Baja California Sur Plant Mortality Event Preliminary Assessment

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Summary and Recommendations

A broadscale phenomenon of plant dieback and stress response was observed in early 2023 at Rancho El Ancón, Cape Region, BCS. The dieback event appears to be concentrated in this region of BCS, but observations as far north as Loreto detect similar effects in columnar cacti in areas beyond the Ancón region. Effects are seen across a variety of taxa, including (1) the development of scarred, gray tissue in columnar cacti, sometimes preceded by tissue chlorosis and strongly associated with loss of chlorophyll in previously green stems; (2) dieback of terminal branches with clear abscission zones in trees such as lomboy (*Jatropha*); (3) basal or stem rot in a variety of woody plants, (4) a prevalence of beetle infestation in wood of living *Bursera,* and (5) the occurrence of polypore fungi on palo blanco (*Lysiloma candidum*) and mauto (*L. divaricatum*) associated with live and decaying individuals.

We concur that the stress/dieback observed first at Rancho El Ancón is a meaningful phenomenon. Close attention to multiple individuals of affected plant species revealed diverse manifestations of stress rather than evidence of a broad-scale pathogen or pest infestation. Meteorological records from the region indicate a pronounced and deep drought from April 2020 to March 2021, which is unprecedented in the instrumental record. This severe drought, coupled with other climatic aberrations, is likely central to understanding the increased evidence of abiotic stress and biotic stress observed in plants of the area.

Climate stresses are likely exacerbated in some areas by damage from land use history, which current conservation approaches by Ancón are actively mitigating. Supporting hydrological improvements as well as promoting re-establishment of biological soil crusts and understory plants by limiting severe grazing, especially when paired with erosion mitigation, is likely a key step in the overall health of the region.

Notably, Ancón occurs at a ecotonal transition from coastal desert scrub to foothills Baja California Cape Region thornscrub. Many of the affected columnar cacti species occur at the margins of their habitat, where climate stressors often act most harshly. It is likely that a region-wide environmental stressor, possibly the 2020–2021 drought, has triggered a stress response in a set of plant taxa leading to rapid decay and in some cases mortality.

Observations were made to assess the potential of heavy metal pollution as a causative force. Several lines of inquiry, especially the observation of abundant and diverse lichen communities (typically strong indicator species for aerial contamination) and the detection of moderate, rather than extreme, heavy metal contamination in soils and to a lesser extent within plant tissues in the affected areas suggest heavy metal pollution is not a primary factor.

It is our view that interventions such as landscape-level applications of fungicide are not recommended. Instead, coupled with ongoing, longer-term conservation approaches, local mitigation steps in a trial framework may be taken, including:

(1) painting cut branches of trees with anti-beetle and antifungal barriers,

(2) carrying out phytosanitation on plants of personal and landscape importance,

(3) in those cacti amenable to doing so, transplanting a small number of green limbs, while taking care to recognize that with the return of seasonal humidity and rains, even apparently damaged limbs may yield new growth,

(4) monitoring lichen growth rates, perhaps with student groups and further identification of lichen species with the possible involvement of Dr. Frank Bungartz, ASU,

(5) considering sulfur, ozone, and other outputs of the power plant in addition to the analyses of heavy metals already accomplished.

We further recommend these longer-term actions:

(6) characterizing the existing soil- and plant microbiomes so that should a pathogen gain a greater foothold due to current stressors, it will be detectable,

(7) Where gabions are placed, do so in a manner that preserves the biological soil crusts to maintain their role in erosion control and soil health.

(8) identifying the fungal species infecting mauto and palo blanco, and understanding its sensitivity to climate, and similarly, identifying and characterizing the impacts of Cerambycidae and other beetles affecting *Bursera* and other trees,

(9) conducting repeated vegetation surveys of transects and plots at permanent sites paired with permanent photo stations at Rancho El Áncon and throughout the region, to characterize and track the fate of both healthy and afflicted plants,

(10) using drones to scale up plant dieback observations and detection to landscape level, with calibration and ground truthing at permanent transect and plot locations,

(11) modeling the areas affected by the widespread 2020–2021 drought as a predictor of plant stress responses and conducting field visits to ecotones and drought perimeter,

(**12**) continuing research into the mechanism of rapid cactus epidermis degradation using advanced microscopy methods.

Nestled in a transition zone within the rich biodiversity of the Cape Region, Rancho El Ancón is exceptional due to its natural beauty and the outstanding conservation actions already in progress over the last decade. The numerous scientific studies and adaptive management approach establish Ancón as a globally unique natural laboratory of the highest quality for studying systems-level responses to climate stress and other factors. Due to early detection and an array of scientific investigations, collaborations, and local treatments, continued study of the plant dieback event at Rancho El Ancón will provide an enhanced understanding of similar changes across the Sonoran Desert, as well as possible remediations.

Observations

A. Meteorological Records

Data sources

Meteorological records have been pooled from two stations nearest to El Ancón since 1952 (Los Planes) and 1982 (El Sargento), and one station to the north at Loreto since 1981. The stations are:

- Estación 3167, El Sargento, La Paz, BCS, 24.080278 -109.994444, 20 m.
- Estación 3037, San Juan de los Planes, BCS, 23.968056 -109.936511, 20 m.
- Estación 3168, Loreto, BCS, 26.0166667 -111.347222, 6 m.

