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Supplementary Information for

Historical reconstruction unveils the risk of mass mortality and ecosystem collapse during pan-continental megadrought

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Supplementary Information Text

Materials and Methods. Further details on information sources, database development and data analyses.

Database development

The primary source of data consisted of digitised newspaper articles contained in the National Library of Australia's Trove platform (www.trove.nla.gov.au). Trove contains a very large, searchable repository of online historical digital resources that includes newspapers, journals, photographs and other material. We conducted a series of searches of Trove's digitised newspaper collection that contained the terms *drought*, *dead* OR *dying*, followed by one of 296 terms or phrases relating to geographic locations or features (*n* = 273) or broad vegetation groups or plant genera (*n* = 23). Geographic search terms were selected from 90 different meteorological forecast districts (see Australian Bureau of Meteorology, www.bom.gov.au) in all six Australian states and two territories. Terms include towns, rivers, major geographic regions (e.g., 'Darling Downs', 'Kimberley', 'Goldfields'), or isolated telegraph or private stations (e.g., 'Avon Downs', 'Tennant Creek'). Searches based on regional population centres were particularly important because many observations at the time were reported by local correspondents. Vegetation terms were selected to represent major vegetation groups present in Australia (*Acacia, Callitris, Eucalyptus, forest, grassland, heath, mallee, rainforest, shrub, tussock and woodland*) or a range of colloquial or more general terms used at the time [*alpine, brigalow* (= *Acacia harpophylla*), *gum, mulga* (= *Acacia aneura* sens. lat.), *river red gum* (= *Eucalyptus camaldulensis*), *savannah, scrub, spinifex* (= *Triodia* sens. lat.), *timber*, *tree*, *vegetation* and *wetland*].

For each search we reviewed up to the first 2000 (drought + dead OR dying search; *n* = 1), 400 (vegetation searches) or 100 (geographic searches) newspaper articles, for a total of >35,000 potentially relevant articles. In virtually all searches this exhausted the number of articles relevant for use in our study, and the great majority of newspaper reports that documented either an impact of drought on plants or non-domestic animals (hereafter referred to as biotic impact records; BIRs) were identified in multiple searches. Thus, our approach provided a near-comprehensive screening of all digitised newspaper articles potentially relevant to our work. We also identified a small number of explorer journals and other sources based on references in newspaper articles and also reviewed these for relevant information. We retained all sources that documented either an impact of drought on biota (BIRs) or an especially significant event or attribute of drought-affected areas, such as dust storms, livestock death, or social impacts (drought impact record; DIR). We excluded sources with impacts that were attributable to non-drought factors (e.g., poison, bounties). A total of 556 BIRs (541 with geolocations) and 1748 DIRs were identified.

For DIRs we then simply estimated the geolocations of observations of 1) dust storms, sand storms and drift, 2) livestock death, 3) hydrological impacts (low water levels in rivers, lakes, etc.), 4) bare understory, and 5) general drought conditions. This allowed us to determine the geographic extent of perceived drought and the locations of more severe impacts associated with agriculture or "dust bowl" conditions. For BIRs we extracted information for the following data fields (e.g., *SI Appendix*, Fig. S6): 1) estimated observation date (as opposed to the publication date), 2) broad morpho-taxonomic group (8 animal and 6 plant groups, see *SI Appendix*, Table S2), 3) taxonomic identity (family, genus or species), 4) impact type (mortality, stress or absence, which includes any evidence of rapid population decline or disappearance), 5) estimated geolocation (latitude, longitude), 6) estimated extent of impact, 7) IBRA bioregion, 8) ecosystem type, 9) presence of livestock-related factors, 10) location relative to area of severe rabbit infestation in 1891, and 11) evidence of population collapse or mass mortality.

The estimated observation date was determined as precisely as possible to the last full calendar month prior to the date of the relevant report, or earlier based on textual evidence if available. This allowed for the typical several days to three weeks that occurred between an observation being made and its subsequent reporting in newspapers. These dates were used in subsequent data analyses (see below). Animal and plant morpho-taxonomic groups were as follows: Actinopterygii (fish), Amphibia (frogs), Aves (birds), Eutheria (i.e., European rabbit, *Oryctolagus cuniculus* and hare, *Lepus timidus*), Insecta (insects), Malacostraca (shrimp), Marsupialia (marsupials), Reptilia (reptiles), woody trees (>7m), tall shrubs (3-7m), low shrubs (<3m), herbaceous – graminoid (Poaceae), herbaceous – other (i.e., Asteraceae) and succulents (i.e., *Opuntia stricta*). Taxonomic identity was determined to the lowest level possible.

It was possible to estimate indicative geolocations for 541 BIRs based on textual evidence. We estimated the area of impact (A_T) based on a circle of radius r (the estimated extent of impact) centred on each indicative geocoded location, classified according to r = 0.5, 1, 5, 10, 25, 50, 100, 150, 200, 250…..km unless specific information was provided in the text. The IBRA bioregion was determined based on Thackway & Cresswell (1995). Ecosystem types were defined using the following general categories based on textual evidence and location: aquatic (marine, lake or river/creek), terrestrial [dry, wet (floodplain, ephemeral wetland), arboreal, mixed], mixed (aquatic + terrestrial), and other.

We also determined whether livestock-related factors (e.g., overgrazing, trampling) were stated by the observer as a contributing factor to each BIR. BIRs referring only to mortality or stress associated with overgrazing or heat and not drought were therefore excluded from the database. BIRs were also classified into occurring inside or outside the main area of rabbit infestation. The geographic extent of this area (RIA) was determined based on textual evidence of hyperabundant populations of rabbits at the beginning of the study period (1891) and on distribution maps provided in Stodart & Parer (1988). This excluded some areas where rabbits were present but only in latter stages of the study period, or where there was little or no evidence of hyperabundance, and in particular starvation associated with overpopulation. Non-terrestrial BIRs were also excluded. The RIA identified is shown in Fig. 3 and the *SI Appendix*, Fig. S5A.

We also assessed each BIR for evidence of population collapse or mass mortality. We first classified each relevant BIR into one of four categories: 1) extirpation of population (E), with evidence of total disappearance and lack of subsequent recovery, 2) near-extirpation (NE), with evidence of population decline to extreme scarcity, 3) mass mortality based on area (Ma), with evidence of mortality affecting a large proportion of a particular population or assemblage over a given area, and 4) mass mortality based on numerical estimate (Mn). We classified categories 1-3 into local (patchy impact on scale of hundreds of m to < 10km radius), district (impact on scale of 10 - <100 km radius, usually the district around a town, area between two towns, or a large agricultural station, or regional (scale >100 km radius, multiple districts or large stations). We classified the Mn category into 1) hundreds to thousands (10^2-10^3), 2) tens to hundreds of thousands (10^4-10^5), and 3) millions or more (10^6+). BIRs were allocated to categories based on interpretation of textual evidence, the stated magnitude and/or area of impact, and the geographic context of the report.

Rainfall data and association with BIRs

Rainfall data were obtained from the public SILO enhanced climate database (daily rainfall since 1889) hosted by the Science Delivery Division of the Department of Science, Information

Technology and Innovation (DSITI) found at https://legacy.longpaddock.qld.gov.au/silo/. We determined, for Australia, 1) mean annual precipitation (P_{AV}; 1889-2015), 2) total annual precipitation P (all years 1890-1903), 3) percentile annual P (all years 1890-1903, Nov 1901-Oct 1902), 4) total P as a percentage of the mean (all years 1890-1903; 1891-94, 1895-1902 and Nov 1901-Oct 1902), and 5) lowest annual P as total and as percentage of P_{AV}. These data were used to construct rainfall total, deviation and decile maps for relevant time periods (see Fig.1 and *SI Appendix* Fig. S2).

We investigated evidence of an increase in BIRs during dry years by comparing the number of BIRS across "wet" years and "other" years. This was performed in three continental regions: 1) western (W; west of E 131°), north-eastern (NE; east of E 131° and north of S 26°) and south-eastern (SE; east of E 131° and south of S 26°) (*SI Appendix,* Fig S4A). Wet years were defined as: W = 1890, 1893, 1896; NE = 1890-1891, 1894, 1896; SE = 1890-91, 1893-94. During "wet" years the total rainfall across the majority of each region exceeded P_{AV}. For each region we compared the frequency of BIRs in "wet" and "other" years using simple χ^2 contingency analyses with the expected frequency of counts proportional to the number of years in each category. To avoid dependency among data points we included only BIRs with unique spatial coordinates and observation dates in these analyses.

We used analysis of cumulative sum of monthly rainfall residuals (R) to quantify the depth and magnitude of drought for each geocoded BIR (n = 541) prior to the last full calendar month before each estimated observation date (T_0). R was extended back to Jan 1889 (the start of the SILO record). We then determined three measures of drought duration, 1) the number of consecutive months of negative monthly rainfall residuals prior to T_0 (D_{CDM}), 2) the duration of continuous drought in months (D_{CON}) prior to T_0 (no prior unbroken period of 12 months or more of above average rainfall), and 3) the duration of semicontinuous drought in months (D_{SCO}) prior to T_0 (no prior unbroken period of 24 months or more of above average rainfall). Drought magnitude after the period of continuous drought was defined as the total cumulative rainfall residual over the period (R_{CON}), expressed as a percentage of mean annual rainfall (which allows for comparison across sites with different mean precipitation). A worked example is provided in *SI Appendix* Fig. S7. Subsequent analyses included only rainfall data with terminal D_{CDM}, D_{CON} or D_{SCO} dates; for a small subset of data this excluded records with insufficient rainfall history (i.e., pre-1889) to determine terminal values for these metrics.

We developed a percentile-based index, (PR_R), to determine the strength of association between the magnitude of preceding cumulative 12-month rainfall (R_{12}, expressed as percentage deviation relative to the 1889-2015 average) and the estimated timing (observation date) of a given biotic impact record. We determined PR_R according to $PR_R = ((f_b + 0.5f_w)/N) \times 100$ where f_b is the frequency of R_{12} values below the observed R_{12} value at the estimated observation date of a given BIR, f_w is the number of R_{12} values with the same value, and N is the total number of all cumulative 12-month rainfall intervals. R_{12} values were calculated for all 12-month intervals beginning in Jan-Dec 1890 and ending in Jan-Dec 1903 (n = 157). We then determined PR_R for all BIRs with unique spatial coordinates (n = 326) and compared the mean PR_R of BIRs both within and outside the primary rabbit infested area (RIA) using generalised least squares linear model analysis. Spatial autocorrelation was accounted for by incorporating an exponential correlation structure which had the lowest Akaike information criterion (AIC) among tested structures (see below).

We also tested whether the mean R_{12} across all BIRs differed from a statistical null model. This was constructed by randomly selecting, for each BIR, one R_{12} value from among the 157 values between Dec 1890 and Dec 1903. This process was repeated 1,000 times, and the mean and standard deviation of sample means determined (according to the central limit theorem, the sample means are normally distributed). The difference between mean of the observations (n = 541) and the null distribution was then assessed using standard z statistic.

Finally, we determined whether the frequency of spatially and temporally unique BIRs citing livestock impact differed between rabbit-infested and other areas, and whether BIR frequency differed from equal expectation across winter (J,J,A), spring (S,O,N), summer (D,J,F) and autumn (M,A,M) seasons in RIAs as well as other northern (-16 to -26°S) and southern (-26 to -42°S) regions using simple χ^2 contingency analyses.

