Sage Science

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To predict cheatgrass die-offs we must understand their cause

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In brief

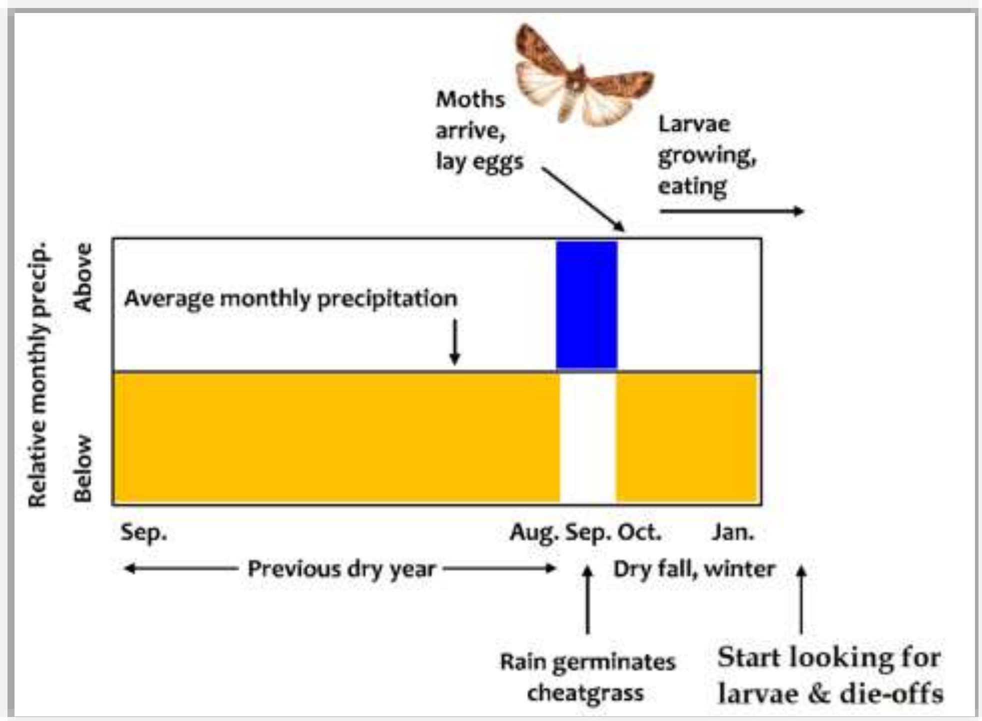
- Exotic cheatgrass fuels rangeland wildfires in the intermountain west.
- Cheatgrass die-offs are large bare patches that appear suddenly in cheatgrass-invaded areas.
- Die-offs are opportunities to reseed invaded areas with native species while there are few cheatgrass seeds in the soil to sprout and compete with sown plants.
- Army cutworms (ACW) consume cheatgrass seedlings to produce die-offs and can also defoliate native shrubs. The larvae hide in plain sight by feeding at night in winter and spring and hiding during the day. Later, they pupate in the soil and fly away.
- Major ACW outbreaks and die-offs in 2003 and 2014 occurred during drought broken by late summer rain to germinate cheatgrass for larvae to eat.
- Two recent federal land management reports overlook ACW as the most likely cause of die-offs.
- Both reports state that fungal pathogens cause cheatgrass die-offs. However, fungi have not been linked to die-offs, are rare during drought, and would require a more complex series of events to damage cheatgrass.

Cheatgrass (*Bromus tectorum*) die-offs are bare areas, often covered with gray plant litter, that appear suddenly within stands of normal-looking cheatgrass. Die-offs have distinct boundaries and can cover up to several square miles. Perennial grasses and forbs within die-offs are unaffected, but the exotic annual mustards (Brassicacaea) that often grow with cheat-grass are also missing. Cheatgrass die-offs are sporadic in time and space: widespread die-offs occur relatively rarely, and die-offs only infrequently reappear in the same place.

