rabalais and Turner measured concentrations of silicon in core samples. Silicon is a major constituent of the cell walls of diatoms, so it's a good measure of phytoplankton abundance. They found that silicon concentrations rose slowly between 1970 and 1989, tracking well with increasing nitrogen levels. Along with other groups, Rabalais and Turner have done other experiments to show that dissolved nitrates from the Mississippi supply nearly all the nutrients that fuel phytoplankton blooms in the dead zone.

Experts say they have made a compelling case tracing the bulk of the nitrates to human activity. In a study in last July's *Eos, Transactions, American Geophysical Union*, hydrologist Donald Goolsby of the U.S. Geological Survey (USGS) in Denver used water-quality monitoring data from 42 watersheds in the Mississippi Basin to model the nitrogen cycle throughout the basin. Some 7 million metric tons of nitrogen, about 30% of the total flowing into the gulf, came from fertilizer, and that total has risen sixfold over the last 50 years. An equal amount came from soil decomposition and the rest from sources such as animal manure, sewage treatment plants, airborne nitrous oxides, and industrial emissions. Goolsby also found that 56% of the nitrogen inputs into the Mississippi were from five heavily farmed midwestern states, with Iowa and Illinois the biggest sources. Other studies have come to similar conclusions.

While acknowledging that the dead zone is real, farm advocacy groups have de-



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Hard to pin down. The dead zone encompasses different swaths of water from one summer to the next. Researchers are trying to find out which factors influence this shifting mosaic.