Density and network analyses, spatial interpolation, and statistical modelling

Kernel density analysis was performed on geocoded mortality records (for this and most subsequent analyses this combined the absence and mortality classes of impact type) for birds, marsupials, fish, rabbits (*Oryctolagus cuniculus*), trees, tall shrubs, low shrubs and grasses using the R package GISTools (v. 0.7-4) with a bandwidth (H) of 5 which minimised data overfitting. Modularity network analysis of the network based on spatial co-occurrence of broad impacted plant and animal groups was conducted based on stochastic simulated annealing algorithm using the package netcarto (see Guimera & Amaral 2005 for details of the SA modularity method). We also tested the significance of the observed modularity using a randomisation test with N=1000 replicates implemented in the netcarto command line program (https://bitbucket.org/amarallab/network-cartography). Spatial interpolation of D_{CON} and R_{CON} was performed using variogram fitting and ordinary kriging approaches described in Bivand *et al*. (2013) and Brundson & Comber (2015)(84, 85) and relevant functions in R packages gstat v. 1.1-6, sp v. 1.2-4 and raster v. 2.5-8.

We determined mean values of D_{CS}, D_{CON}, R_{CON} and D_{SCO} based on mortality records for native animals, native plants, major taxonomic or morphological groups (marsupials, birds, fish, *Oryctolagus cuniculus*, trees, tall shrubs, low shrubs and grasses) across all BIRs and both within (native animals, native plants, *Oryctolagus cuniculus*), and outside the rabbit-infested region (native animals, native plants). We then modelled each parameter using linear model analysis with generalised least squares and with broad biotic group (native terrestrial animals vs. native plants; Tgroup), occurrence inside or outside rabbit-infested areas of central and western NSW (RIA), and mean site precipitation (P_{AV}) as predictor variables. The two-way RIA × Tgroup interaction was also tested in each model and removed due to non-significance. Three model types were tested for each dependent variable: 1) model including all observations (full, non-spatial; FNS), 2) models using all observations [with very small random deviations (average ≈ 1km) added to spatial coordinates] but incorporating spatial autocorrelation (full, spatial; FS), and 3) model using only BIRs with unique spatial locations (restricted, non-spatial; RNS). For FS models we tested five autocorrelation structures (exponential, Gaussian, linear spatial, rational quadratic and spherical) and selected the model with the lowest Akaike information criterion (AIC). In most models the rational quadratic structure provided the best fit, and autocorrelation in FS and RNS models was greatly reduced compared to FNS models. Dependent variables were transformed where necessary to conform to model assumptions. Model parameters including adjusted means and tests of main effects were constructed and extracted using R packages stats v. 3.4.2 and nlme v. 3.1-139.

References for Materials and Methods

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Brundston C, Comber L (2015) An introduction to R for spatial analysis and mapping. Sage Publications Ltd. London. 343p.

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Stodart E, Parer I (1988) Colonisation of Australia by the rabbit *Oryctolagus cuniculus* (L.). Canberra, Commonwealth Scientific and Industrial Research Organisation.

Thackway R, Cresswell ID (1995) An Interim Biogeographic Regionalisation for Australia: a framework for setting priorities in the national reserves system cooperative program. Australian Nature Conservancy Agency, Canberra, ACT.

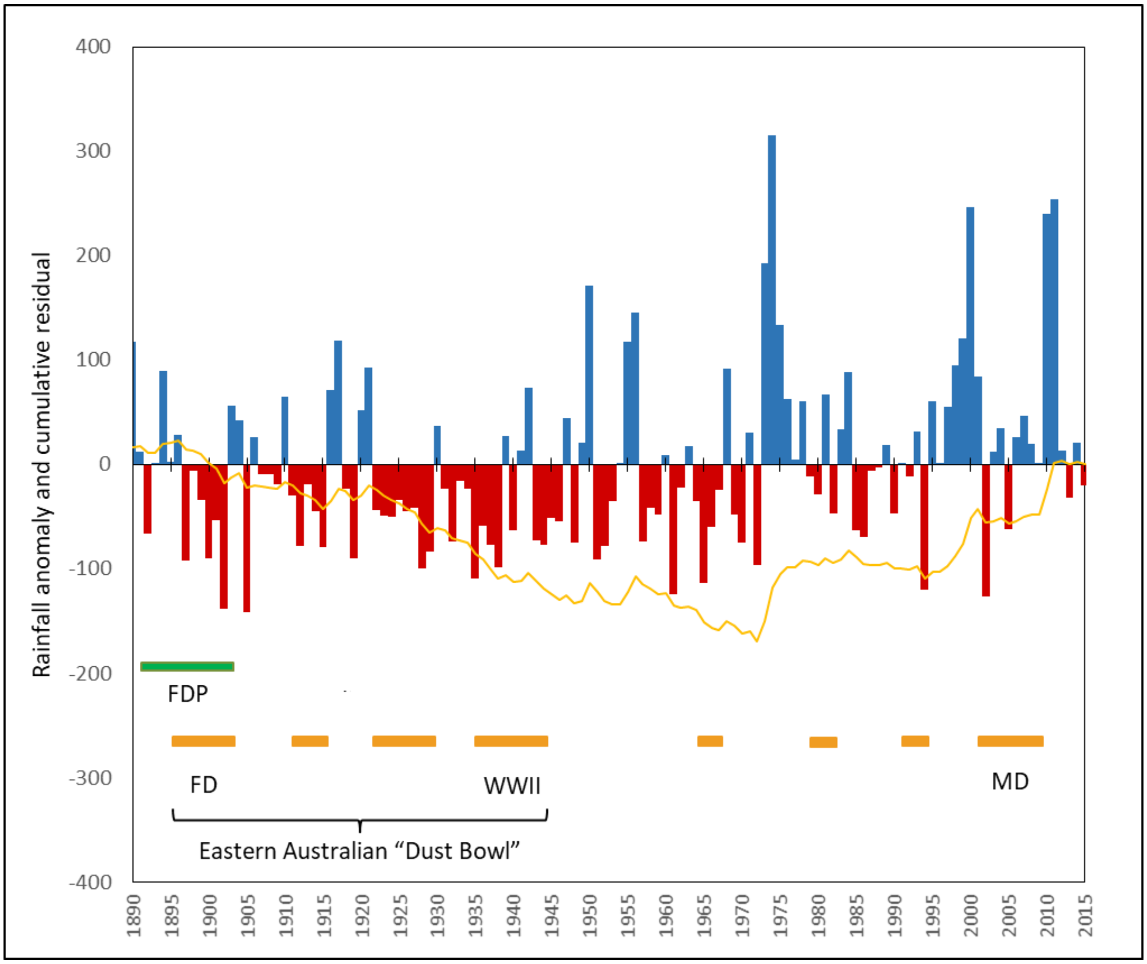
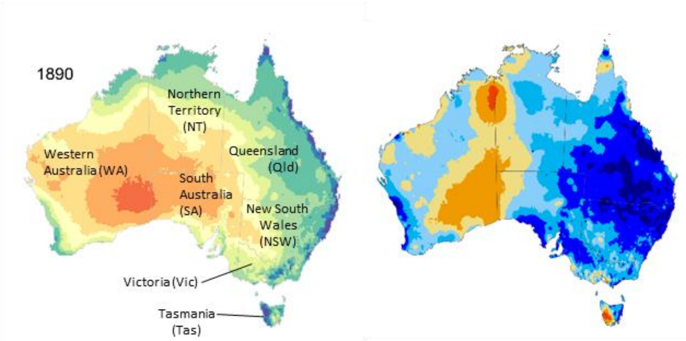
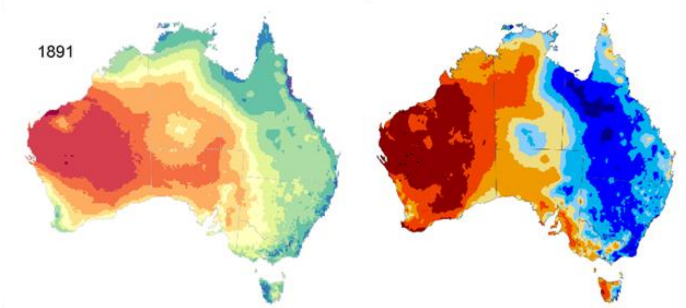


Fig. S1. Annual continental rainfall anomalies and significant eastern Australia droughts 1890-2015. The data show increasing mean continental rainfall since approximately 1972 with particularly wet periods in the 1970s, 1990s and 2010s. Major decade-scale droughts that affected part or all of eastern Australia include the (1892-) 1895-1903 Federation Drought (FD), World War II (1935-) 1937-1945 drought (WWII) and the (1997-) 2001-2009 Millennium Drought (MD; numbers in brackets are sometimes used). Other severe droughts occurred during 1912-15, 1920s, 1964-67, 1979-82 and 1991-94 (mainly affecting eastern Qld and NE NSW). The 1891-1903 study period (Federation Drought Period, FDP) is shown in green; the period 1895-1945 is known as the eastern Australian "Dust Bowl". The orange line is the cumulative residual rainfall curve for the continent as a whole. Regional rainfall trends can be obtained at the Australian Bureau of Meteorology home page (www.bom.gov.au).

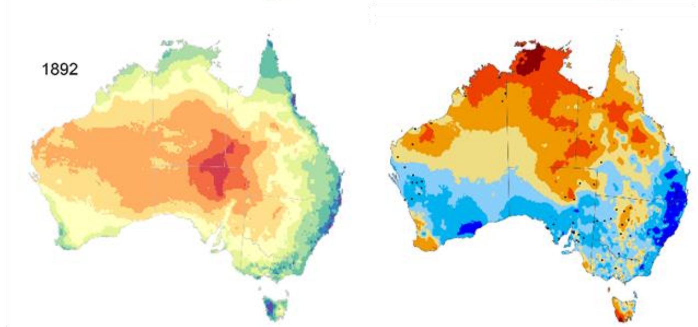
Annual precipitation across Australia, 1890-1903



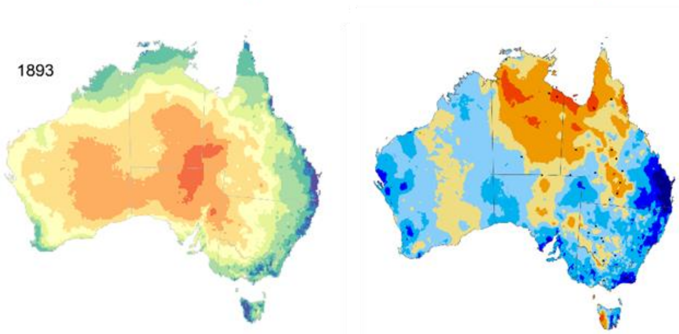
No major rainfall deficiencies; very high rainfall across eastern Australia.



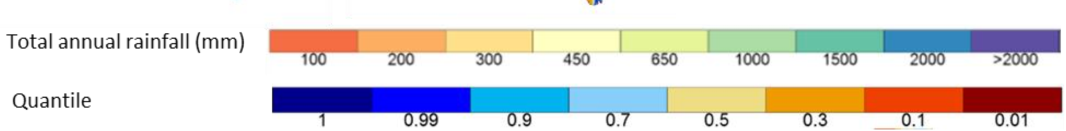
Extremely low rainfall across western Australia, known as the "Great Drought"; many areas receiving little or no rainfall. Very high rainfall across most of eastern Australia.