Die-offs first appeared in low, dry areas of the intermountain west in 2003, during a major army cutworm (ACW) (*Euxoa auxiliaris*) outbreak. B. Hammon of Colorado State University (*personal communication* 2003) described conditions leading to the outbreak and die-offs:

1. a first year of dry weather created many egg-laying sites,
2. late summer rain germinated cheatgrass for larvae to eat,
3. a large flight of ACW (miller) moths in fall laid many eggs,
4. dry fall and winter weather allowed many larvae to survive and consume cheatgrass seedlings. (Figure next page)

Ranchers and at least one researcher watched ACW eat cheatgrass in early 2003. Entomologists saw extensive ACW damage to crops in southwest Colorado and northern New Mexico. I saw a cheatgrass die-off in Nevada on April 17, 2003, but didn't learn the cause of the bare area until later that year.



Army cutworm outbreaks in the intermountain west are most likely after a year of dry weather is broken by September rain, followed by a large flight of miller moths, and a second period of dry weather through January.

My 2004 research poster described how ACW outbreaks could create cheatgrass die-offs (Salo and Zielinski 2004). I recognized the appropriate conditions in January 2014 and found ACW in cheat-grass die-offs in late February in Owyhee County, Idaho. Die-offs also occurred in northern Nevada in 2014. In a research paper, I documented larval damage and vegetation recovery (Salo 2018).

A remote sensing study has since confirmed that cheatgrass die-offs are most likely during a dry winter following a previous dry year (Weisberg et al. 2017). The lead author told me their study did not look at the effect of September precipitation.

Army cutworms are the most likely cause of cheatgrass die-offs

A recent U.S. Geological Survey report (Remington et al. 2021) and an earlier U.S. Department of Agriculture report (Crist et al. 2019) both recognize cheatgrass die-offs as opportunities to reseed cheatgrass-invaded areas with desirable native species, but both overlook ACW as the most likely cause of die-offs.

Army cutworms are the simplest, most direct cause for these events. Ranchers, who are out on rangelands in winter and at night far more than researchers and federal land managers, are familiar with ACW eating both cheatgrass and crops. Entomologist watch for ACW damage to wheat and canola, closely related to cheatgrass and weedy mustards.

The life histories of ACW and cheatgrass interact to create sporadic and spotty die-offs. To reach outbreak levels, ACW need cheatgrass seedlings for food in winter and early spring. Cheatgrass seeds need significant rain during usually-dry September to germinate in time to feed ACW. The rarity of significant rain at this time means that ACW outbreaks are relatively rare. The larvae earn their common name for their habit of marching *en masse* to find and consume essentially all their preferred plants—creating bare areas.

After ACW pupate, the adult miller moths fly to high elevations, leaving no fingerprints behind. The moths spend the summer feeding on nectar and being fed upon by grizzly bears.

The following fall, the moths catch wind currents back to low elevations. The capriciousness of wind makes it unlikely that eggs will be laid in the same place more than once. A remote sensing study found that over 80% of die-off sites do not experience die -offs the following year (Weisberg et al. 2017).

However, both recent federal reports overlook the evidence and state that fungal pathogens cause cheatgrass die-offs. Both cite Meyer et al. 2016's book chapter, "Community ecology of fungal pathogens on *Bromus tectorum.*"

Occam's Razor shaves away fungal pathogens

Occam's Razor reminds us that the simplest explanation that fits the evidence is usually the correct one. Army cutworms are the simplest explanation for die-offs—with the most evidence. None of the fungi studied by Meyer et al. and described in their 2016 book chapter have been clearly linked to die-offs. They do not report studying pathogenic fungi of exotic mustards, which are also missing from die-off areas and are readily eaten by ACW.

Meyer et al. 2016 state that fungal pathogens "sometimes interact to increase the total impact on *B. tectorum* stand structure, which can result in stand failure or 'die-off'," (page 193). They suggest that "thick litter created by [Rutstroemiaceae] may create conditions conducive to the success of *Fusarium* seed rot organism the subsequent year," (page 218). This explanation is more complex, less direct, and supported by less evidence than the ACW explanation.