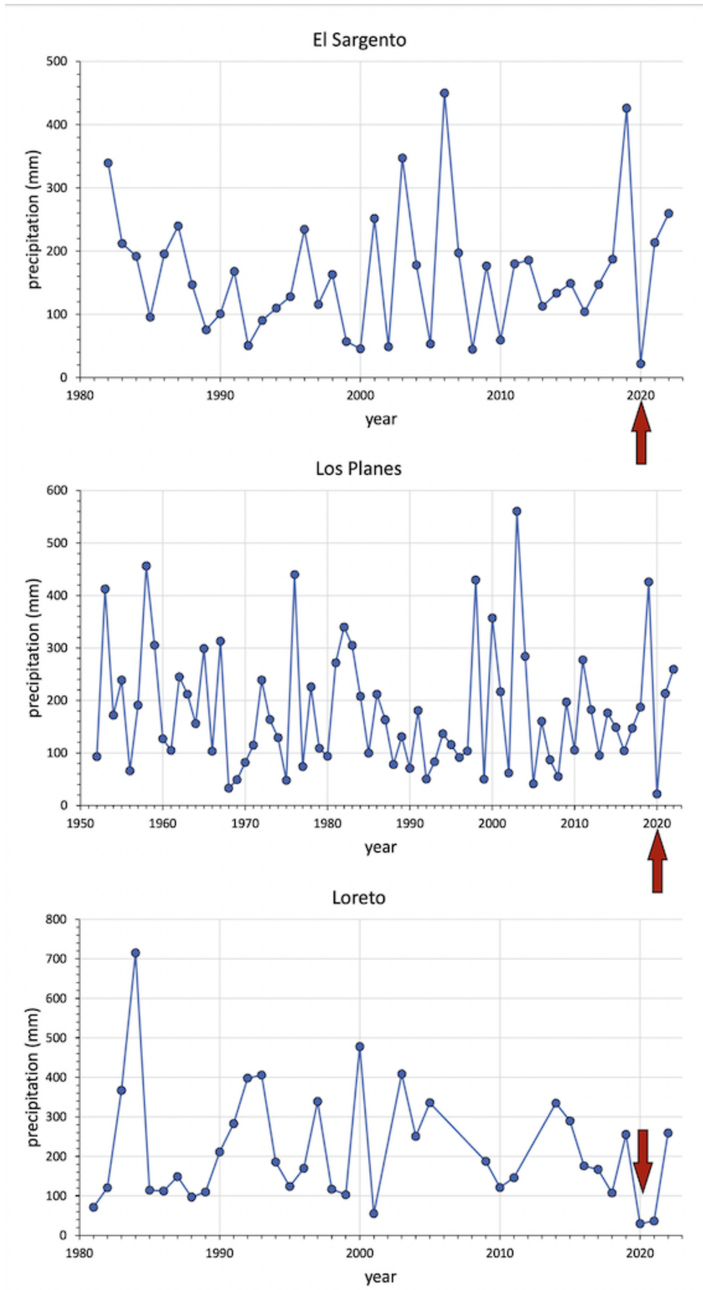
Data from before 2018 were obtained from non-automated weather stations and downloaded from CONAGUA's "Información Estadística Climatológica": https://smn.conagua.gob.mx/es/climatologia/informacion-climatologica/informacion-estadistica-climatologica

Data from January 2018 onwards were obtained from automated weather stations and downloaded from CONAGUA's "Resúmenes Mensuales de Temperatura y Lluvias": https://smn.conagua.gob.mx/es/climatologia/temperaturas-y-lluvias/resumenes-mensuales-de-temperaturas-y-lluvias

Because the two first series (El Sargento and Los Planes) were highly correlated (r=0.62), missing data points in one series were filled in with the corresponding month from the other series as a predictor. Years 1988, 1989, 1981, and 1982 in El Sargento had one or more missing monthly readings, while 1990–1993 and 1998–2000 at Los Planes had some missing months. Using both series as complements, precipitation at Los Planes was reconstructed from 1982 to 2023 for El Sargento, and from 1952 to 2023 for Los Planes.

Main findings

All three stations (El Sargento, Los Planes, and Loreto) show the year from April 2020 to March 2021 as the driest year on record for the last 70 years. That period was preceded by one of the wettest years (2019) on record and then followed by two relatively, though not extraordinary, wet warms seasons. This brief period has seen alternations between extreme rain and extreme droughts, similar as to the early 2000s. The recent extraordinary drought should be considered as a likely driver of the plant stress response being observed.



Fitting a probability density function (Gamma distribution; Rodrigues & Ezcurra 1986) to the data, we found a probability for the observed 2020 anomaly of approx. 1% (*P*=0.01) for El Sargento and Los Planes, indicating that the recurrence interval of a drought as serious as the 2020 anomaly is on average one-in-a-hundred years.

It was, indeed, a dry period of historic proportions. For Loreto, the probability of the 2020 anomaly was 2% (*P*=0.02), that is, a drought with a mean recurrence time of 50 years.