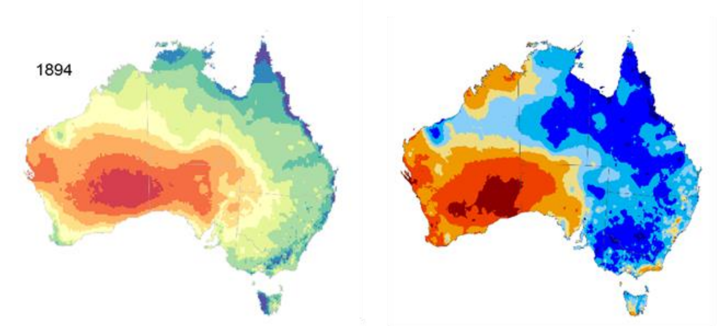


Low rainfall across northern and central Australia. Semi-annual drought in central NSW.

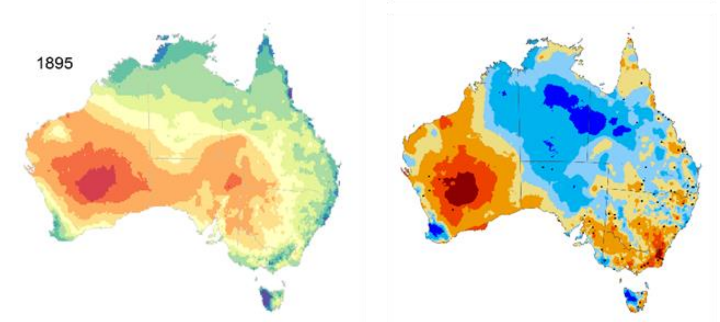


Low rainfall across NT, northern and central Qld, and parts of central NSW. Wet along east coast.

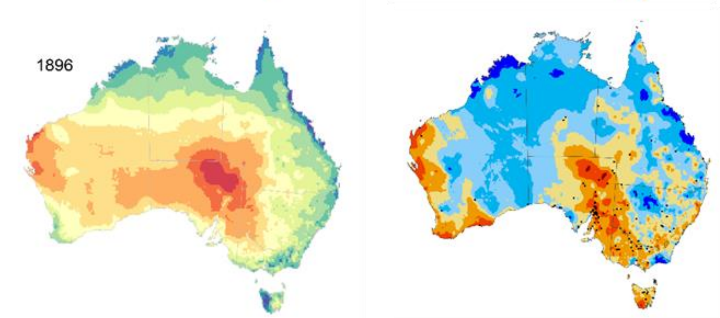




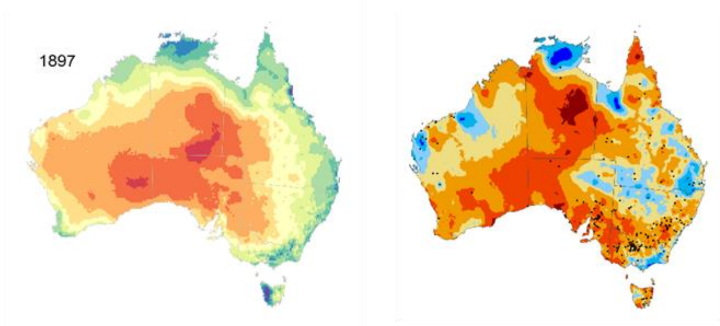
Onset of multi-year period of drought in western Australia. High rainfall across eastern Australia, breaking drought conditions experienced during 1892-93.



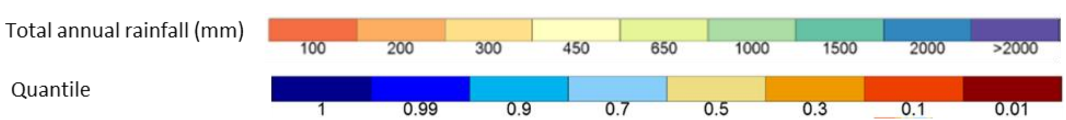
Onset of 'Federation Drought' in south-eastern Australia; ongoing severe drought in WA.

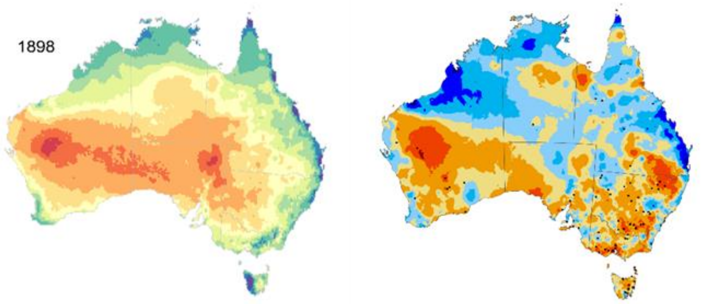


Ongoing drought in southern Australia; severe in Lake Eyre region to western Victoria.

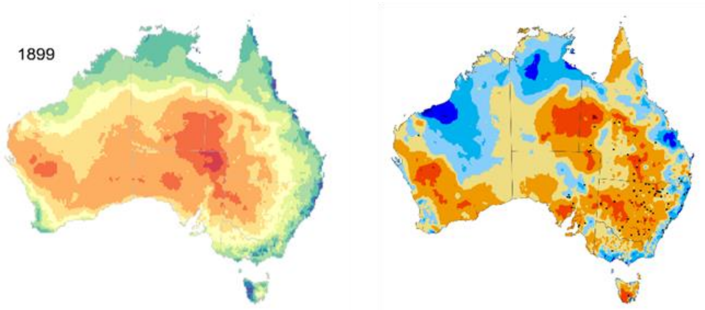


Very low rainfall across much of continent; severe drought in SA, Vic, southern NSW and Pilbara region of WA; drought also widespread in Qld, NT and Tas.

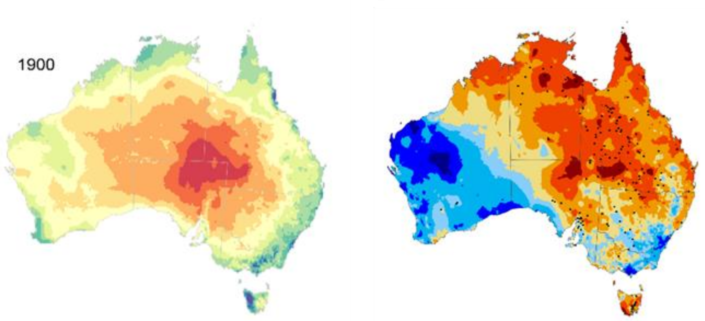




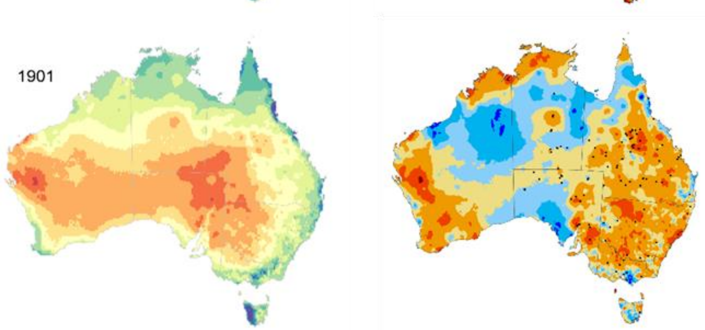
Ongoing drought in WA and south-eastern Australia.



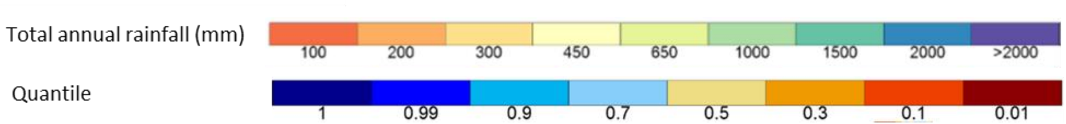
Ongoing drought in southern, central and eastern Australia. Eastern coastal fringe and northwest mainly unaffected.

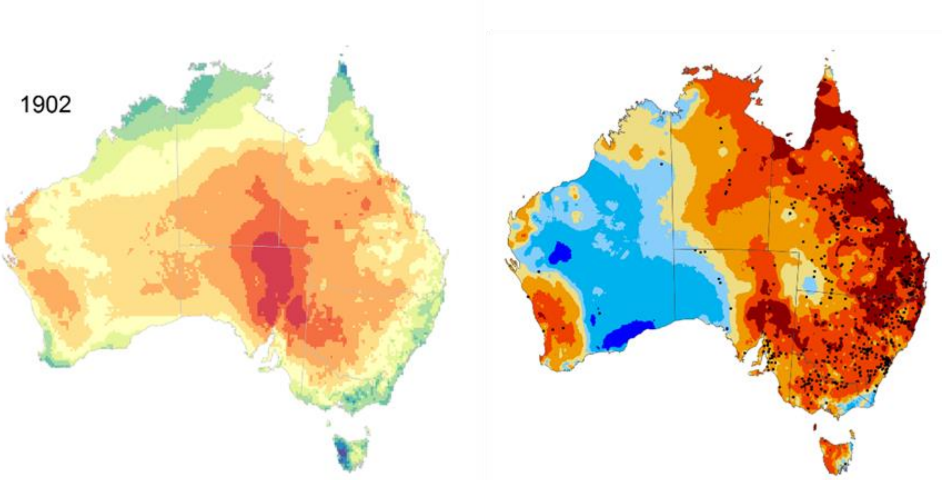


Extremely severe drought in NT, arid SA, NSW and especially inland Qld, extending to coastal areas. Very heavy stock mortality in western Qld and NT. Drought-breaking rains across western Australia.



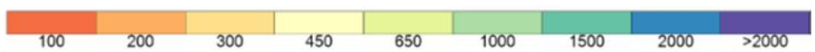
Ongoing drought across central and eastern Australia, especially central Qld to Victoria, and onset of dry conditions in Western Australia.



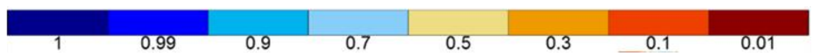


Most extreme year of the Federation Drought, with exceptionally low rainfall and severe drought extending across virtually all of the eastern half of the continent. Very low to record low rainfall extending to coastal areas of QLD and NSW. Devastating stock losses, especially in inland areas of Qld, NSW and SA. Re-emergence of drought in far southwestern WA.

