taneously respond to the rotational motion of the night sky. No obvious reward or change in external motivation can account for this importance of rotational information. Yet this visual exposure not only is necessary but must occur at a certain stage of development (*3*) if normal stellar orientational capabilities are to develop. I further hypothesized that there is no genetic template for recognition of certain star groupings. Rather, patterns of stars are learned. Yet there is a predisposition for inexperienced buntings to learn patterns located in the northern circumpolar area of the sky (*1, 3*), the region of least rotation.

Through this complex ontogenetic process, a young bunting acquires a celestial reference system, a necessary prerequisite for stellar orientation. The use of this reference to select a southerly heading in preference to any other remains a topic for future investigation.

Many questions remain unanswered. We need additional ontogenetic studies of orientation systems. We need more comparative studies of the types of cues used in long-distance direction finding. What we do *not* need is a premature categorization of orientation behavior according to outdated nature-nurture controversies.

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4 May 1971

Man-Made Climatic Changes: Seeding by Contrails

Landsberg's review of the impacts of man's activities upon climate (*1*) is certainly to be appreciated for its comprehensiveness and conciseness. His paragraph on the effects of "pollution caused by jet aircraft," however, and, in particular, his statement that evidence for the nucleation of precipitation by ice crystals falling from aircraft vapor trails is lacking, move me to offer the following comment.

It is true that appreciable effects of such cloud seeding in modifying rainfall patterns cannot be expected except in a heavily clouded area, because only there will sufficient cloud water be present to generate appreciable precipitation. At the same time, the observation of a contrail seeding a massive cloud system is unusual because the cloud system obscures the sky for the ground-based observer. Only an airborne observer can see such an event.

However, the seeding effect of "airplane cirrus" upon lower cloud decks is easily seen under less stormy conditions. On 19 November 1969 a high, thin altocumulus deck under contrails at Ann Arbor showed this seeding effect, and high-level snow showers were produced (Fig. 1). Had these clouds overriden a thicker cloud system, there is little doubt that the seeding effect would have affected the rain pattern. The difficulty of getting adequate photographs of this phenomenon is an important problem in acquiring the needed documentation, but the effect itself is frequently and easily observed.

Fig. 1. Snow showers from an altocumulus deck under contrails.

A more detailed documentation of the seeding effect of cirrus upon lower clouds has been reported by Braham and Spyers-Duran (*2*). Although this report does not specifically refer to "airplane cirrus" or "contrails," it should be clear that the ice crystals from contrails are just as effective for cloud seeding as those from natural cirrus clouds or from PbI_2 and AgI nucleation.

Within the context of my own observations, associated with the teaching of cloud-watching to students of meteorology over the last 23 years, I have had the strong impression that the cirrus cloud cover over the continental United States has been appreciably enhanced by aircraft exhaust products placed in the layer at 30,000 to 40,000 feet (9145 to 12,190 m). This impression has been vindicated by work recently reported by Machta and Carpenter (*3*) on the frequency of cirrus clouds at Denver. This increment of cirrus cloud cover must certainly have its effect upon the precipitation distribution. The total effect, however, even though it may be substantial, is at most a small fraction of the observed variability of rainfall amount patterns (*4*). Thus, again, the direct observation of precipitation changes attributable to airplane cirrus is not likely in the context of currently accepted procedures for measuring and recording precipitation.

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16 February 1971; revised 23 April 1971

If my statements had no other effect than to bring out the valuable information presented by Dingle, it would have been a worthwhile effort. Perhaps my remarks on the possible influence of ice cloud streaks produced by airplanes on rainfall from lower natural clouds could have been more judiciously worded. While freely admitting that such cases indeed exist and perhaps, as Dingle implies, are not uncommon, I believe that their restriction in time and space on a global scale makes it likely that their effect on climate is minimal and disappears in the "noise" discussed in my article.

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17 May 1971

Role of Animals in Suppression of Herbs by Shrubs

Bartholomew (*1*) has challenged the idea that phytotoxins are causative in the production and maintenance of bare zones associated with shrub borders impinging upon annual grassland in California. However, we feel he has oversimplified the problem. In our descriptions (*2*) of the interactions of phytotoxins, animal grazing and seed predation, and variable physical and competitive factors in the production of "bare" zones and inhibition zones separating *Salvia leucophylla* from annual grassland, we have tried to dissuade readers from accepting any simplistic, "single-factor" explanation of the phenomenon, and have admitted repeatedly that even phytotoxins fail to control in some situations.