B. Plant Responses

Species of focus
The primary species of plants that displayed signs of stress were:

Bursera microphylla (Burseraceae), torote, elephant tree
Pachycereus pecten-aboriginum (Cactaceae), cardón barbón
Pachycereus pringlei (Cactaceae), cardón
Stenocereus gummosus (Cactaceae), pitaya agria
Stenocereus thurberi (Cactaceae), pitaya dulce

Other species reported to display signs of stress, which we feel are exhibiting more expected responses within a normal range of environmental response are:

Cyrtocarpa edulis (Anacardiaceae), ciruello
Ficus palmeri (Moraceae), zalate
Jatropha cinerea (Euphorbiaceae), lomboy
Lysiloma candidum (Fabaceae), palo blanco
Lysiloma divaricatum (Fabaceae), mauto

In addition to the 123Survey data being collected on stressed individual plants, a general quantification of the frequency of stressed individuals among select species was conducted on trails of Rancho El Ancón. In general, the columnar cactus species show the greatest evidence of stress. There does not seem to be a difference between stress response in adults compared to juveniles or in the foothills relative to higher elevations (above 630m) on the property.

Species	Healthy	Uncertain health	Ailing	N
Bursera microphylla	18 (95%)	1 (5%)	0	19
Cyrtocarpa edulis	13 (72%)	5 (28%)	0	18
Pachycereus pecten-aboriginum	8 (50%)	5 (31%)	3 (19%)	16
Pachycereus pringlei	6 (8%)	48 (65%)	20 (27%)	74
Stenocereus gummosus	10 (26%)	23 (59%)	6 (15%)	39
Stenocereus thurberi	66 (65%)	18 (18%)	17 (17%)	101
ALL	**121 (45%)**	**100 (37%)**	**46 (17%)**	**267**

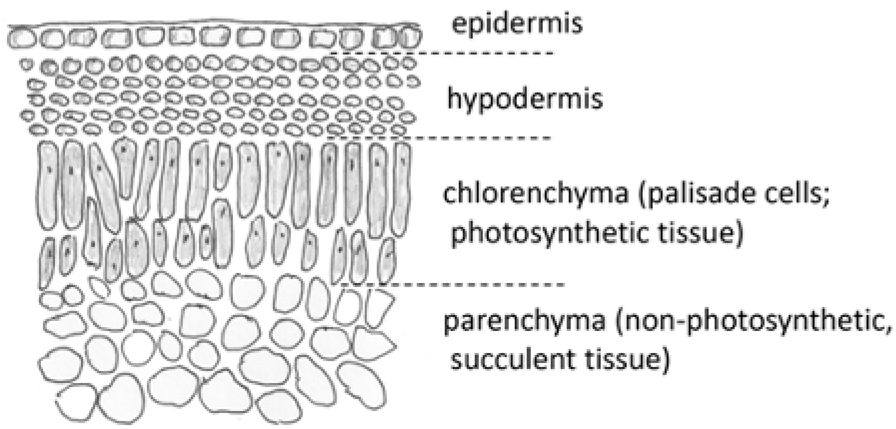
Rapid tally of health status of select plant taxa along trails of Rancho El Ancón. (Data: B. Wilder)

It should be noted that the populations of all columnar cacti occur at the margins of their primary habitat range at Rancho El Ancón and are all relatively less common than in adjacent areas. Ancón is in a transition area from coastal desertscrub (where cardón and pitaya agria are more prevalent, pitaya dulce rare, and cardón barbón absent) to a foothills thornscrub at higher elevations (where cardón barbón is most common, pitaya dulce prevalent, and cardón and pitaya agria increasingly rare).

It is possible that these individuals at the margins of their habitat preferences are displaying greater degrees of stress than in adjacent core habitat zones. For example, healthy cardon were common along the road inland from Los Planes, with most exhibiting extensive new growth and lacking the damage observed upslope.

Cactus epidermal degradation

Most cacti have green, photosynthetic stems protected by a tough outer covering composed of a membranaceous epidermis together with one-to-many layers of a thick-walled protective hypodermis. Despite its toughness, the dermis (epidermis + hypodermis) in columnar cacti is quite transparent; it forms a live layer of cells that protects the underlying photosynthetic tissues from water loss and UV radiation.