Differences between ACW and fungi in weather conditions when outbreaks occur, local patterns of damage, and local persistence point all to the former as the most likely cause of die-offs (Table 1).

Weather: *Cheatgrass die-offs occur during dry weather.*
Most pathogenic fungi need wet conditions to grow, spread, and infect plants. Army cutworm outbreaks typically occur during dry weather lasting about 1½ years, broken by unusual late summer rain, to reach outbreak levels. Remote sensing work has also found that die-offs occur during drought (Weisburg et al. 2017).

Local damage pattern: *Cheatgrass die-offs are bare soil.*

Three of the five fungi discussed in Meyer et al. 2016, *Ustilago bullata*, *Tilletia bromi*, and a type of Rutstroemiaceae, infect cheatgrass without killing the plants. These organisms prevent the production of normal seeds, but do not destroy plants: they do not create the bare patches seen in cheatgrass die-offs.

Pathogenic fungi can't move to seek out host plants. Fungi are moved by wind or water, which typically produce spotty local patterns of fungal diseases. Some fungal diseases, such as late blight of potato, which led to the Irish potato famine, can kill essentially all plants in an area. However, these fungi leave fields of decaying plants, not bare areas. Army cutworms consume plants to bare soil.

Local persistence: *Cheatgrass die-offs usually last only one year.*

The other two fungi discussed in Meyer et al. 2016, *Pyrenophora semeniperda* and *Fusarium* spp., kill seeds in the soil; *Fusarium* spp. can also kill seedlings. *P. semeniperda* is one of many soil fungi that kill cheatgrass seeds, but the effect of this fungus on cheatgrass stands is negligible (Meyer et al. 2016, page 208). *Fusarium* spp. can be a serious problem in crops, as pathogenic fungi usually persist in an area longer than one year. For example, gardeners rotate tomatoes with other crops and plant resistant varieties to avoid Fusarium wilt (*F. oxysporum*). Army cutworms, in contrast, leave the scene after creating die-offs, and winds rarely carry moths back to the same spot in later years.

Table 1. Broad differences between army cutworm and fungal outbreaks.

	Army cutworms	Fungal pathogens
Weather	Dry, broken by late summer rain	Wet
Local damage pattern	Complete: active spread	Spotty: passive spread
Local persistence	Migratory: adults fly away	Resident: live in soil

Previous reports of cheatgrass die-offs

Meyer et al. 2016 discuss previous reports of abnormal cheatgrass growth. However, neither appears to have been caused by pathogenic fungi. The first seems to describe an ACW outbreak; the second, a dense stand of cheatgrass.

Report 1: *Cheatgrass winterkill in southwest Idaho in 1960*

Meyer et al. 2016 cite winterkill of cheatgrass observations by Piemeisel 1938; the source is actually Klemmedson and Smith 1964. Klemmedson's original photos and descriptions of the event are archived at the Rocky Mountain Research Station (next page).

Klemmedson describes an event in 1960 near Glenns Ferry, Idaho strikingly similar to the 2003 and 2014 die-offs: large, litter-covered bare areas that end abruptly normal-appearing cheatgrass; unaffected perennial Sandberg bluegrass (*Poa secunda*); and a summer cover of Russian thistle (*Salsola kali*). I have suggested that this event, and a similar one in 1949 in Payette County, Idaho, were caused by ACW outbreaks (Salo 2017, slides 26, 27).

Glenns Ferry, Idaho recorded conditions before the 1960 die-off strikingly similar to those before the 2003 and 2014 ACW outbreaks and cheatgrass die-offs: a previous year of dry weather, heavy September rain, and a dry fall and early winter from October through January (Table 2).

Klemmedson and Smith 1964 suggest that desiccation or pink snow mold caused the 1960 event and cite Sprague's 1953 description of the mold. According to Sprague, *Microdochium nivale* = *Fusarium nivale*) attacks grasses "in late winter, either under the snow or during raw winter weather." The attacked leaves turn into "pink or straw-colored mats, which dry to paper films," (page 271).