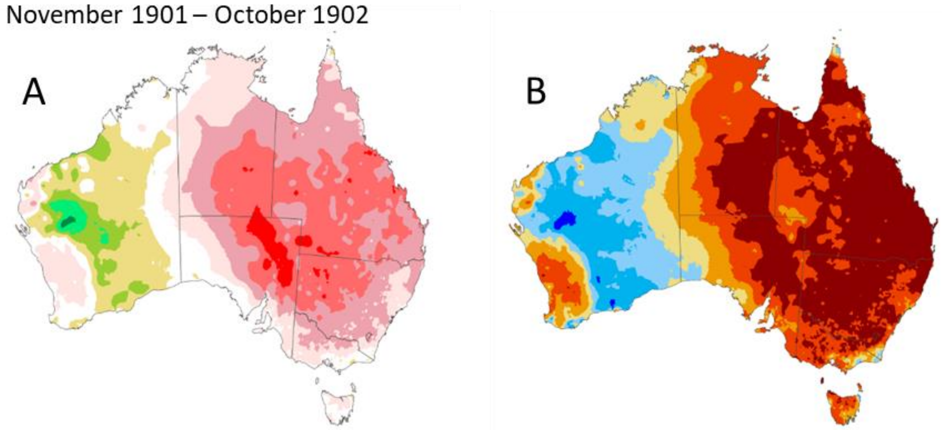
Total annual rainfall (mm)



Quantile

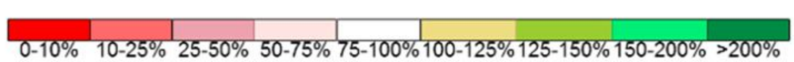


November 1901 – October 1902

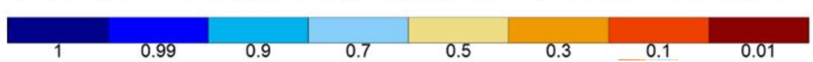


Total rainfall (% of normal; A) and quantiles (B) for the period November 1901 – October 1902. Areas receiving <20% of normal rainfall extended from central NT to southern SA and coastal Qld.

Total rainfall (% average)



Quantile



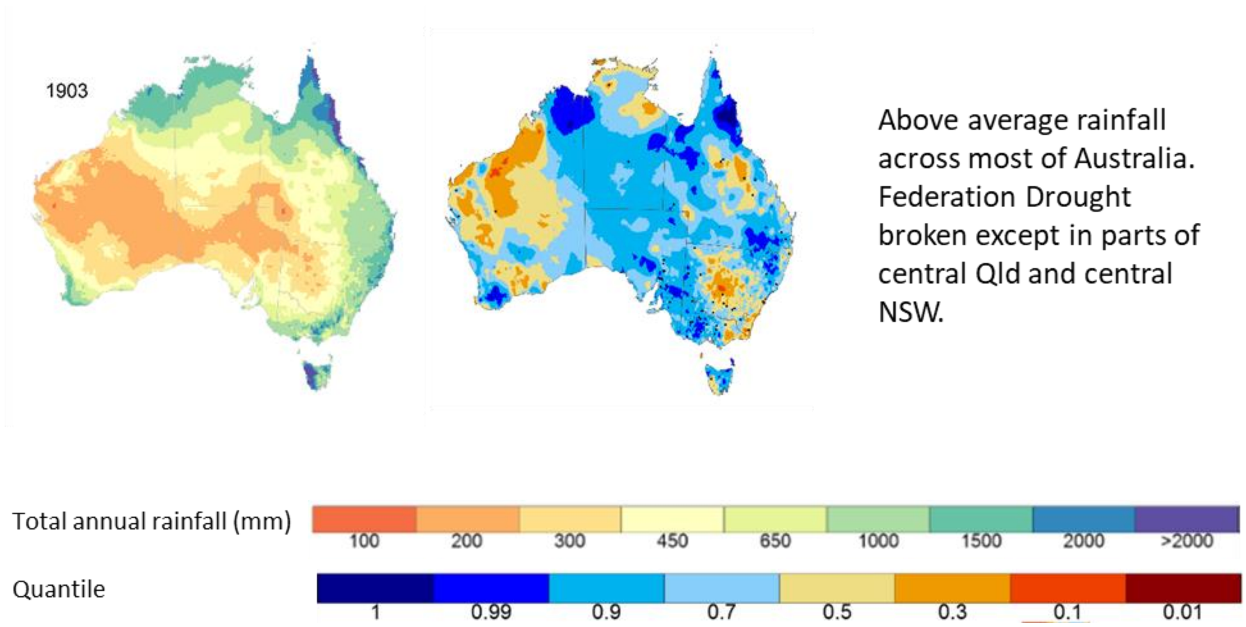


Fig. S2. Total annual rainfall (left panels) and quantiles (right panels) for 1890-1903. A brief description of the pattern of drought in each year is provided. Quantile maps contain geolocations of drought records recorded in that year (black dots). States and abbreviations are shown in the first panel. Also shown for the period November 1901 – October 1902 are total rainfall (% of normal) and associated quantiles.

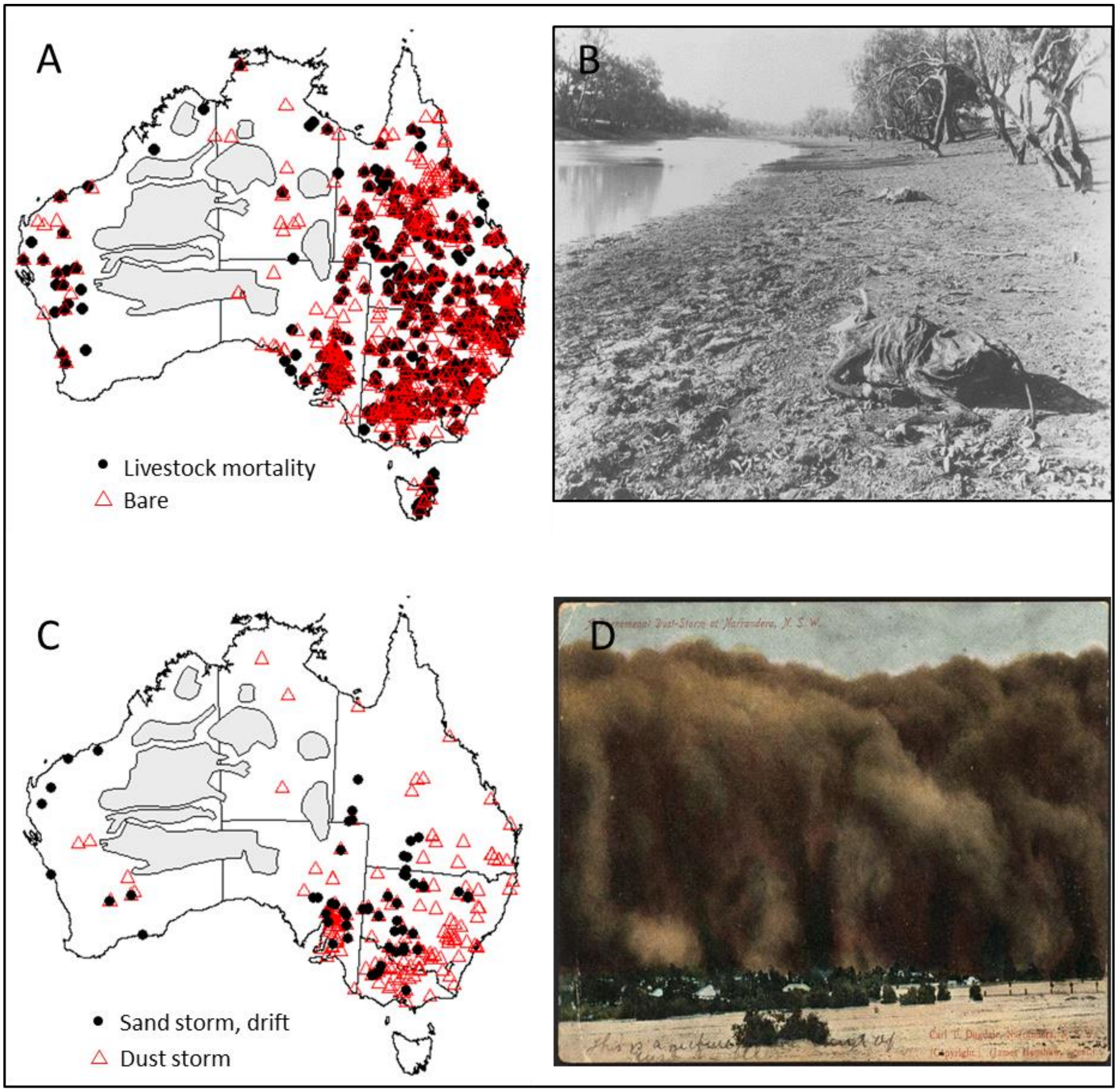


Fig. S3. Secondary indicators of drought extracted from historical sources, 1890-1903. (*A*) Locations of reported livestock mortality and vegetation denudation (bare). (*B*) Carcasses of cattle at drying waterhole on Bowra Station, north of Cunnamulla, Queensland, ca. 1900-1902. (*C*) Locations of reported dust storms, sandstorms and soil drift (wind erosion). (*D*) Severe dust storm at Narrandera, central NSW, on Monday Feb 2, 1903 [photo: Carl T. Dugdale (d. 1939); courtesy National Library of Australia]. Recoloured from the original. Gray shading in *A* and *C* represents the approximate extent of areas unexplored by Europeans in 1896 reproduced from Hill JG (1905) The Calvert scientific exploring expedition. F. Philip & Son, Ltd., London, 44p.