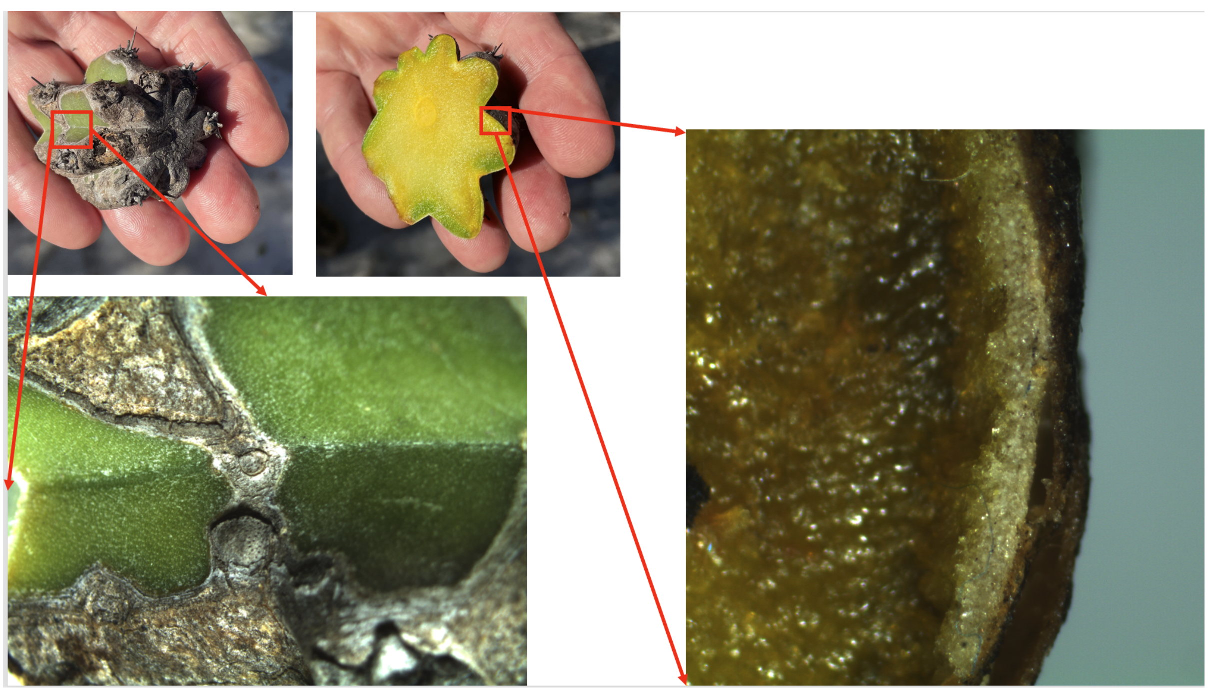
Simplified diagram of the cortex in Ceroid cacti. See text for a detailed description.

It is believed that the entire dermal membrane remains alive and functional for the entire time span of these plants, which in the case of cardón can reach well over 100 years. Beneath the dermis, the photosynthetic tissues (chlorenchyma) extend to the depth of where light reaches. Below the chlorenchyma, a mass of large thin-walled cells extends inwards on to the pith, forming the succulent, non-photosynthetic tissues that are characteristic of the cactus family. The role of the chlorenchyma is basically that of water storage and also of metabolic support for the particular type of photosynthesis of the family, known as Crassulacean Acid Metabolism or CAM: in the large vacuoles of the parenchyma, CO_2 fixed during the night is stored in the form of malic acid.

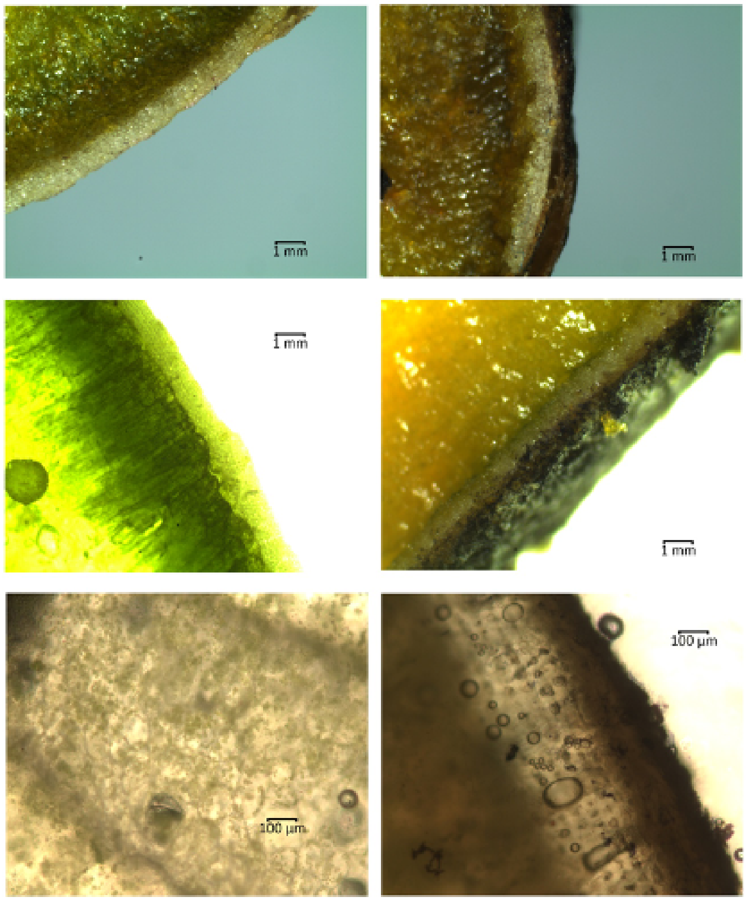
To better understand the damage observed on the exterior of several of the columnar cacti, especially pitaya agria (a graying of the stem) and pitaya dulce (a yellowing followed by a graying of the stem), fresh cuts were made from the pitaya agria.

Assessment under a dissecting scope and a compound microscope revealed that there was no pathogen present and the gray metallic crust that covers the columnar cacti is dead epidermis. When samples from the area were examined more broadly, microfungi were detected that would be expected in this environment (often highly melanized Dothideomycetes, for example, and yeasts from rotting cacti). This further supports the unlikely cause of a pathogen, especially a recently introduced one, to be causing the graying of cactus tissue.

