Detecting "Zombie-Ecosystems" in the Sagebrush grasslands of the arid West, with Bunchgrass Age-Pyramids, and curing that condition by adding fertilizers and organic matter, based on Waypoint Lab tests.

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In the arid Western United States, many perennial native grasses are "bunchgrasses" that grow isolated from one another, growing in individual tufts, instead of forming a turf or mat--also called "tussock" grasses in the southern hemisphere.

Prior to the accidental introduction and intentional sowing of exotic grassland plants, these bunchgrasses produced the principal forage for native grassland mammals, and more recently, the introduced Eurasian grazing cows and sheep. The native bunchgrasses, living as separate clumps, produce a similar growth pattern as the trunk of a tree--their basal diameter increases over time, and in some cases, the center dies and forms a ring, or living crown.

The term "Zombie-ecosystems" was proposed by Roger Bradbury an Australian ecologist, in his 2012 "zombie-reef" thesis, in a NY Times op-ed: "Overfishing, ocean acidification and pollution are pushing coral reefs into oblivion. They have become *zombie ecosystems*, neither dead nor truly alive in any functional sense, and on a trajectory to collapse within a human generation." (NY Times July 7, 2012 – "A World without Coral Reefs" https://www.nytimes.com/2012/07/14/opinion/a-world-without-coral-reefs.html)

Another New York Times editorial, *"Insect Armageddon"* was published on October 29, 2017, where the total biomass in nature preserves across Germany, in just 25 years, declined by 76 percent. (www.nytimes.com/2017/10/29/opinion/insect-armadeddon-ecosystem-.html)

"Zombie ecosystems" may already exist within many of our Western native grassland communities, where you have adult perennial plants still producing viable seeds, but no young seedlings are observed in populations being surveying. The lack of seedlings could be due to domesticated grazing animals eating the seed heads before the seeds mature and disseminates. If cows and sheep consumption of the immature seeds, is the cause of that type of Zombie Ecosystem, the easy cure would be to allow the seeds to ripen every few years, so seedlings are then produced at a regular rate, to replace any older plants that die.

DOMESTICATED ANIMALS CREATING ZOMBIE-ECOSYSTEMS by removing soil nutrients--However, a more diabolical cause of Zombie Ecosystems in the arid West, and perhaps within many other arid parts of our planet, is the removal of soil nutrients and soil surface organic matter by domesticated grazing animals--below the threshold levels required by each native species seedling's survival.

I discovered this "Zombie Ecosystem" concept in the Great Basin sagebrush habitat in 1993 while working on replanting a 100-mile Tuscarora gas pipeline north of Reno, between Susanville and Alturas, California. We measured the basal diameters of native bunchgrass populations, and placed each measured plant diameters into age classes, such as—

<1 inch to 1 inch
1-2 inches
2-3 inches
3-4 inches
4-5 inches, etc.

Then, after surveying 25, 50 or 100 plants, looked at the shape of the population structure.
By measuring the basal diameters of several random plants in a population, that produced a very clear picture, that allowed us to detect Zombie Ecosystems that were hidden in our midst.

For example, a survey in October 2018 north of Reno produced these results—

SQUIRRELTAIL grass
0-4 inches basal diameter-Zero plants
4-6 inches – 0
6-8 inches – 0
8-10 inches – 1
10-12 inches – 1
12 inches or more – 0

Many squirreltail plants were dead in that population, and in this case, should have measured the diameters of the a few dozen dead plants separately. The lack of any living plants less than 8 inches in diameter, means it has been a long time since this population reproduced, and this population is headed toward local, spatial extinction, when the 8-12 inch diameter plants eventually die.

BLUEBUNCH WHEATGRASS
0-2 inches basal diameter – zero plants
2-4 inches – 0
4-6 inches – 0
6-8 inches – 3
8-9 inches – 4
9-10 inches – 6
10-12 inches – 8
12-16 inches – 9

Bluebunch wheatgrass forms a crown when the basal diameter is 12 inches or more. This is a much better age-pyramid than the squirreltail, but not much. This is an upside-down pyramid, with no seedlings less than 6 inches in diameter. Once again, a long time since last reproduction, and again I am encountering another Zombie Ecosystem.

INDIAN RICEGRASS
0-1 inch basal diameter – zero plants
1-2 inches – 5
2-3 inches – 9

3-4 inches – 4
4-5 inches – 1
5-6 inches – 0
6 or more inches – 0

This is a relative new colonizing population from along a roadside, with mostly young plants and no old plants larger than 5 inches basal diameter, and a reproducing population, so far. The nutrient levels could change from grazing or erosion, so another survey 10-20 years hence should be conducted, to confirm that it has fallen into the Zombie Ecosystem nutrient zone.

GREAT BASIN WILD RYE
Here is what you ideally what you want to see in an age-pyramid, more like an "Age-column".
0-1 inch basal diameter – 1
1-2 inches – 3
2-3 inches – 4
3-4 inches – 4
4-6 inches – 6
6-8 inches – 5
8-10 inches – 3
10-14 inches – 3
14-18 inches – 2
18-24 inches – 1
24-36 inches – 1
The largest was 36 inches in diameter, a really old plant of that plant population.

To conclude, the upside-down pyramid confirms that you have encountered a Zombie Ecosystems.

SETTING THE THRESHOLDS FOR EACH SPECIES with WAYPOINT LAB A-17 and A-19-2 tests—During the 1993 pipeline project, when we found Zombie-Ecosystems created by the grazing animals lowering the soil nutrients, below the thresholds needed by that species, we also needed to find populations that contained seedlings, to know that they were still reproducing.