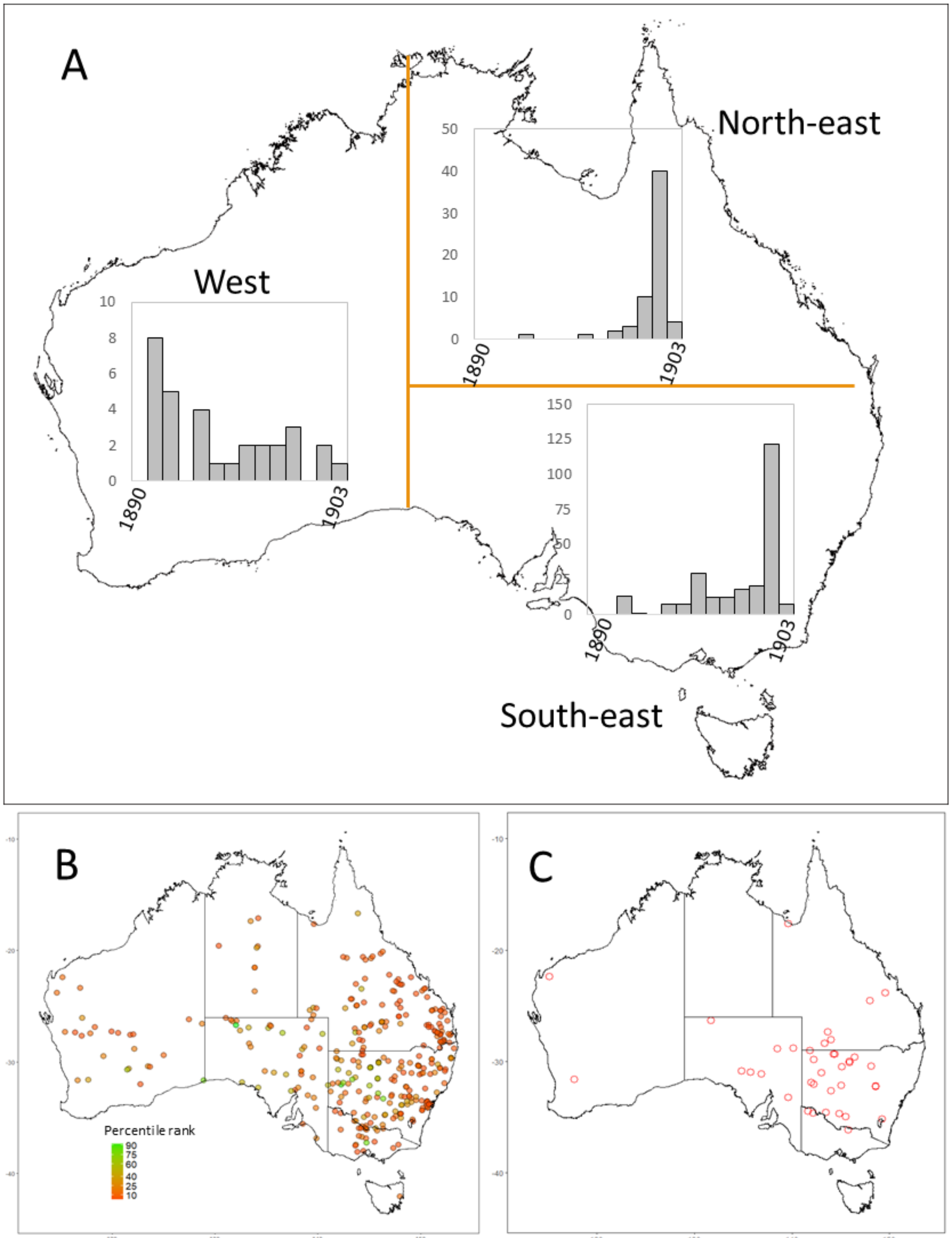


Fig. S4. Timing of biotic impact records across Australia and association with rainfall deficiencies and overgrazing. (*A*) Biotic impact records by year (x axis). (*B*) PR_{R} index for all BIR locations. PR_{R} is the percentile rank of the rainfall deficiency observed in the 12 months prior to a given BIR relative to all 12 month intervals 1890-1903. High values indicate that the BIR occurred in a relatively wet period while low values indicate a drier period. For example, a PR_{R} value of 10 indicates that the BIR observation was made during the lowest decile or 10% of 12 month rainfall totals. (*C*) Locations of BIR sites at which overgrazing was cited as a contributing factor to biotic mortality or stress. All figures were constructed using unique records (removing site-level duplications).

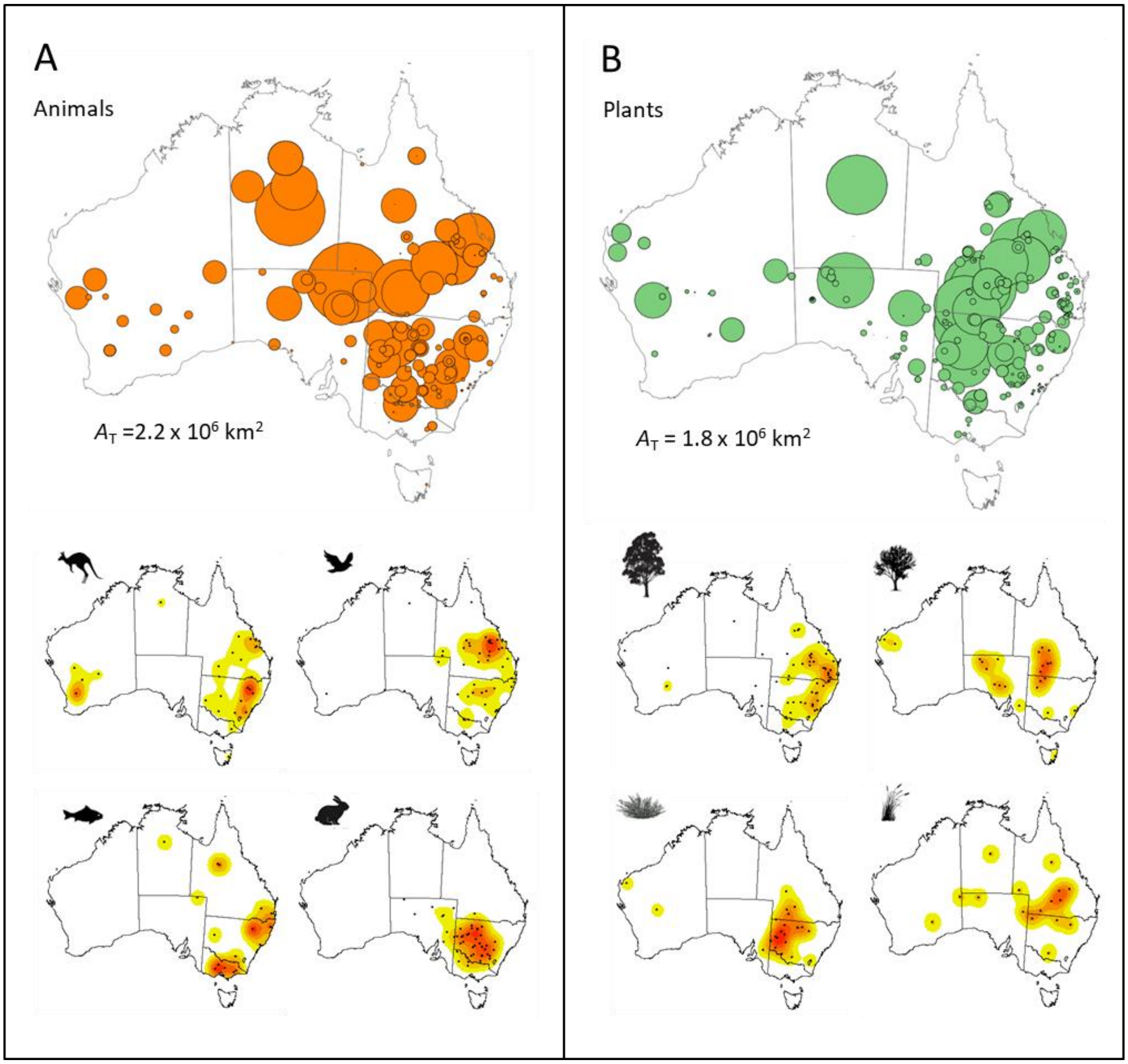
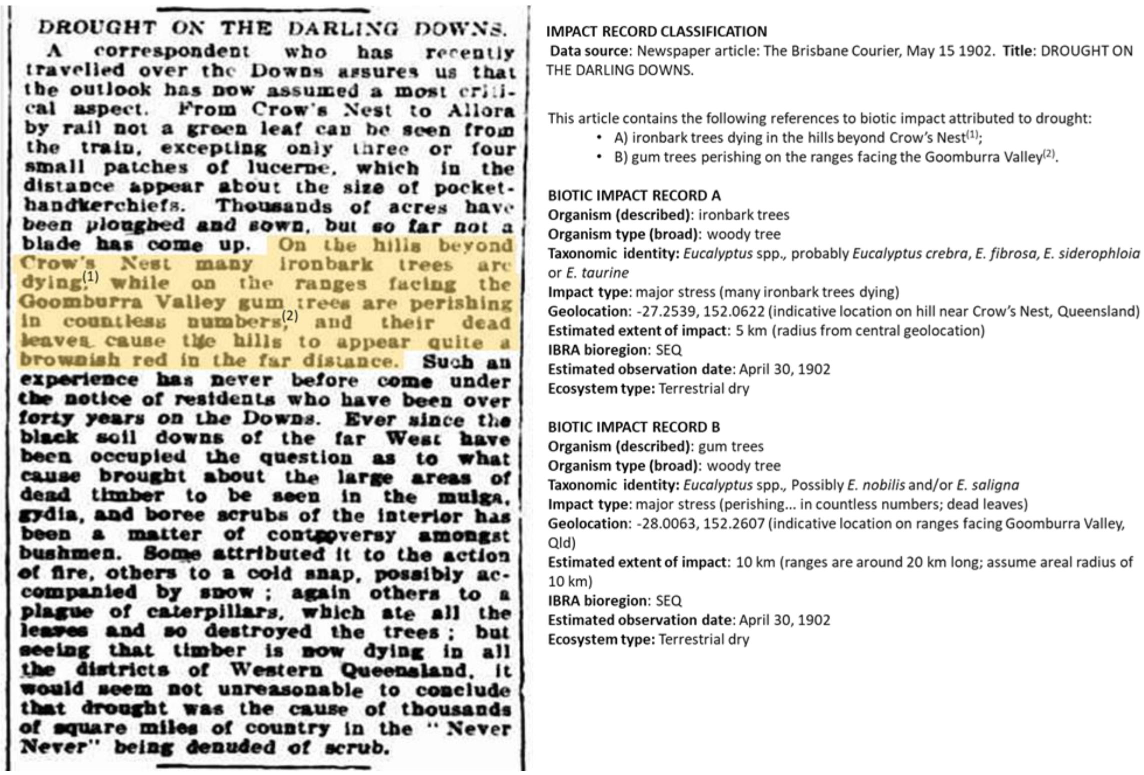


Fig. S5. Estimated total area of impact across BIRs (A_T) and mortality hotspots for animals (A; kernel density estimate maps for marsupials, birds, fish and rabbits shown below) and plants (B; kernel density estimate maps for trees, tall shrubs, low shrubs and grasses shown below) during 1891-1903. The combined A_T of all animal and plant records is 2.76 x 10^6 km^2.



DROUGHT ON THE DARLING DOWNS.

A correspondent who has recently travelled over the Downs assures us that the outlook has now assumed a most critical aspect. From Crow's Nest to Allora by rail not a green leaf can be seen from the train, excepting only three or four small patches of lucerne, which in the distance appear about the size of pocket-handkerchiefs. Thousands of acres have been ploughed and sown, but so far not a blade has come up. On the hills beyond Crow's Nest many ironbark trees are dying(1) while on the ranges facing the Goomburra Valley gum trees are perishing in countless numbers(2) and their dead leaves cause the hills to appear quite a brownish red in the far distance. Such an experience has never before come under the notice of residents who have been over forty years on the Downs. Ever since the black soil downs of the far West have been occupied the question as to what cause brought about the large areas of dead timber to be seen in the mulga, gydia, and boree scrubs of the interior has been a matter of controversy amongst bushmen. Some attributed it to the action of fire, others to a cold snap, possibly accompanied by snow; again others to a plague of caterpillars, which ate all the leaves and so destroyed the trees; but seeing that timber is now dying in all the districts of Western Queensland, it would seem not unreasonable to conclude that drought was the cause of thousands of square miles of country in the "Never Never" being denuded of scrub.

IMPACT RECORD CLASSIFICATION

Data source: Newspaper article: The Brisbane Courier, May 15 1902. **Title**: DROUGHT ON THE DARLING DOWNS.

This article contains the following references to biotic impact attributed to drought:

- A) ironbark trees dying in the hills beyond Crow's Nest(1);
- B) gum trees perishing on the ranges facing the Goomburra Valley(2).