Epidermal browning, or the gradual development of a true cortex from the epidermis of cacti, has been reported many times in the literature (see Evans & Cooney 2015 for a comprehensive review), associated with solar damage from UV-B radiation. In the case of the cacti at El Ancón, the dead layer observed was massive in many plants, and had not yet developed the typical corky layering that normally develops as a result of the formation of a cortex cambium, or phellogen. It seems that the epidermis died suddenly, leaving behind the dead cellular remains that stay on the cactus surface as a thin, dry crust (i.e., the smooth, gray-metallic layer).



Dissection microscope images of the gray/dead epidermis of pitaya agria.



Epidermal cuts of the sour pitaya Stenocereus gummosus*. Healthy epidermis sections on the left, dead epidermis on the right. First row shows dissecting scope images illuminated from above. Second row shows thin dissections lit from below. The third row shows healthy (left) and degraded (right) epidermis in the compound microscope. Note:*

- *the formation of a dead epidermal layer in cortex-degraded plants,*
- *the survival of some healthy hypodermis behind the dead epidermis, and*
- *the disappearance of chlorophyll in the palisade tissues under dead epidermal layers.*

The chlorenchyma under the crusty, opaque cortex is non-functional, as it has lost the chlorophyll in the palisade tissue cells. If the cover of the gray cortex is less than, ca. 40% of the plant, it is possible the plant may be able to recover with the photosynthetic capacity that still remains. However, in those plants that have 50–70% of their epidermis turned gray and dead, the prospect is quite bleak, *unless* offset by new shoot growth.

Although no direct research has been done on cacti specifically, there is a solid body of research associating epidermal solar damage and physiological stress in plants that can provide a testable mechanism for the epidermal decay.

As a means of alleviating the harmful effects of ultraviolet-B radiation (UV-B), many plants utilize radiation-screening agents, such as flavonoids and phenolics, generated by natural biosynthetic pathways and fine-tuned to absorb the destructive photons of high-frequency ionizing radiation (Bieza and Lois 2001). This is particularly important in columnar cacti, which, lacking leaves, have to maintain the same photosynthetic tissues in the cortex of their stems for decades or even centuries. The molecules of the plants' natural sunscreen are synthesized in the internal parenchyma and are transported to the epidermal layer, where they accumulate in relatively high concentration to prevent penetration of UV-B radiation into the underlying layer where photosynthesis occurs (Ruegger and Chapple 2001).

Molecular research in model plants (Arabidopsis thaliana) has shown that the main compounds providing UV filtering to the plants' epidermis are sinapate esters, or sinapates (although other phenolics may be playing a similar role in cacti). They are metabolic derivatives of sinapic acid, and sinapoyl malate that are opaque to UV-B (Dean et al. 2014). Because, while fulfilling their role as radiation filters, the sunscreen molecules get degraded by ionizing radiation, the plant needs to divert part of its metabolism to the synthesis of fresh UV-intercepting molecules.

It follows, then, that if the cactus is physiologically stressed by some abiotic stressor, its ability to produce new sunscreen molecules will be reduced, rendering the plant vulnerable to solar damage in the epidermis.

We observed the frequent presence of stems constrictions in cardón, cardón barbón, and sweet pitaya. In all cases, stem constrictions appear some 8–15 cm below the apex, consistent with a very serious drought event having taken place recently. Because annual stem elongation of cardón normally is ca. 4–10 cm/y (Delgado-Fernández et al. 2016), presence of these stem constrictions in early 2023 suggests the occurrence of extraordinary water stress two years before, during the 2020–2021 growth season.

Apical constriction in Stenocereus thurberi*, pitaya dulce, representing a cessation of growth in the recent past couple years.*

It is quite possible, in fact expected, that these columnar cacti will produce new growth in this year's coming rainy season. Likewise, there is some evidence that even dormant and damaged epidermis can re-activate. Because of the special traits of having a persistent epidermis, relative to other plants in which it is an ephemeral organ, it seems that some regenerative renewal/reactivation can occur (Mauseth 2023).

*Example of regrowth from highly damaged stem of senita (*Lophocereus schottii*). This image, from Tucson, Arizona, shows the result of severe drought stress in 2020 (the silver-metallic, damaged branch), and emergence of a new, healthy branch with onset of seasonal rains in 2022-2023.*

Collectively, while many individuals have experienced significant graying and deadening of their stems, there is still the capacity for many if not most individuals to recover. Accordingly, it is best to not undertake too severe of cutting back in the management of the damaged cacti in order to maintain the resources of the plant in its own maintenance and recovery.

Cerambycid beetles and other insect attacks

An epidemic outbreak of wood borers, also known as longhorned beetles or cerambycid beetles (family Cerambycidae), as well as others, has also been observed in the winter of 2022–2023, chiefly attacking the trunks of elephant trees (genus *Bursera*, Burseraceae) and copalquin or ciruelo (*Cyrtocarpa edulis*, Anacardiaceae). These two families are closely related, and both burseras and ciruelos share a very similar growth form: large fleshy stems with soft parenchymatic radii intermixed with the woody tissues, or xylem (a syndrome known as "sarcocaulescence").