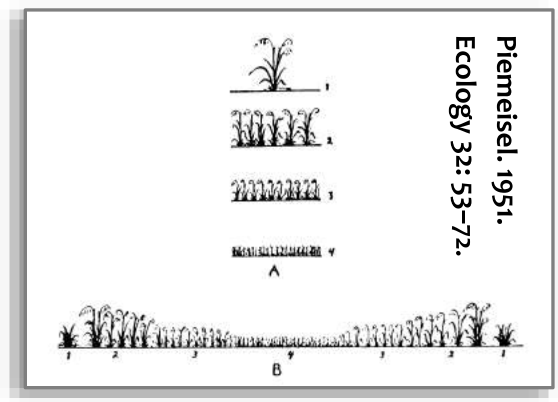
However, snow and raw winter weather would have been unlikely during the dry winter of 1959–1960. In addition, Klemmedson's photos and descriptions show the litter that often covers cheatgrass die-offs, not the papery films of pink snow mold. The weather conditions, photos, and descriptions all point to ACW, rather than pink snow mold, as the cause of the 1960 die-off.

Table 2. Conditions preceding three cheatgrass die-offs and two army cutworm outbreaks.

	Location, year, event →	Glenns Ferry ID, 1960 die-off	Grand Junction CO, 2003 out-break & die-offs	Grand View ID, 2014 outbreak & die-offs
Precipitation (portion of average)	Initial year, Sept.–Aug. (1958 – 59, 2001–02, 2012–13)	0.49	0.59	0.46
	Previous September (1959, 2002, 2013)	9.2	1.8	9.8
	Winter, Oct.–Jan. (1959–60, 2002–03, 2013–14)	0.41	0.65	0.66
Moth flight size		Unknown	High	High
Weather data source and years used to calculate precipitation averages.		NOAA NCDC 1939–1958	NOAA NCDC 1981–2010	USBR Agrimet 1993–2012

Report 2: *Cyclic succession on abandoned cropland in southern Idaho in 1941*
Meyer et al. 2016 cite Piemeisel's 1951 report of "degenerate" cheatgrass stands "in which seed production was prevented and stand loss ensued," (page 195). Meyer et al. 2106 continue, "He credited this effect to increasing intraspecific competition, but it seems plausible that plant pathogens… could have played a role. This process is very similar to the 'die-off' or stand failure in *B. tectorum* monocultures documented in recent years."

However, the pattern Piemeisel 1951 describes (right), and that Meyer et al. say is similar to cheatgrass die-offs, is the opposite of that seen on cheatgrass die-offs.



Piemeisel reports islands of cheatgrass, “as small as a few feet in diameter… in parts of a field in 1941 where downy chess [=cheatgrass] was beginning to establish,” (page 56). The “degenerate” stand at the center was “a disk composed of a very dense, short growth of immature plants… with barely emerging heads.” Plants in the outer portions of the islands were progressively more robust as the plant density decreased.

Cheatgrass die-offs, on the other hand, are large bare areas cut out of normal-appearing cheatgrass stands—the inverse of Piemeisel’s islands. He certainly seems to describe intraspecific competition in cheatgrass, not a die-off.

Army cutworms are the most likely cause of cheatgrass die-offs

Researchers and ranchers have watched the larvae consumer cheatgrass, mustards, and the leaves of native shrubs (Salo 2018). The life cycles of cheatgrass and ACW, driven by weather, interact to produce periodic larval outbreaks that create die-offs sporadically across low, dry areas in the intermountain west.

When we understand ACW enough to predict their outbreaks, we’ll know when and where to look for die-offs. My “trapline” in Owyhee County, Idaho monitors fall miller moth flights; nearby weather stations in Grand View and Murphy record precipitation. When conditions that lead to ACW outbreaks occur though the end of January, it’s time to start looking for larvae and die-offs. Reseeding die-offs with desirable native species will let the sown plants get started while there are few cheatgrass seeds in the soil to sprout and compete with them.

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