We used the top two inches of soil from next to the seedlings, as the proper soil nutrient thresholds and organic matter thresholds for that ecosytpe of that particular population of native grasses.

The soil sampling is done, by removing a one-quart sample of soil from around the base of the seedlings, to 2 inches deep, and use a ¼ mesh screen to sift out any rocks or vegetable matter. Then, send that one quart sample in to the Waypoint Lab in Anaheim, California and for $71 have them run their A-17 soil test with data only in a "bar-graph" format, and also have them run their A-19-2 Organic matter test.

The key for setting the thresholds for each species, is testing the soil nutrients and the percentage of organic matter in the top two inches (5 cm), because that is where the seeds are located when they are sprouting. Seedlings need those nutrients as soon as the roots emerge, because without them, they can easily die as one and two-inch tall plants otherwise.

Then, obtaining a second soil sample, to test soil in bare areas within 10 feet of your seedling-soil sampling point, can confirm your threshold numbers that you are setting with the seedling soil sample.

For example, for Indian Ricegrass north of Reno, the soil organic matter threshold for seedlings is 2.2% organic matter, but if you drop to 2.0% organic matter, then there is no seedling survival. For Bluebunch wheatgrass, the soil nitrogen threshold for plants growing near Susanville in 10 inches of rainfall at 5,500 feet was 32 ppm, but if you dropped to 12 ppm then seedlings could not survive.

Each native plant species is going to have its own soil nutrient threshold and soil organic matter thresholds. For example, Poa Indian Ricegrass and Squirreltail grasses in the Great Basin, can thrive at the lowest nutrient thresholds, but if you want Bluebunch wheatgrass or Great Basin Wild Rye to survive, then you need much higher organic matter and soil nutrient numbers for those two species.

Additionally, the rainfall and elevation will change the soil nutrient and soil organic matter threshold numbers within each species, indicating that they are different fixed ecotypes based on their soil nutrient and organic matter needs. Generally, if you start at the lowest annual rainfall limit for the species, and the lowest elevation limits, and go up in either elevation or rainfall, then the thresholds will also go up.

For example with three Great Basin Wild Rye populations only 60 miles apart, we found three different annual rainfall "ecotypes", each with a different nutrient threshold, especially when looking at the organic matter content in the top two inches of soil around the seedlings--

Rice Canyon 8" = Nitrogen 21 ppm, Phosphorus 27 ppm, and Organic matter 3.2%
Secret Creek 10" = Nitrogen 15 ppm, Phosphorus 79 ppm, and Organic matter 5.7%
Sage Hen Summit 12" = Nitrogen 32 ppm, Phosphorus 73 ppm, and Organic matter 9.3%

The organic matter percentage when charted against the annual rainfall numbers, forms a nice curve, that could be extrapolated out and predictions made for other populations in higher rainfall areas, and those sites tested to confirm this suggested "Rainfall-Soil-Nutrient-Ecotype" relationship.

For example the higher rainfall thresholds for Great Basin Wild Rye, according to the curve might be—13% organic matter in 14 inches of annual rainfall, 17% in 16 inches of rainfall, and 21% organic matter in the top two inches of soil, in a populations growing in 18 inches of annual rainfall.

However, the threshold relationships between the species will still be the same. Poa or Indian Ricegrass will always have lower thresholds when comparing the Great Basin Wild Rye thresholds, when comparing one species with another in the same rainfall and elevation location.

The key to our success in replanting the 100-mile pipeline in 1993 north of Reno, was determining the local ecotype thresholds were for each species of grass we were planting, and focus on the nitrogen, phosphorus, and organic matter levels, and add the proper amounts of fertilizer and saw dust, to meet those nutrient thresholds every time.

USING "ZOMBIE ECOSYSTEMS" as a new reason to LISTING ENDANGERED SPECIES OF WESTERN BUNCHGRASSES?

There are many different reasons why a plant is listed by the US Endangered Species Act as either Threatened or Endangered, for example--fragmentation of habitats, impacts from development, exotics, agriculture or grazing are commonly cited.

Currently there are 1,300 Listed Endangered or Threatened species in the United States today, plants and animals that have become so rare in numbers that like the Passenger Pigeon, are in danger of becoming extinct. (USEPA website "Learn more about Threatened and Endangered Species-What Are Endangered and Threatened Species?" https://www.epa.gov/endangered-species/learn-more-about-threatened-and-endangered-species)

What I am suggesting about the Western US grassland species and sagebrush ecosystem, is that all of the perennial plants, all of the grasses, herbaceous perennials and shrub, may all need to be listed as Endangered in the future, because they belong to a Zombie Ecosystem that has not reproduced for years to a century or more. A good example are the Galleta grass species from the California desert and New Mexico, that may not have produced seedlings for over 100 years or more, once the soil nutrients dropped below their seedling survival thresholds.

I am posting the soil nutrient thresholds as we do the tests, at www.ecoseeds.com/seed-thresholds.html -- or others do the A-17 and A-19-2 seedling-soil tests, to set each threshold for all of the commonly sown native seeds.

By establishing the soil nutrient threshold for each native species we sow each year, then we can stop the 70-90% annual failures in native seeding projects that were reported in the 2014 and 2017 USGS reviews. (Kevin Knutson et al 2014 "Long-term effects of seeding after wildfire on vegetation in Great Basin ecosystems" at
https://besjournals.onlinelibrary.wiley.com/doi/full/10.1111/1365-2664.12309
and David Pilliod et al 2017 "75 years of land treatments on public rangelands in the Great Basin of North America" at https://pubs.er.usgs.gov/publication/70180019)

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