Remembering Chernobyl ….

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As the plume from the Fukushima nuclear plant accident in Japan makes its way across the Pacific toward California, it brings back memories of the Chernobyl nuclear plant accident 25 years ago. I was working at the Palomarin field station on the Point Reyes National Seashore in coastal Marin County, California, at that time and was in the final stages of analyzing 10 years (1976-1985) of landbird breeding productivity data as a function of the amount of rainfall that occurred during the preceding fall/winter/spring. We had just found that the number of young birds produced during summer was highest following winters with average rainfall and decreased following winters with either reduced or excessive amounts of rainfall. Based on this relationship between numbers of young birds and winter rainfall, and on the amount of rainfall that occurred during the winter of 1985-86, which was slightly above the 10-year mean, we expected that numbers of young birds produced during the summer of 1986 would be about 10% above the 10-year mean. To our surprise, however, we found that the numbers of young landbirds produced at Palomarin during the summer of 1986 was 63.3% *below* the 10-year mean and represented a highly statistically significant outlier from the relationship established during the previous 10 years.

Our subsequent analysis of this event led to the hypothesis that the 1986 landbird reproductive failure at Palomarin was caused by radioactive iodine from the Chernobyl plume which passed over northern California and fell out coincident with rainfall on May 6. The timing of the reproductive failure, its geographical extent in California, and the landbird species most affected were all consistent with this hypothesis, which suggested that elevated levels of radioactive iodine adversely affected the development of hatchling birds by being absorbed into their thyroid glands during the 9-12 days when they were being fed by their parents in the nest. Similar reproductive failures of landbirds were documented from farther north in coastal California and from the western slope of the Sierra Nevada Mountains where rain, and thus large amounts of fallout, were coincident with the passage of the Chernobyl plume, but not from the east slope of the Sierra or southern California where rain was not coincident with the passage of the plume.

In addition, the reproductive failure at Palomarin did not begin at the onset of the breeding season nor did it extend throughout the entire breeding season, but coincided with the roughly 10 weeks between about May 6 and July 16 during which time young birds were in the nest and elevated levels of radioactive iodine were present in the environment (Iodine-131 has an 8-day half-life, such that elevated levels were reduced by over 99% after about 72 days). Other hypothetical causes for the 1986 reproductive failure, such as unusual weather during the preceding 12 months or during the breeding

season itself (in terms of both averages and extreme events in either rainfall or temperature), decreases in food supply, habitat changes, and applications of pesticides, were rejected because such conditions either did not occur or were not consistent with the productivity data. All of these results were published in a peer-reviewed paper in the prestigious North American ornithological journal, *The Condor* (DeSante, D. F., and G. R. Geupel. 1987. Landbird productivity in central coastal California: the relationship to annual rainfall and a reproductive failure in 1986. *The Condor* 89:636-653).

Analyses of subsequent data showed that the survival of older adult individuals (i.e., those that were four or more year old in 1986 – the average lifespan of adult landbirds is only about two years) of three non-migratory landbird species at Palomarin was *lower* during the winter following Chernobyl (1986-87) than during any of the previous six winters. In contrast, survival of younger adults (individuals that were 1-3 years old in 1986) of these three species at Palomarin during the winter of 1986-87 was *higher* than during any of the previous six winters, presumably because the winter of 1986-87 saw weather conditions favorable for landbird survival. This suggests that the excess mortality of landbirds exposed to the Chernobyl plume was limited to very young birds (nestlings) and very old adults.