Possibly because of this trait, they have been repeatedly reported as target trees for wood-borer attacks from a wide array of cerambycids, such as *Mallodon dasystomus* and *M. spinibarbis* (García et al. 2021); *Leptostylus transversus* (MacRae 1994, 2013); and *Mecotetartus antennatus* and *Chyptodes dejeani* (Noguera et al. 2002).

Beetle damage, Bursera microphylla

Although both the Burseraceae and the Anacardiaceae are protected by resins that fend off insect attacks to their live cortex and leaves, longhorn beetles seem to have evolved a mechanism to bore past the live sapwood onto the internal dead heartwood, where resin ducts are not active. Cerambycid outbreaks, therefore, tend to occur after the plant resin defenses have been weakened by some environmental factor, such as drought or fire (Speight 1983), and frequently occur in Mexican dryland ecosystems (Rodríguez del Bosque 2004). It seems logical to conclude, then, that the current epidemic of longhorn beetles at El Ancón and elsewhere could be related to the general physiological stress conditions derived from the 2020/2021 extreme drought anomaly.

Plant dieback to the north

Observations recently made in Loreto, Municipality of Loreto, almost 300 km to the north of Rancho El Ancón, indicate that the impacts of these extreme climatic stresses are not limited to the northern Cape Region. Observations at Puerto Escondido and Primer Agua (see map) suggest that while there is some variation in the precise nature of the impacts, the same stresses are observed. Many dead trees and cacti were observed at both sites, in addition to plants in poor health (documented in the Survey123 app developed by Wetherbee Dorshow). Additional species seem to be impacted in the Loreto area, including *Lophocereus schottii* (garambullo, senita) and *Bursera epinnata* (copal blanco).

Map of observed areas in the Loreto area.

Infestations of both Cerambycidae and Buprestidae beetles were observed in the trunks of infested trees. Interestingly the yellowing (chlorosis) of cacti was much less prevalent and almost absent in many cases: plants were more likely to have gone straight to the gray dead tissue as described above.

In general the presence of affected individuals to the north supports the idea that it is not heavy metal pollution or local contamination affecting the individuals at El Ancón, as there is no apparent source of contamination for the two Loreto sites. Notably the Primer Agua site has a history of severe overgrazing, and dead cows and horses were observed nearby on the initial site visit. The site at Puerto Escondido does not have a known history of overgrazing although some grazing activity was evident. The steep hillside and eroded soils may well have contributed to the conditions that resulted in the more extreme numbers of affected plant individuals.

Species observed in the Loreto region: Pitaya dulce graying (no yellowing), b) affected cardón, c) affected garambullo, d) fungus on palo blanco, e) fungus on cardón base, f) dead pitaya dulce, g) affected copal blanco, h) Cerambycidae larvae, i) Buprestidae larvae, j) dead torote, k) affected copal blanco, l) dead cacti and trees on the landscape, m) damage from Cermbycid beetles on torote.

"Plaga de mauto" and branch dieback on palo blanco

We observed several dozen occurrences of basidiomycete fungi (bracket fungi/shelf-fungi) fruiting from mauto (Rancho El Ancón) and palo blanco (Cacachilas). In both plant species, the sporocarp (fruiting body) of the fungus was evident in older trees. Betsy Arnold and Blanca Lopez are collaborating to identify this fungus: it may represent a group of fungi associated with mild pathogenicity to trees, and often the effects of such fungi are more prevalent when trees are already stressed by climate. However, observations are consistent with this basidiomycete being indigenous, rather than introduced. We anticipate that it likely is present in many trees and only fruits from older individuals. It likely is not the cause of mortality for otherwise healthy, vigorous, young trees in a short period of time, and it is not likely responsible for the dieback of lower branches on younger palo blanco trees, which seem to undergo natural senescence as trees mature. Presence of the shelf-fungi may be better understood as an indirect response of stressed host plants and an increased ability for fungal establishment.

Fungal fruiting body associated with Lysiloma, *March 2023.*

Biological soil crusts
Biological soil crusts, also known as biotic soil crusts or cryptobiotic crusts, are important in arid and semi-arid lands worldwide. They stabilize soil, retain water, reduce dust, decrease erosion, and are important drivers of nitrogen fixation and other essential ecosystem services. They are sensitive to trampling, as by cattle, and can be slow to re-establish, especially if their removal on the local landscape increases severity of erosion (Heckman et al. 2006, Antoninka et al. 2020, Katz and Arnold 2021).

Biological soil crusts were observed at Rancho El Ancón, especially in areas at the base of plants where trampling damage from cattle was restricted by branches and stems. Here they are clearly assisting in erosion control. Composition was dominated by cyanobacteria and lichens, including Psoraceae. They do not show obvious signs of dieback due to deposition of airborne contaminants. The land conservation actions underway at El Ancón are important for improving crust health, enhancing soil health, supporting re-establishment of understory vegetation, and improving the hydrology of the system. Such changes can only have positive effects in mitigating climate stress in the region.

Biological soil crusts, El Ancón, March 2023. Crusts are visible as dark brown, black, or greenish-black surfaces on soil. Cyanobacteria and other crust components bind soil particles, reducing erosion (left and top) and contribute to soil health and water retention. Lichens (especially Psoraceae) are common in mature crusts.

