Appendix C: Guidance for applying threats map to IUCN Red List Criteria

The threats map can help assess the risk of extinction using Criterion B of the IUCN Categories and Criteria. To apply Criteria B1 or B2, a species must have a limited geographic area **and the** thresholds for AOO or EOO need to be met: Threatened: < 20,000 km^2 EOO or < 2,000 km^2 AOO; Endangered: < 5,000 km^2 EOO or < 500 km^2 AOO; Critically endangered: < 100 km^2 EOO or < 10 km^2 AOO. In addition, the species must meet at least two of the three following conditions (bolded text indicates where the threats map can be applied):
(a) Severely fragmented OR **Number of locations**
(b) Continuing decline observed, estimated, **inferred** or projected in any of: (i) extent of occurrence; (ii) area of occupancy; **(iii) area, extent and/or quality of habitat**; (iv) number of locations or subpopulations; (v) number of mature individuals
(c) Extreme fluctuations in any of: (i) extent of occurrence; (ii) area of occupancy; (iii) number of locations or subpopulations; (iv) number of mature individuals (Committee 2019).

Thus the threats map can be applied to the following:
(a) Number of locations:
IUCN defines locations as a geographically or ecologically distinct area in which a single threatening event can affect all individuals of the taxon present within a single generation or three years, whichever is longer (Committee 2019). The threats map can provide information on the (a) number of locations based on the fire map (but not other threats), but because each single threatening event needs to affect all individuals, only threats with a "very high" magnitude (Table 2) can be used. For other threats, if the species' distribution is severely fragmented (a), the threats map can be used to infer decline in the area, extent, and/or quality of habitat (b), as described below.

(b) Continuing decline observed, estimated, **inferred** or projected in any of… (iii) area, extent, and or quality of habitat:
The threats map can also be used to infer continuing decline based on threats to the area, extent, and/or quality of habitat (biii). The threats map can also be used as a tool to estimate decline in habitat based on urbanization. The threats map provides a projection of urbanization that can assist with estimations of decline near urban areas.

The following considerations should be carefully incorporated into the assessment.
Additional threats
The threats map only contains spatially explicit and available threats data layers, therefore, before calculating threat and completing assessment of the species, a literature search should also be conducted to find additional information regarding threats. Key threat categories missing or incomplete from the threats map include climate change, hunting and gathering (legal or illegal), and invasive plant species. When a full Red List assessment is conducted, besides the threats field, information is gathered regarding population trend of the species, habitat and ecology, use and trade, and distribution, which may also yield relevant information regarding threats. If additional threats are identified, values of extent and magnitude should also be estimated.

Species biology and response to threats

It is critical to remember that threats do not affect all plant species equally. For example, many early successional plants require ground disturbance for establishment. Other plants may benefit from wildfire. Thus, it is critical to examine how the species respond to the threats identified in the model. The presence, or even dominance, of a threat within a species' range is not sufficient to demonstrate a negative impact on the species in question. A thorough examination of the species' response to each potential threat is needed before the results of threat modeling can be applied to inform a Red List assessment.

Suggestions for applying the threats model output with species biology to the assessment

In order to evaluate how threats affect species, there are three characteristics to consider: the geographic extent of the threat within the target species distribution (extent), the relative destructiveness of the threat to the target species (weight or magnitude), and the decay as one travels away from the threat, which can be characterized as linear or exponential (Muhammed et al. 2021; Gaisberger et al. 2020). There is no clear agreement in the literature on whether to apply linear or exponential decay, even to the same threat factor (Muhammed et al. 2021). Where possible, we added buffers around threats to account for decay (Appendix A). There are many different threat index equations available for calculating threats in the literature, depending on the data available and the purpose of the index (Muhammed et al. 2021). Carpenter and others (2008), used population reduction thresholds of IUCN Red List Criterion A based on a decline in extent of occurrence or habitat quality, as determined by coral bleaching threat maps (Carpenter et al. 2008).

Similar to Carpenter et al. (2008), we developed equations based on IUCN Categories and Criteria to help guide the application of the threat map output to assess the extinction risk for plant species in the Sonoran, as follows.

Step 1. Measure extent

Thus, to determine the effect of threats on species, we need to measure extent and magnitude. To measure the extent of each threat within a species range, we applied the following steps. We downloaded points from GBIF (Government of Canada 2021) and the regional database SEINet (SEINet Portal Network 2020), and any other available point data and uploaded these to the threats map. For each 10 km^2 hexbin with distribution points, GIS analysis will produce the area of the hexbin affected by each threat. Then the percent coverage of each threat (extent) is derived by summing the area of each threat and dividing it by the total area of the hexbin (n x 115.30 km^2 = total area; n = # hexbins with distribution points).