Finally, I examined data from the North American Breeding Bird Survey, a network of nearly 3,000 randomly distributed but fixed routes along secondary roads in the United States where, at the height of the breeding season each year, birds are counted at 50 fixed stops along the route. Using these data, I compared the changes between 1986 and 1987 in the numbers of adult birds counted with the analogous changes between 1985 and 1986. The idea was that, if substantially fewer young birds than normal were produced during the summer of 1986, then the numbers of adult birds counted in 1987 would tend to be fewer than in 1986, and the extent of the declines between 1986 and 1987 would tend to be greater than the analogous declines between 1985 and 1986. Indeed, I found that this was the case. But more importantly, I found that the magnitude of the difference between the 1986-1987 changes and the 1985-1986 changes in various regions of the United Sates was significantly correlated with the amount of radioactive Iodine-131 detected in milk in those regions, as measured by the Department of Energy's Environmental Measurement Laboratory. Thus, the greater was the amount of radioactive Iodine that fell from the Chernobyl plume in 1986, the greater was the decline in adult birds in 1987 as compared to the corresponding change in adult birds between 1985 and 1986. This suggests that the landbirds in those areas in the United States that received higher doses of radioactive Iodine from Chernobyl suffered greater reproductive failures during 1986 (or higher mortality of adults during the winter of 1986-87 or both).

Unfortunately, the adverse effects on productivity and survival in the United States caused by the radioactive plume from Chernobyl were apparently not limited to landbirds. Indeed, Jay Gould and Benjamin Goldman present compelling data showing that humans in the United States also suffered extraordinary mortality from the Chernobyl accident (Gould, J. M., and B. A. Goldman. 1990. *Deadly Deceit: Low Level Radiation, High Level Cover-up*. Four Walls Eight Windows, New York. 222 pp). Their

major findings involve statistical estimates of excess deaths following Chernobyl (and other releases of radiation) and indicate that low-level radiation from fallout from nuclear reactor accidents (and from nuclear bomb testing) may have done far more damage to humans than previously thought. In particular, they showed that the arrival of radiation in the U.S. in early May 1986 from the Chernobyl disaster "was followed almost immediately by an extraordinary force of [human] mortality, amounting to perhaps 40,000 excess deaths in the summer months, especially in the month of May." Indeed, they showed sharp increases in mortality in the United States in infants, in persons aged 65 and older, and in persons with pneumonia, AIDS, and other infectious diseases during the summer months of 1986 compared to the same period in 1985. Again, as with birds, these are the very young and the very old, but the excess deaths in humans also included persons with compromised immune systems.

Even more importantly, Gould and Goldman (1990) showed that the percent difference in total human deaths in various regions of the United States between May-August of 1986 and May-August of 1985 was significantly correlated with the amount of Iodine-131 in milk in those regions. Moreover, the best fit to the relationship between excess human mortality during the summer of 1986 and the amount of radioactive Iodine in milk was not linear, but rather was logarithmic, indicating that the increases in mortality associated with increases in radioactivity were proportionally larger at low levels of radioactivity than at high levels. When Gould and Goldman extrapolated the logarithmic relationship that they found for the United States between excess infant mortality (which averaged 12.3% in June 1986) and the relatively low levels of Iodine-131 (which were generally less than 100 picocuries per liter) to the much higher levels of radioactive Iodine in Europe (peaking at over 10,000 picocuries per liter), they were able to correctly predict the elevated rates of excess infant mortality that were found there (e.g., about 68% in the southern parts of West Germany).

This latter result arising from Gould and Goldman's study of the effects of radiation from Chernobyl on humans is very important. It indicates that the conventional wisdom of assuming a single linear dose-response curve extending from high to very low levels of radiation is wrong and "underestimates the effects of low-level radiation on the most vulnerable members of the [human] population by a factor of about one thousand." This may especially be the case when the radioactive particles are ingested into the body by eating, drinking, or breathing, as opposed to the body being bombarded by a very brief pulse of radiation as from an x-ray. The bottom line is that severe deleterious effects on human health in Japan from the Fukushima accident may extend much farther away from the nuclear plant than authorities are suggesting. Moreover, deleterious effects on human health in North America may also be much more severe than Americans are being told to expect, especially perhaps along the West Coast where the plume will first arrive and where there may be a high probability of coincident rainfall which will likely increase the extent of fallout from the plume.