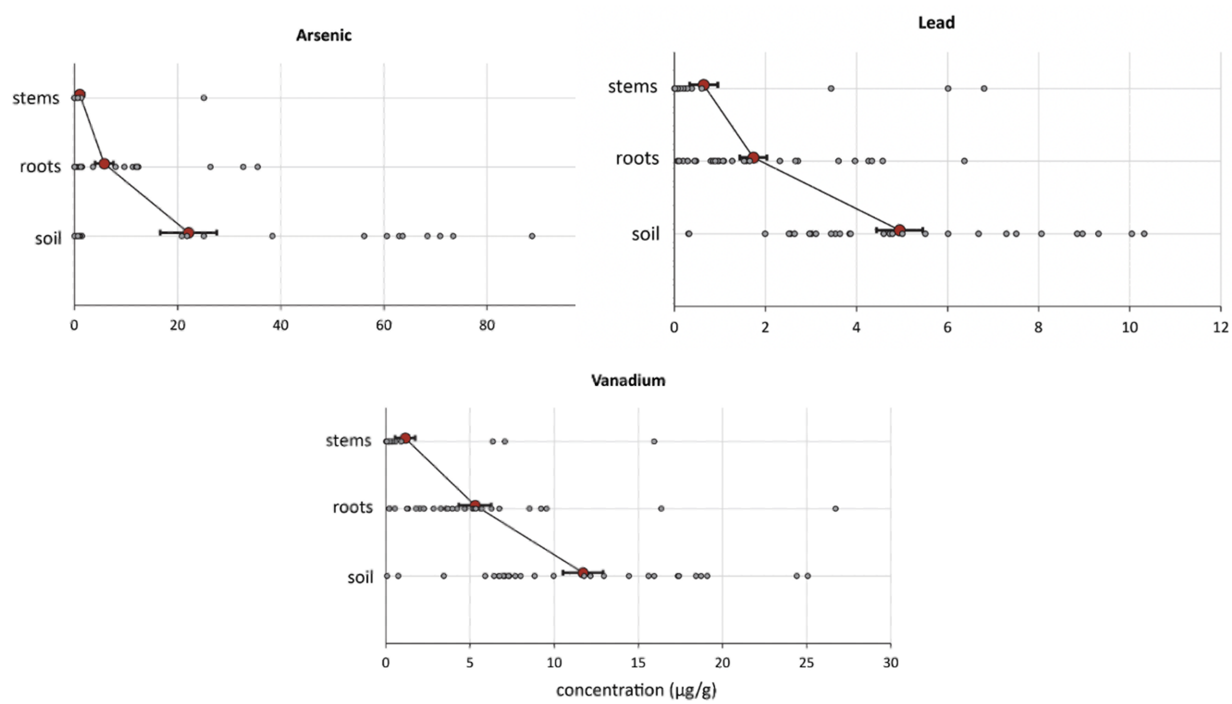
C. Heavy metals

Heavy metal data collected by the team and analyzed at UCSD with the assistance of Richard Kiy contained information on five elements: Arsenic (As), Cadmium (Cd), Lead (Pb), Mercury (Hg), and Vanadium (V). Each sample was also characterized by three factors: Species (the species from where the sample was taken), Location (they are within the larger region where the sample was collected), and the Type of sample, which had three levels, soil, root, and stem, according to the sample source.

Cadmium and Mercury were found at very low levels throughout the region, and do not seem to be a matter of concern. The three most abundant heavy metals were Arsenic, Lead, and Vanadium.

Based on the sample data provided by UCSD, we applied a standard Analysis of Variance test in which we analyzed the response of each heavy metal to the three factors (species, location, and type). We found no significant difference between plant species, indicating that all species respond similarly to the five heavy metals. However, the concentration of heavy metals in the ecosystem did vary significantly from location to location or along the soil-to-root-to-stem gradient within the individual plants.