BIOTIC IMPACT RECORD A

Organism (described): ironbark trees
Organism type (broad): woody tree
Taxonomic identity: *Eucalyptus* spp., probably *Eucalyptus crebra*, *E. fibrosa*, *E. siderophloia* or *E. taurine*
Impact type: major stress (many ironbark trees dying)
Geolocation: -27.2539, 152.0622 (indicative location on hill near Crow's Nest, Queensland)
Estimated extent of impact: 5 km (radius from central geolocation)
IBRA bioregion: SEQ
Estimated observation date: April 30, 1902
Ecosystem type: Terrestrial dry

BIOTIC IMPACT RECORD B

Organism (described): gum trees
Organism type (broad): woody tree
Taxonomic identity: *Eucalyptus* spp., Possibly *E. nobilis* and/or *E. saligna*
Impact type: major stress (perishing… in countless numbers; dead leaves)
Geolocation: -28.0063, 152.2607 (indicative location on ranges facing Goomburra Valley, Qld)
Estimated extent of impact: 10 km (ranges are around 20 km long; assume areal radius of 10 km)
IBRA bioregion: SEQ
Estimated observation date: April 30, 1902
Ecosystem type: Terrestrial dry

Fig. S6. Example of biotic impact records extracted from a newspaper article published in the Brisbane Courier, May 15 1902.

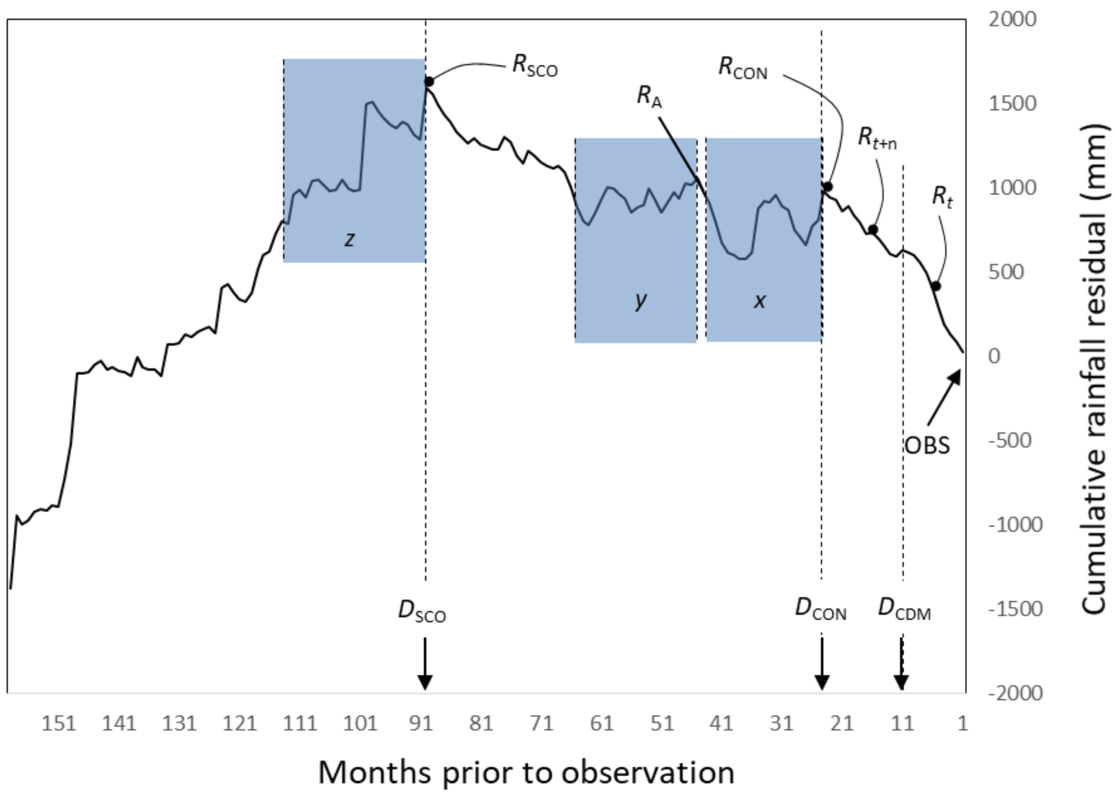


Fig. S7. Method for determining drought depth and duration prior to the time of impact based on analysis of the cumulative sum of monthly rainfall residuals (*R*). For each geocoded BIR we determined the estimated observation date (T_0) and extended *R* backwards by sequentially adding monthly rainfall residuals (determined as $P_{AV} – P_M$ where P_{AV} is the mean monthly rainfall and P_M is the observed monthly rainfall) back to Jan 1889. We then determined 1) the number of consecutive months of negative monthly rainfall residuals prior to T_0 (D_{CDM}), 2) the duration of continuous drought (D_{CON}) prior to T_0, defined as duration of cumulated monthly rainfall residuals working backwards from the observation date with no unbroken period of 12 months or more of declining *R* (i.e., no $R_{(t+n)}…R_{(t+1)} < R_{(t)}$ such that $n \geq 12$), and 3) duration of semi-continuous drought (D_{SCO}) prior to T_0, defined as the duration of cumulative monthly rainfall residuals with no unbroken period of 24 months or more of declining *R* (i.e., no $R_{(t+n)}…R_{(t+1} < R_{(t)}$ such that $n \geq 24$). In the diagram above, prior to the observation (OBS) at t=0, there were 11 consecutive months of below average monthly rainfall (D_{CDM} = 11) and 24 months of continuous drought (D_{CON} = 24) with a total accumulated rainfall deficiency of 950 mm which is 95% of the mean annual precipitation of 1000 mm (R_{CON} = 95). Prior to this there were two intervals (*x* and *y*) of between 12 and 24 months of declining *R*, but no period exceeding 24 months (note *x* and *y* are separated by R_A where $R_A > R_{CON}$. Prior to R_{SCO} there were at least 24 months of declining *R* (i.e, two years with a positive rainfall residual overall; interval *z*) and so the period of semicontinuous drought (D_{SCO}) is terminated at 91 months prior to the observation.

Table S1. Selected accounts describing drought impacts during the study period. 1-4: livestock death, 5: hydrological; 6-9: waterway contamination; 10-14: dust storms, wind erosion; 15-18: social and economic; 19-28: birds, 29-35: native mammals, 36-38: rabbits (*Oryctolagus cuniculus*), 39-42: fish and eels, 43-44: reptiles, 45-62: vegetation, 63-73: use of livestock and carcasses by predatory and scavenging animals, 74-80: evidence of persistent drought impacts on biota.

Account	Trove no.	Publication Date	Details
1	171210142	April 28, 1902	Deaths of hundreds of thousands of sheep documented on multiple Queensland properties
2	76365777	June 2, 1902	Decimation of herds of cattle, deaths of tens of thousands of cattle documented in Queensland
3	84847550	December, 1902	Death of >90,000 cattle documented on 9 pastoral stations in the Gregory District of western Queensland; practically a total extinction of herds
4	14443727	June 17, 1902	Death of 20,000,000 sheep in Western Division of NSW
5	various	1896-1903	**Selected NSW watercourses and water bodies impacted during the Federation Drought Period, date, and TROVE reference**. **NSW**: Bega River 1896 (109913741); Edward River 1896 (161834766); Murray River 1896 (161834766; 161837312); Lachlan River 1899 (103831582); Hunter River NSW 1897 (108055154); Namoi River 1899 (78727450); Mooki River 1899 (138673958); Belubula River 1901 (112580915); Hawksbury River 1902 (114120642); Moruya River 1902 (14434193); Yass River NSW 1902 (64337168); Macquarie River 1902 (157251392); Paroo River 1902 (61386050); Macleay River 1902 (121566667); Bogan River 1902 (112282489); Darling River 1902 (14442739, 100617833); Molongolo River 1902 (14454991); **QLD:** Mitchell River 1898 (42935270); Warrego River 1900 (226867959); Taldora and Milungra waterholes 1900 (52577585); Brisbane River 1901 (97387717); Cooper Creek 1901 (174956136); Fitzroy River 1902 (19198923); Darr River 1902 (19204924); Condamine River 1902 (176979750); Balonne River 1902 (172587346); Walsh River 1902 (82353324); Dawson River 1902 (68275707); **SA:** soakages at Indulkana 1896 (209059219); Bung(y)eroo Creek and Bratchina Creek 1896 (162365416); Oooraminna rock hole 1901 (209679279); **WA:** Ashburton River and larger creeks 1899 (3222836); **NT:** Anthony's Lagoon 1902 (196579571); **VIC:** Bear's Lagoon 1896 (88990278); Horsham River VIC 1898 (73037973); King River 1898 (197302144); Winton Swamp 1898 (197300890); Lake Learmonth 1899 (215320429); Buffalo River 1903 (197895777); Molesworth Lagoon 1903 (9819253); **TAS:** Meander River TAS 1896 (91163201);
6	189051183	November 1, 1895	"A terrible picture of the drought......a traveller who arrive in town on Tuesday informed us that there were fully 100 head of cattle dead and bogged in Rolfe's Lagoon [in Peak Downs area of central eastern Queensland]."

Account	Trove no.	Publication Date	Details
7	135375219	December 20, 1899	"News from Birdsville Point, on the Diamantina, about 1000 miles west of Brisbane, states that the effects of the droughts within a radius of 100 miles of Birdsville, will be ruinous to pastoralists. Waterholes never before known to be dry now contain but little water, and stock are dying in large numbers, and filling the waterholes with rotting carcases [*sic*]. People are disheartened by the fact that there has not been a decent season since 1894 [≈5 years]".
8	157251392	September 27, 1902	"In the [Macquarie] river, and along its banks, between Wellington and Bathurst [central NSW], there must be thousands of dead animals, victims of the past appaling [*sic*] drought, and the recent rains must have washed into the water poison from countless putrid carcases [*sic*] which are thickly spread over nearly the whole of the catchment area of the river."
9	121397351	January 27, 1905	"Should I live for ages, I shall never forget some of the heartrending sights I have witnessed in unfortunate Queensland ; the most pitiful being near Charleville, on the Warrigo [*sic*; refers to Warrego River], four years ago [around 1900] when a party of us counted no less than 1700 cattle bogged in one waterhole. As we approached they would turn their heads towards our horses, being guided by the sound, and we saw to our horror and dismay their sightless sockets, the eyes having been ruthlessly torn out by crows and hawks."
10	56586979	June 18, 1904	"The open plains-which during these disastrous years were swept and devastated by continual windstorms that carried away the surface soil, depositing it in sand-banks and overwhelming fences and stockyards with its drift-are now, owing to the favourable rain which fell last year [1903], and to the flood waters which inundated a portion of the country, gradually becoming covered with bush and herbage...." [referring to wind erosion in northwest NSW in 1902]
11	199400311	May 29, 1902	"Hundreds of square miles of the country are absolutely bare of any kind of vegetation, and the surface soil of great areas has been swept off by the furious westerly winds. The soil so displaced has been piled up round trees and buildings and banked up over fences till, in many instances, they are completely covered, and carried into tanks, which have been filled with sand to the level of the surrounding country. Roots of trees, shrubs and grass have been exposed to the scorching sun of these wind-swept areas, with the result that they have perished outright....The violence of the Darling dust storms is terrific. They occur with unpleasant frequency during the summer.....immense damage is done. Business in the towns has to be completely suspended...It is no uncommon experience for persons who happen to be driving to be compelled to camp all day, because neither man nor horse can face the blinding, suffocating clouds of dust." [Balranald - Darling River area, western NSW]