Step 2. Estimate magnitude

Each threat identified in the previous step with more than a 5% extent needs to be ranked according to its threat magnitude for each plant species from 0-1 point scale (Table 1, Gaisberger et al. 2020). One may consider magnitude as the degree to which a threat will reduce the target species where that threat occurs. When choosing a ranking, the threat itself

and the expected species response to the threat should be considered. For example, if a mine will likely extirpate a species in that area, it would have a magnitude of 1.0, but another threat, such as recreation may reduce a population by about 30% where it occurs, therefore it would have a magnitude of 0.3. Researchers have published such values in the literature (see Muhammed et al. 2021; Gaisberger et al. 2020). Information on the species may be available through the following sources:

- a literature search (i.e., published journal articles or, for information on fire sensitive species, go to https://www.feis-crs.org/feis/),
- Environmental Conservation Online System website that houses reports from U.S. Fish and Wildlife Service on Threatened and Endangered Species at: ecos.fws.gov)
- and/or expert opinion

Table 1. Five-point rating scale to define the threat magnitude classes (Gaisberger et al. 2020).

Numerical threat magnitude	Categorical threat magnitude	Definition
<0.01	No threat	The threat is likely to not degrade/reduce the species or reduce its population by less than 1%
0.01-0.10	Low threat	The threat is likely to only slightly degrade/reduce the species or reduce its population by 1-10%
0.11-0.30	Medium threat	The threat is likely to moderately degrade/reduce the species or reduce its population by 11-30%
0.31-0.70	High threat	The threat is likely to seriously degrade/reduce the species or reduce its population by 31-70%
0.71-1.00	Very high threat	The threat is likely to destroy or eliminate the species, or reduce its population by 71-100%

Step 3. Estimate overall threat

To estimate the overall threat to the species habitat, using the threats map we calculate the % extent * magnitude (e*m). For example, if the threat extent would likely affect 70% of the species habitat and the magnitude of the threat to the species was 0.5, then an overall threat of 35% to the species' habitat can be estimated.

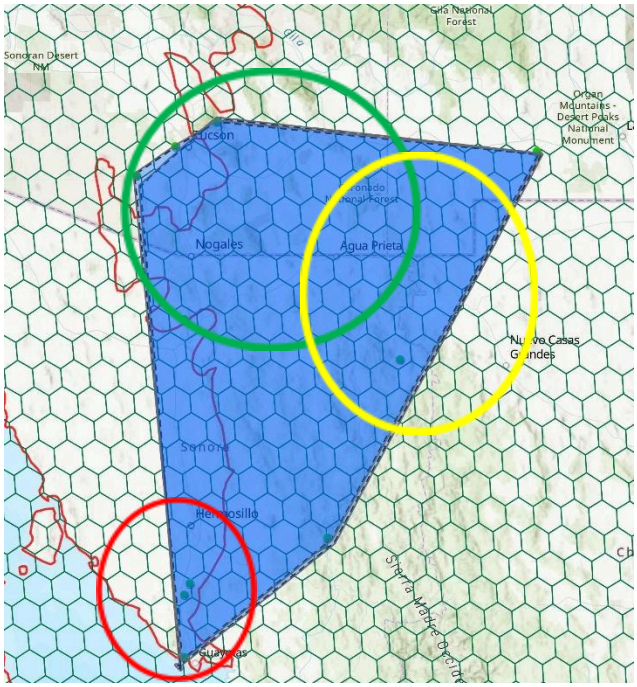

Figure 1. Example extent of occupancy with 1km buffer (blue) with 10 km^2 hexbins. Red indicates fire threat, green indicates icrop agriculture, and yellow indicates oil & gas drilling. Green dots are species distribution points (n=10).

If there are multiple threats, then the overall threat can be calculated as the sum of each threat or (e*m)+ (e*m)+ (e*m). As an example, using a mock species pictured in Figure 1, we will assume a threat magnitude for this species of 1.0 for fire, 0.49 for crops, and 0.61 for oil & gas drilling. If the extent of threats for this species is 30% for fire, 20%

for crop agriculture, and 10% for oil & gas drilling, then the overall threat for this species' habitat is 30% +9.8%+6.1% = 45.9%. However, if the plant benefits from fire, but is highly affected by crop agriculture and mining, then the overall threat would be only 15.9%. Again, other threats such as invasive plant species, climate change, and hunting and collecting should be considered before finalizing an assessment. There are no specific guidelines for applying these estimates of habitat decline to Criterion B, but if the species in consideration has an EOO or AOO that meets the criterion and the distribution of that species is fragmented, then the estimates of overall threats based on the threats map can also be used to infer continuing decline based on threats to the area, extent, and/or quality of habitat (biii).

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