CRISPR is a breakthrough gene editing method. (I can't refrain from noting that a key role in the discovery was played Jennifer Doudna at Berkeley.) There are potential risks from gene editing to the environment, similar to other types of GMOs. But there may be environmental benefits too. Here are a few that have been suggested to date.

Climate adaptation. Some scientists are thinking about ways gene editing could help with climate change adaptation. For instance,

> Warming oceans are already resulting in a breakdown of the symbiotic union between coral animals and the billions of photosynthetic microbes called Symbiodinium that inhabit them and make their food. . . . Writing in *Frontiers of Microbiology*, Levin proposes using CRISPR to prevent this breakdown. Rare strains of Symbiodinium can survive in warmer waters, and the relevant genes could be copied and transplanted into the Symbiodinium strains from temperate regions.

Some might think that we shouldn't play God in this way, but if it's a choice between losing all our coral reefs and some genetic tinkering, this option might call for serious consideration. (here)

Agriculture. CRISPR could obviously be used as a way to accelerate improvements in productivity and pest resistance in major crops. Increased productivity means less land is needed for agriculture, reducing pressures on wild lands by farmers. CRISPR could also offer a way to expand humanity's use of plants, reducing our reliance on huge monocultures of a relatively small number of plants. According to a news report in Nature:

> Exciting practical applications of CRISPR tools for sustainable agriculture can now be envisioned. The relatively low cost and ease of use of CRISPR tools are spurring innovative research in academia and in companies of all sizes, essentially democratizing crop-trait development. It is now feasible to consider performing research dedicated to niche crops that have typically been neglected. Moreover, instead of expanding the environmental and disease tolerance of already domesticated crops, plant species that are already well adapted to different environments could be

> domesticated with high-value traits.

Biofuels. Although the present hope is to electrify transportation, biofuels may be important as a transitional technology or in settings where electrification is impractical. Last June ScienceAlert reported that:

> Scientists have created a strain of algae that produces twice as much lipid as its wild parent, a substance that can be processed into a biofuel. By using a combination of gene editing tools, including the famed CRISPR-Cas9 technique, they identified and switched off genes that limited the production of lipids. Creating an alga that can pump out commercial amounts of sustainably obtained biofuels.

Invasive species. There has been serious discussion of using gene editing to neutralize invasive species. For instance, according to an article in PlosOne, "last year, New Zealand announced a plan to eliminate all its rats, possums, and stoats —– all destructive invasive species — by 2050. The nation is considering using gene drive systems to achieve this goal quickly, cheaply, and on a large scale." Ecological risks clearly have to be very seriously considered before any program of this kind is attempted. We need to be sure that the genes wouldn't jump to other species, wreaking ecological havoc.

Toxicology. Toxicologists are excited at the prospect that CRISPR might make it possible to better understand how chemicals harm the body:New Statesman reported on a conference that explored some of the possibilities.:

> Suppose preliminary research suggested a chemical might cause a cell's signals to go awry because the molecule binds to a particular receptor . . .Gene-editing tools could quickly and efficiently modify cells to confirm whether or not the chemical binds to the receptor…

CRISPR might also identify what genes make individuals more susceptible to toxic effects, making it much easier to take precautions to protect vulnerable groups. From the same conference:

> Researchers also can use gene-editing technologies to study specially designed laboratory mice that are genetically diverse and, therefore, potentially more representative of the diversity in the human population. The methods can help identify which gene variation is responsible for a greater or lesser toxic response to a chemical. . .That information helps identify vulnerable populations under pesticide and chemicals laws the EPA oversees.

Time will tell which, if any, of these possibilities will pan out. But given the environmental crises facing us, any additional tool is welcome.