Account	Trove no.	Publication Date	Details
12	29531171	February 22, 1900	"Of the 117 miles of country which lie between Bourke and Wanaaring on the Paroo [Paroo River, northwest New South Wales], 90 miles of the journey is over loose rolling desert sand...The surface of the country [western NSW] has everywhere been broken up and the bushes have been destroyed, so that fences fences have been all but obliterated and tanks [dams] filled up with sand-laden tornados which rush across the plains."
13	124133075	November 15, 1902	"A DUST-STORM of exceptional violence passed over Melbourne [VIC] at noon yesterday, and its severity was not appreciably lessened until night had fairly set in. A scorching wind blew...blinding clouds of dust...such a darkening effect that early lighting up became necessary...in some districts the residents were thrown into a state of alarm by the terrific nature of the storm. At Pyramid Hill [north-central VIC] the township was plunged into total darkness by the dust-storm, and persons who were out of doors at the time had to cling to whatever they could lay their hands upon to prevent themselves being blown off their feet. *At Boort* [north-central VIC] *great balls of fire fell in the paddocks and in the streets, throwing up showers of sparks as they struck the earth*.
14	3030516	January 18, 1892	"Presently the storm broke over the town [Roeburn, WA]. Its first effect was to cast a brilliant colour wherever the suns rays struck its face. As it increased in fury so did the density of the dust, until everything was in utter darkness, and even in the street one's hand held before one was not visible...This is the heaviest and most durable dust-storm every experienced in the district since its settlement... When the dust had settled, on some places there was nearly half-an-inch of sand on places one which previously to this there was hardly anything but stones, and these places, now resemble a huge river bed."
15	200507374	August 3, 1902	Detailed description of economic, unemployment, impoverished families and social hardship in Queensland
16	36960215	June 16, 1900	"The abandoned runs to the north of our track [in northwestern SA] include Mount Vivian, of 1,125 square miles...Parakylia South, 1,550 miles; Andamooka, 1,832 miles; portion of Arcoona, 141 miles; ...southern portion of Wirramiana, 327 miles; Mahenewo, 420 miles; Kokotha, 608 miles; Emu Bluff, or Lake Everard, 373 miles; and Moonaree, 700 miles."
17	200509861	August 10, 1902	"...The drought in Central and South-western Queensland has paralysed all business, prevented the investment of capital, rendered work scarce, added to the ranks of the unemployed, increased the destitution prevailing, and, generally speaking, thrown back the development of the State for another 10 years." [details on impacts of drought provided]
18	168027110	July 12, 1902	"STARVING FAMILIES IN SINGLETON.- As a result of the protracted drought settlers in the Singleton [NSW] district are experiencing fearful hardships. At the last meeting of the borough council there, the Mayor drew and awful picture of what he had seen of the silent sufferings of many of the settlers, some of them were almost starving and had only rags on their backs."

Account	Trove no.	Publication Date	Details
19	13844549	July 2, 1892	"I went with Messrs. Hutchinson and Bavister to Paddington station. This was 43 miles from Cobar [central western NSW]...Dead animals were strewn all over the ground, and we saw skeletons of all kinds. Kangaroos, emus [*Dromaius novaehollandiae*], sheep, cattle, and horses had perished-the firstnamed by hundreds, and left their bones to whiten on the ground."
20	172065471	October 31, 1893	"The Bulletin has received the following letter from a correspondent at Gambola, Mitchell River: "I am just off a prospecting trip to the Walsh Country [north-eastern QLD]. I saw nothing but large silver lodes, but the silver was too low to pay. The country is fearfully dry, and cattle are dead and dying everywhere. Every waterhole is full of dead pelicans [*Pelecanus conspicillatus*] and native companions [*Grus rubicunda*]. Parrots [Psittacidae] seem to be starving in the bush.""
21	88972198	April 9, 1897	"A report received to-day from Wamboo, on the border of New South Wales, states that the drought has had such a terrible effect on the pastorage that numbers of emus [*Dromaius novaehollandiae*] are dying of starvation, a fact unprecedented in that part."
22	71329854	June 24, 1899	"Butterbone is a station near the town of Warren(N.S.W)...The emus (*Dromaius novaehollandiae*) are so weak that hundreds of them are bogged and perishing in the creek.”
23	71490585	July 19, 1902	"An index of the severity of the drought in the Camden district [eastern NSW] ... Many of the native birds, notably laughing jackasses [*Dacelo novaeguineae*] and magpies [*Cracticus tibicen*] are dying, and a number of the eucalypti, ironbark, box, and gum trees are losing their leaves..."
24	196579571	November 8, 1902	"Even the natives [aboriginal people] can find no living thing on which to feed-snakes and iguanas [monitors], kangaroo rats and bandicoots, birds, beasts and fishes, have all succumbed to the drought...”
25	176979750	October 7, 1902	"[Logie Plains, Warra, Darling Downs, QLD]...We are having fearful droughts here. Very few birds to be seen; nearly all dead. Hundreds of white cockatoos [*Cacatua galerita*] have died all along the river and creeks; also, very few jackasses [*Dacelo novaeguineae*] are left...I have not seen a frog or snake for months. The land is all cracked deep down on black earth. They fall into the cracks and cannot get out."
26	97396904	January 17, 1903	"...the driest and most disastrous year ever known in the Maranoa [central QLD] district since it was stocked. Forest trees have died in the thousands, and even birds have perished in large numbers. I have seen as many as thirteen laughing jackasses [*Dacelo novaeguineae*, kookaburra] dead under one tree. It is a rare thing to see or hear a jackass now; many other birds have also died, and numbers of marsupials."

Account	Trove no.	Publication Date	Details
27	52977048	February 28, 1903	"One marked effect of the drought is the absence of animal life with the exception of native dogs, while bird life has practically disappeared...there is an entire absence of all insectivorous birds [central eastern QLD]."
28	71945259	January 10, 1903	"In some places [in eastern Queensland] thousands of birds have died, some species being nearly defunct, such as magpies [*Cracticus tibicen*], butcherbirds [*Cracticus* spp.], and jackasses [*Dacelo novaeguineae*]. In some places numbers of cockatoos [*Cacatua galerita*] have died."
29	19198923	August 13, 1902	"The native timbers are dying wholesale, especially the ironbarks. Viewing from an eminence, the country presents the appearance at a distance of a tremendous bush fire, and the marsupials are dying of sheer starvation [QLD]."
30	106785089	June 24, 1902	"All grass has vanished, and timber is dying fast on the ranges about Bullio [eastern NSW], where marsupials are frequently found dead."
31	211843195	December 18, 1897	"It was about two years ago, and just at the end of the great drought....There was not a blade of grass, nor a leaf on tree or bush. In many places they saw the carcases of kangaroos suspended in the branches of trees, up which they had struggled to get a bite at a stray leaf, but their strength failing they had fallen back and been hung on the branches.""
32	227208158	June 17, 1897	"The effects of a severe drought must be seen to be realised. The one-time verdant pastures resemble a desert...The tanks and dams are filled with dead and dying stock, together with kangaroos [*Macropus fuliginosus* or *Macropus rufus*], rabbits [*Oryctolgaus cuniculus*], and other wild animals..."[Riverina district of Victoria and NSW]
33	13844549	July 2, 1892	"...Paddington Station...43 miles from Cobar [western NSW]...Dead animals were strewn all over the ground, and we saw skeletons of all kinds. Kangaroos [Probably *Macropus fuliginosus* or *M. rufus*, possibly *M. giganteus*], emus, sheep, cattle, and horses had perished-the firstnamed by hundreds, and left their bones to whiten on the ground."
34	76367268	September 21, 1902	"Owing to the drought wallabies [Macropodidae] have been dying in the thousands [in NSW], and the Board abolished the bonus on scalps last month."
35	71945259	January 10, 1903	"I think I am right in saying that the year now ended has been the driest and most disastrous since white man first trod this land of droughts and floods. Thousands of opossums [*Trichosurus vulpecula*], bears [*Phascolarctos cinereus*], kangaroo rats [probably *Bettongia* spp.], and bandicoots [Peramelidae] have perished, whilst kangaroos [*Macropus* spp.] and wallabies [Macropodidae] have in many instances died of weakness or become and easy prey to the hunter."[coastal Queensland]

Account	Trove no.	Publication Date	Details
36	14470161	April 9, 1902	"There is no doubt in my mind that the drought as far as grass is concerned has been accentuated by the rabbit [*Oryctolagus cuniculus*] pest, but the pests are now dying in thousands from starvation. They have ringbarked nearly all the scrub, and even the roots of the large box and gumtrees [*Eucalyptus* spp.], and have lately taken to eating the prickly pear [*Opuntia stricta*] plants, and killing them."
37	99732140	February 17, 1899	"From reliable estimates, by acreage and by actual count, over 10,000,000 rabbits [*Oryctolagus cuniculus*] died on Dunlop [Dunlop Station, a very large grazing property in western NSW] from Drought [*sic*] and slaughter in less than nine months. Winbar Station, below there, paid two cents each for 100,000 rabbits killed on its run in four months. More than 5,000,000 more died from starvation and other causes on the plains between the miles of mesh fences which confined them."
38	91547201	March 12, 1892	"Wilcannia [western NSW] wires that the country is in a worse state than in the great drought of 1888 owing chiefly to the devastation of rabbits [*Oryctolagus cuniculus*] ...The rabbits are, however, reported to becoming scarce, as millions are dying from the effects of the drought."
39	67446669	December 10, 1895	"...in the Tambo [eastern VIC] district, that snakes are dying in considerable numbers, and that dead eels [*Anguilla* spp.] are to be seen in all the reaches of the Tambo River. There have also been many dead eels observed in the Mitchell [River]. From several widely-separated localities in Australia I have heard of the native bears [*Phascolarctos cinereus*] dying in large numbers. This may be accounted for by their supply of food falling short owing to the drought."
40	61299668	February 28, 1899	"The Namoi River [northern central NSW] is dry for miles, and the stench arising from the dead fish and carcases is described as terrific."
41	138673958	March 11, 1899	"...the drought is playing sad havoc with the inland rivers [in NSW]...the Alumny Creek, flowing into the Clarence River [northeastern NSW], has shown lots of dead mullet [Mugilidae] along its banks."[also noted that due to low flow rivers are more salty than they have been for years]
42	139118761	September 17, 1904	"...the last drought played great havoc with both fish and fowl life. The first steamer that tried to get down the river after the breaking of the drought came from Wilcannia [western NSW], and it pushed tons of dead fish in front of it for miles of the way."
43	21808452	January 10, 1903	"When the drought was at its worst, the Clutha waterhole [northern QLD] was a great place for crocodiles [*Crocodylis johnsonii*]. Scores were shot on the banks of the river, and some even came out of the dried-up waterholes and died on the Downs."
44	n/a	Emu 27: 35-37 (1927)	"...the whole of Central Queensland was without a vestige of grass, when timber on miles of country completely died out, and insects and small birds and reptiles completely disappeared, they died as freely as any other kinds of birds."