We hold that Bartholomew's and our experiments combined permit no definitive characterization of animal roles. More instructive have been our negative results, that is, the frequent failure of animal pressure to reduce herb growth within its sphere and also the failure of phytotoxins to have effect under certain circumstances. More pertinent still are the instances in which bare zones develop in the absence of animal pressure. The following observations required few counts or measurements because they exhibited "all-or-none" attributes. Each manipulation and observation of natural variables was fully controlled by corresponding checks; most results with statistical qualities were recorded in the form of data for which there is no space here.

1) Some herb species (for example, *Bromus rigidus*) were absent from the inhibition zone which extended several meters past the range of rodents as revealed in our baiting experiments (Fig. 1), although only rodents feed on the seeds of *B. rigidus*.

2) Seeds of *Bromus rubens* and *B. mollis* were not taken by birds and were taken only sparingly by rodents in baiting experiments. Seeds of *Festuca megalura* were taken only by harvester ants which were absent over most of the area examined.

3) Natural shade and the resulting conservation of moisture permitted dense growth of these species which eliminated the bare zone, thus proving that the seed supply was undiminished, that *Salvia* toxic effectiveness required normal drought stress, and that animal pressures failed to support a bare zone.

4) Repeated observation of young seedling mortality without evidence of animal grazing in typical bare zones negated the requirement of grazing.

5) Exclosure cages (with or without sides) in bare zones contained seedlings from 10 to 50 percent the height of the same species at the same time in adjacent unprotected grassland early in the growing season.

6) Fog drip and conservation of moisture beneath all cages resulted in lush growth later in the season so that harvesting and weighing at the season's end missed the period of toxic stunting and were therefore meaningless.

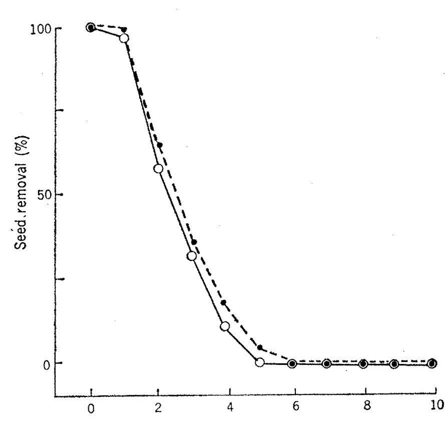

Fig. 1. Nocturnal (mammalian) removal of the most palatable seeds during March 1966 (a period of low availability of seed and high density of animals). *Salvia* zone (0 m), bare zone (0 to 2 m), and inhibition zone (2 to 10 m); solid line, *Bromus rigidus*; dashed line, *Avena fatua*.

7) Lush growth in the protection of sideless cages strongly contrasted with death of stunted (ungrazed) seedlings due to drought in adjacent open bare zones.

8) Total removal of isolated *Salvia* thickets left a bare zone with no grass the first year and only stunted, sparse growth the second; this fact indicated some persistence of toxic effect where there was no cover for animals.

9) Gross differences in grassland inhibition characterized shrub thickets of different species, *Salvia leucophylla* being distinctly more effective than *Ceanothus cuneatus, Adenostoma fasciculatum*, or *Artemisia californica*.

10) The areas beneath the cover of artificial shrubs of nontoxic *Ceanothus* branches within grassland, heavily inhabited by *Peromyscus* and *Sylvilagus bachmani*, were barren of herbs after 2 years, but after 7 years there was no diminution in the size or density of herbs beyond their limits.

From these facts we conclude that (i) early stunting of grass seedlings by toxins and their eventual failure in the bare zone require the moderate stresses of periodic drought characteristic of normal conditions of rainfall in southern California (without protection such as cage roofs); (ii) grazing by small animals in exposed grassland without the support of phytotoxins does not result in bare zones; (iii) very favorable conditions of soil moisture can counteract phytotoxic and animal effects combined; (iv) the pattern of bare zones is neither initiated nor maintained by animals acting alone; (v) the pattern is maintained by phytotoxins even where animal pressure is lacking and may be initiated largely by inhibition of germination.

Bartholomew has criticized our failure to demonstrate sufficient concentrations of *Salvia* terpenes in soil to give positive inhibitory results in vitro. These toxins must act in our bioassays within 48 to 72 hours under optimum growing conditions, but their activity in the field extends over several weeks of slow growth under normal periodic drought stress. Stunting of herbs in the first few weeks of growth in the absence of grazing cannot be otherwise explained. We have recently obtained good positive results (*3*) from in vitro bioassays of soil from *Artemisia cali-*