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Global Warming Found to Displace Species

By ANDREW C. REVKIN

Global warming is forcing species around the world, from California starfish to Alpine herbs, to move into new ranges or alter habits in ways that could disrupt ecosystems, two groups of researchers say.

The two new studies, by teams at the University of Texas, Wesleyan, Stanford and elsewhere, are reported in today's issue of the journal *Nature*. Experts not associated with the studies say they provide the clearest portrait yet of a biological world driven into accelerating flux by warming caused at least in part by human activity.

Plants and animals have always had to adjust to shifting climates. But climate is changing faster now than in recent millennia, and many scientists attribute the pace to rising concentrations of heat-trapping greenhouse gases.

In some cases, species' ranges have shifted 60 miles or more in recent decades, mainly toward the poles, according to the new analyses. In others, the timing of egg laying, migrations and the like has shifted weeks earlier in the year, creating the potential to separate species, in both time and place, from their needed sources of food.

One academic not associated with the studies, Dr. Richard P. Alley, an expert on past climate shifts who teaches at Pennsylvania State University, said that climate had changed more abruptly a few times since the last ice age and that nature had shifted in response. But, he noted, "the preindustrial migrations were made without having to worry about cornfields, parking lots and Interstates."

Citing the new work and studies of past climate shifts, Dr. Alley saw particular significance in the expectation that animals and plants that rely on one another were likely to migrate at different rates. Referring to affected species, he said, "You'll have to change what you eat, or rely on fewer things to eat, or travel farther to eat, all of which have costs."

The result in coming decades could be substantial ecological disruption, local losses of wildlife and extinction of some species, the two studies said.

The authors express their findings with a certainty far greater than in the last decade, when many of the same researchers contributed to reports on biological effects of warming that were published by the Intergovernmental Panel on Climate Change, the top international research group on the issue.

The authors of one of the new *Nature* papers, Dr. Camille Parmesan, a biologist at the University of Texas, and Dr. Gary Yohe, an economist at Wesleyan University, calculated that many ecological changes measured in recent decades had a 95 percent chance of being a result of climate warming and not some other factor.

"You're seeing the impact of climate on natural systems now," Dr. Yohe said. "It's really important to take that seriously."

Some butterflies have shifted northward in Europe by 30 to 60 miles or more, with the changes closely matching those in average warm-season temperatures, Dr. Parmesan said. The researchers were able to rule out other factors — habitat destruction, for example — as causes of the changes.

Some of these changes meshed tightly with variations in temperature over time. Dr. Parmesan cited bird studies in Britain. There, populations of the great tit adjusted their egg laying earlier or later as climate warmed early in the 20th century, then cooled in midcentury and warmed even more sharply after the 1970's.

Over all, Dr. Parmesan's study found that species' ranges were tending to shift toward the poles at some four miles a decade and that spring events, like egg laying or trees' flowering, were shifting 2.3 days earlier a decade.

Around Monterey Bay in California, warmer waters have caused many invertebrates to shift northward, driving some species out of the bay and allowing others to move in from the south.

Authors of both new papers said they were concerned that such significant ecological changes had already been detected even though global temperatures had risen only about one degree in the last century.

They noted that projections of global warming by 2100 ranged from 2.5 to 10 degrees above current levels, should concentrations of carbon dioxide and other heat-trapping gases, which flow mainly from smokestacks and tailpipes, continue to rise.

By comparison, the world took some 18,000 years to climb out of the depths of the last ice age and warm some five to nine degrees to current conditions.

"If we're already seeing such dramatic changes" among species, "it's really pretty frightening to think what we might see in the next 100 years," said Dr. Terry L. Root, an ecologist at Stanford University who was the lead author of one of the new studies.

The two teams of researchers used different statistical methods to analyze data on hundreds of species, focusing mainly on plants and animals that have been carefully studied for many decades, like trees, butterflies and birds. Both teams found, with very high certainty, a clear ecological effect of rising temperatures.

Several of the researchers said the effects of other, simultaneous human actions, like urban expansion and the introduction of invasive species, could greatly amplify the effects of climate change.

For example, the quino checkerspot butterfly, an endangered species with a small range in northern Mexico and Southern California, is being pushed out of Mexico by higher temperatures while also being pushed south by growing suburban sprawl around Los Angeles and San Diego, Dr. Parmesan said.

"The butterfly is caught between these two major human factors — urbanization in the north and warming in the south," said Dr. Parmesan, who has spent years studying shifting ranges of various checkerspot species.

Dr. Alley said the studies illustrated the importance of conducting much more research to anticipate impending harms and devise ways to maintain biological diversity, for instance with green "wildlife corridors" linking adjacent pockets of habitat.

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