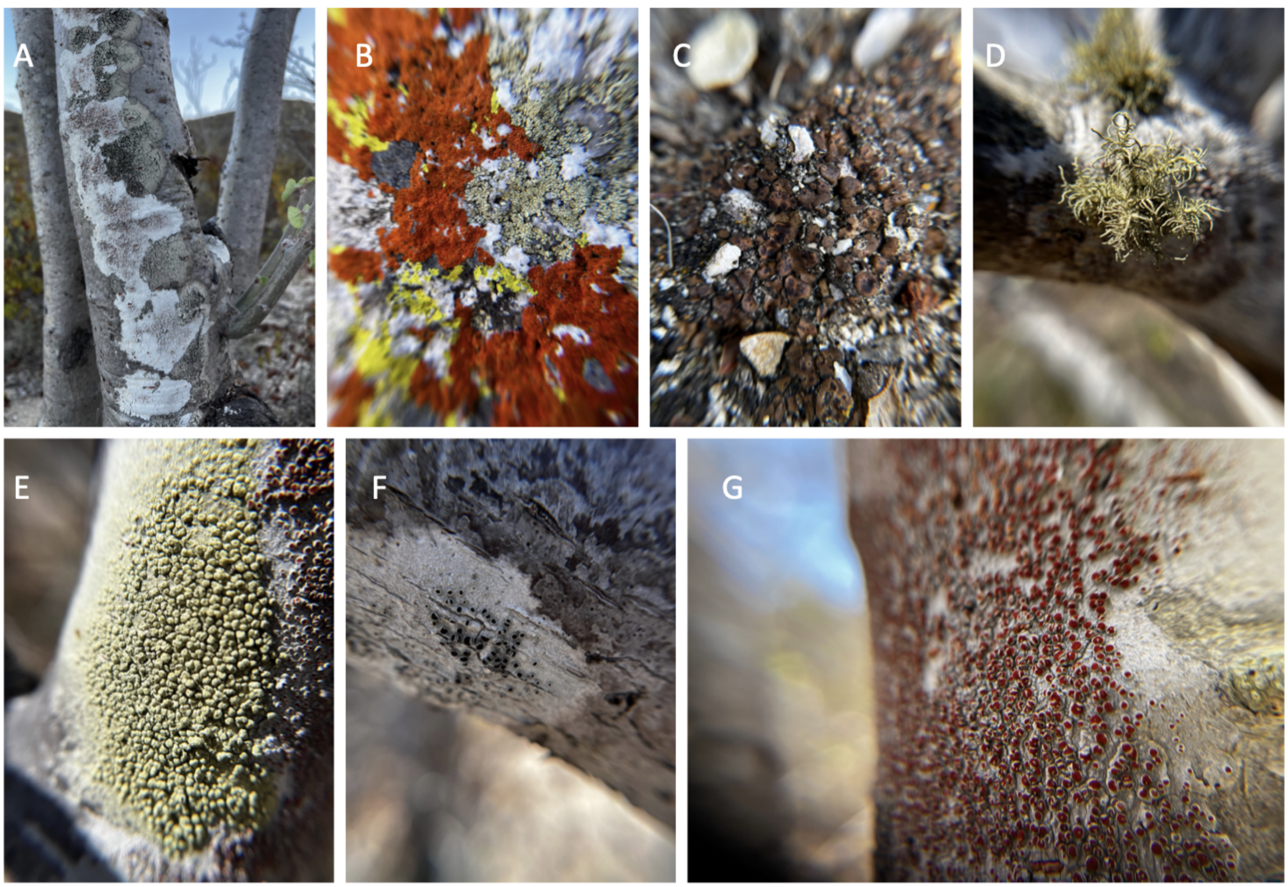
Arsenic varied significantly (*P*<0.0001) along the soil-root-stem gradient, but was also significantly higher (*P*<0.0001) in soils from the Road to San Antonio. Cadmium, in contrast, responded weakly (*P*=0.02) to the soil-to-stems gradient, but showed significant variation (*P*=0.002) between locations: Los Planes and the Road to San Antonio had higher concentrations of cadmium in the soil than Agua Ademada, El Sargento, and Peregrino. Lead did not differ significantly among locations, but showed, like Arsenic, a highly significant (*P*<0.0001) decrease along the soil-to-stem gradient in the plants. Mercury was found in low quantities in all samples, and did not vary significantly as a function of location, position within the plant, or species. Finally, Vanadium showed a statistical pattern very similar to that of Lead: it did not differ significantly among locations, but showed a highly significant (*P*<0.0001) decrease along the soil-to-stem gradient in plants.



Concentration of three heavy metals present in larger amounts within the region, plotted as a function of the height along the soil-to-stem gradient. All values in mg/g (ppm).

Importantly, the concentrations in the soil of Lead and Mercury were in all cases within levels that are considered non-toxic (AAP 1993, Hanus-Fajerska et al. 2021). The concentration of Arsenic in the region is higher, with an average of 22.1 mg/g (or ppm). This concentration is on the highest tail of the natural range (Missimer 2018) but not harmful for the plants, which seem to be effective at excluding Arsenic at the root level. That is, even if the concentration of Arsenic in the ground could be high, over 20 ppm, concentrations in the fruits of the wild scrub are going to be around 1 ppm, a perfectly safe level for human consumption.

Moreover, diverse lichen species and communities were well-developed on trees, remnant biological soil crusts, and rocks throughout the area of El Ancon, including areas with extensive plant stress responses. We recorded more than 40 lichen species during the visit, suggesting a very rich lichen flora for which characterization would be a meaningful contribution to lichenology.



Representative lichen thalli in Rancho El Ancón, March 2023, including a) epiphytic species, which likely are not major sources of stress for trees, b) rock-inhabiting species, and c) species that are important in soil crust resilience. In general thalli were healthy and robust (panels a-g). Epiphytic species generally were more prevalent on older plants, consistent with the relatively slow growth rates of lichens. There was no evidence of lichen die-back due to heavy metals.

Lichen thalli of all observed species were robust and often reproductive, consistent with the conclusion that heavy metal pollution is not likely the key driver in plant stress observed in the region. Usually, lichens are ‘canaries in the coal mine’ for early detection of impacts from both airborne heavy metals and acid rain.

Consistent with this interpretation is the observation that plant stress responses were identified in the region of Loreto, which does not have a point source for pollution like La Paz. The presence of healthy lichen communities within affected zones and plant die-back in the absence of heavy metal pollution both indicate an unlikely connection.

In summary, we do not observe evidence that the burning of contaminating heavy oils near Pichilingue may be contributing to the accumulation of heavy metals in the environment near Bahía El Sargento, Los Planes, or El Ancón.

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Field group at Rancho El Ancón, March 2023

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