Account	Trove no.	Publication Date	Details
45	101822013	April 8, 1897	"The writer declares that the continuous drought, which lasted since 1894 in the Minilaya part of the district [western WA], is quite without parrallel in the history of the Western Australian coal country. Within 90 miles of the coast there is nothing but a drifting mass of earth, all timber, with the exception of the river gums [probably *Eucalyptus camaldulensis*], having entirely died out."
46	14096483	May 29, 1897	"[Molong District, central NSW]...On the crowns of the ridges in various parts of the district gum and stringybark trees [*Eucalyptus* spp.] are dying in large numbers-a circumstance which has not been known in the memory of the oldest inhabitant...Many attribute the phenomena to the fact that the small quantity of arable soil on the hilltops has been depleted of moisture, and there is, consequently, not sufficient sustenance to keep the trees alive."
47	133049952	April 17, 1902	Towards Basin Creek and on The Peaks Silver Mines [Camden district, eastern NSW] the whole country has the appearance of being burnt up, as far as the eye can reach the timber trees and undergrowth are dead from the drought."
48	156366764	May 13, 1902	That this is the severest drought experienced for many years in these parts is proved by the number of big bush trees dying. They represent a good span of time. In some places, strips of country show most dead and dying gums [*Eucalyptus* spp.]." [New England region of NSW]
49	111402145	May 17, 1902	"Miles upon miles of the bush timber, large and small trees, are as dead as if ringbarked for years; and although he has been a close observer of events for many years, he does not remember any similar circumstances in his long experience." [Baradine region, north central NSW]
50	82273010	June 28, 1902	Near Pittsworth [southeast Qld], forest trees which have stood and flourished for ages are now dying out wholesale, and patches of these trees, varying in extent up to 20 acres in which every tree has succumbed, may be seen, whilst scrubs are dying out in much larger areas."
51	71945259	January 10, 1903	"Very many miles of timber on ridgy country everywhere [coastal Qld] is absolutely dead, whilst a great deal not dead looks very sickly."
52	21812170	April 25, 1903	"...Adrian Downs [pastoral station] ...in the corner near the South Australian border. This country is a desert, only 4in. [100 mm] of rain having fallen there in the last four years. All the trees and shrubs and spinifex [probably *Triodia basedowii*] are dead."

Account	Trove no.	Publication Date	Details
53	56586979	June 18, 1904	"...the country is very dry, only half an inch of rain having fallen since the beginning of this year...Very convincing evidence of the severity of the recent drought is furnished by the fact that over large area of mulga [*Acacia aneura*] forest these hardy trees have died, and are still dying, and many of the box [probably *Eucalyptus largiflorens* although other species are present] and gum trees [probably *Eucalyptus camaldulensis* but *E. coolabah* and *E. ochrophloia* are present] in the watercourses are also dead."[Wilcannia, northwest NSW to southwest Qld, including Paroo River area]
54	84557367	May 22, 1897	"That long stretch of once-important grazing country on the coast, from the Murchison [River] to the de Gray [River] [Western Australia], and extending inland from 50 to 100 miles or more, is almost uninhabitable. Several of the stations near where I write have been deserted...On the grass country no feed is left. Most of the mulga [*Acacia aneura*] is dead, while salt bush [*Atriplex* spp.] went long ago."
55	3213175	September 28, 1898	"...after leaving Queen Victoria spring [southern Western Australia] the herbage was absolutely dead, even to the spinifex [*Triodia* spp.], the ground being blackened by continual droughts...the sugar tree," or the South Australian sandalwood [*Santalum spicatum*]...Even that limited vegetation is dying out..."
56	18550666	June 23, 1900	"Far over Western Queensland; far down into New South Wales; far over South and Central Australia, and far out into the Northern Territory, stretches that dark cloud of awful drought ...All trace of herbage had long since perished. Great belts of mulga [*Acacia aneura*] itself had perished, the ground littered by the barkless trunks and broken branches, the survivors standing gaunt, leafless, and withered, outlined against the cloudless sky."[southwestern Qld]
57	24743058	April 17, 1902	"Generally speaking, this season is one of the driest and longest we have had for a number of years [Northam district, Western Australian wheatbelt]...As I have before observed, the natural scrub and various kinds of trees are dying, especially the jam [*Acacia acuminata*], from the long drought."
58	52762973	June 13, 1902	"From Charleville to Adavale [south-western Qld]...all along the road trees such as box, gum [*Eucalyptus* spp.] and mulga [*Acacia aneura*] and other edible shrubs are dying in large numbers, no doubt from the severity of the drought, and one manager tells me that on his run the leopard tree [*Flindersia maculosa*], which is a fairly good food for stock, will be about entirely wiped out. In pine country I saw hundreds of acres of dead pine [*Callitris glaucophylla*].

Account	Trove no.	Publication Date	Details
59	42955419	October 3, 1902	"Right through the western country [of NSW] the drought is killing trees by scores. The hills for long distances are marked with yellow treetops. All sizes and ages are being affected, and as many of the trees must be a century old, it suggests that the present drought takes the cake or thereabouts for severity. On the watershed of Lachlan and Bogan [Rivers]...the following timbers are dying: Bimble box [*Eucalyptus populnea*], apple box [Eucalyptus], grey box [Eucalyptus], mountain or rocky pine [Callitris.., broom, wait-a-while, come-back, lawyer bush, copper wattle [*Acacia* sp.], currawong, common pine [*Callitris glaucophylla*] and ironbark [*Eucalyptus* sp.]. Jackasses [kookaburra] have died everywhere; in fact they are almost extinct."
60	207504179	August 3, 1901	"Traces of the late drought were visible all along the telegraph line [the Overland Telegraph Line, Alice Springs to approximnately Tennant Creek-Daly Waters, Northern Territory], and in many places the grass and trees seemed permanently destroyed."
61	78727450	June 8, 1899	"For hundreds of miles, in every direction, there are huge tracts where not a blade of grass, dead or alive, is to be seen, and not a leaf of any kind of shrub or herbage. The country is just like an ash heap. The roots of the grass have long since crumbled away and the wind moves the surface to and fro like a sand-drift every now and again." [north-western NSW]
62	64684005	July 4, 1902	"Not a decent season has been experienced since 1894 till the present year. We lost over 11,000 head of cattle and 150 horses...Vast areas of mulga and bushes died off, and even the gum trees in water courses perished...Since the late rains the grass has been growing luxuriantly, but only the annual varieties, the deep rooting varieties having died off." [Beirbank Station, Qld]
63	104657660	Feb 3, 1900	"The increase of dingoes in New South Wales...With rabbits always available..."
64	3666972	Feb 23, 1896	"...a great many trapped rabbits are taken by the blacks, hawks, dingoes, &c."
65	162383210	Oct 23, 1897	"He found some eaglehawks feasting at midday on his sheep...hawks are very keen and prompt in discovering a disabled and dying animal...hundreds of sheep are killed in his district by tiger-cats [quolls]..."
66	71321359	Dec 10, 1898	"...losses of lambs...traced to the iguana [monitors]..."

Account	Trove no.	Publication Date	Details
67	106809606	Feb 17, 1899	"When sheep are stuck there overnight the crows pick out their eyes..."
68	148186402	Jun 23, 1902	"...where crows have been feeding on carcasses of bullocks or sheep..."
69	3636070	Oct 2, 1896	"...rabbits, as reported, were dying in large numbers...to the attacks of crows and hawks, which abound at that spot."
70	125512981	Sep 14, 1900	"...the crows are encouraged to prey upon the carcases [of rabbits], when they also attack the lambs..."
71	217870573	Mar 31, 1896	"The condition of the pastoral affairs in the western portion of South Australia in consequence of the abandonment of runs, chiefly owing to the destruction caused by dingoes...":
72	168900442	Apr 8, 1897	"But rabbits have their enemies. Horses eat them when dead, iguanas [monitors] and snakes makes many a good feast from their carcasses. But the only animal that kills them for the pure love of the thing is the dingo, and he does great destruction among them."
73	121379888	Jun 21, 1901	"The fox has now made his appearance...lambs are being destroyed wholesale..."
74	92804020	Dec 21, 1944	“Most of the saltbush [*Atriplex* spp.] seems to have gone out after the drought of 1902, and it has nowhere re-appeared. “ [Referring to the West Darling region of western NSW]
75	108774747	April 21, 1896	“All the cotton-bush is dead and not likely to come again. About four-fifths of the saltbush is dead-quite beyond recovery.” [Account of loss of edible shrubs in western NSW due to drought and overgrazing by rabbits and livestock.]
76	18550666	June 23, 1900	“Country that was heavily stocked will take years to recover. In some of it even the roots of the grass must be dead, and there can be little or no seed in the ground.” [Referring to much of inland eastern Australia]
77	39004147	February 10, 1939	“Most bushmen formerly believed that these forests of dead iron-bark [Eucalyptus spp.] represented the ordinary process of growth and decay...But 1902 brought knowledge...The [1902] disaster may be a quarter-century away, but its shadow is cast already by the girth of those young trees...almost wiped out in 1903, the birds, the native animals, the squatter pigeons, are breeding up once more to pre-drought standards...[article reflecting on the long term impacts of the catastrophic 1902 drought, which killed mature forests and nearly drove animals to extinction, and took decades to recover]

Account	Trove no.	Publication Date	Details
78	52977048	February 28, 1903	"One marked effect of the drought is the absence of animal life with the exception of native dogs...bird life has practically disappeared...an entire absence of all insectivorous birds...where they [marsupials] which used to be exceedingly numerous, not a single track is now to be seen". [Article reported in early 1903 after significant rains had improved conditions in the Clermont region of Queensland].
79	109478289	October 20, 1903	"...there are miles of trees in some of the watercourses that are past recall as a result of the drought." [Article written in late 1903, after the break of the drought, and indicate a persistent loss of larger cohorts]
80	38377376	July 5, 1928	Detailed account of loss of native fauna from the wheatbelt of Western Australia during 1894-1902. Article notes that some species did not recover, partly recovered, or underwent a range contraction.

Table S2. Biotic impact record counts of plant and animal taxa during the 1891-1903 study period. *exotic species

Herbaceous - graminoid				17
	Poaceae	*Astrebla* spp.	Mitchell grasses	2
		Triodia basedowii	spinifex	4
		Zygochloa paradoxa	canegrass	1
Herbaceous - other				3
	Asteraceae		"marigold"	1
Succulents				5
	Cactaceae	*Opuntia stricta**	prickly pear	5
Low shrubs				41
	Chenopodiaceae	*Atriplex* spp.	saltbushes, esp. *A. numm*	16
		Maireana spp.	bluebushes	4
		Maireana aphylla	leafless bluebush	1
	Polygonaceae	*Duma florulenta*	lignum	1
Tall shrubs				33
	Fabaceae	*Acacia acuminata*	jam	1
		Acacia aneura	mulga	23
		Acacia doratoxylon	currawang	1
		Acacia mearnsii	black wattle	1
		Acacia pendula	weeping myall	1
	Pittosporaceae	*Bursaria spinosa*	blackthorn	1
	Rutaceae	*Geijera parviflora*	wilga	1
	Santalaceae	*Santalum acuminatum*	quandong	2
	Scrophulariaceae	*Eremophila mitchellii*	false sandalwood, budda	2
		Myoporum platycarpum	sugarwood	1
Trees				185
	Casuarinaceae	*Allocasuarina* spp.	she-oak	1
		Casuarina cristata	belah	1
		Casuarina cunninghamiana	river she-oak	3
		Casuarina pauper	black she-oak	1
	Cupressaceae	*Callitris endlicheri*	black cypress pine	1
		Callitris glaucophylla	white cypress pine	10
		Callitris gracilis	slender cypress pine	2
	Fabaceae	*Acacia salicina* or *A. stenophylla*	cooba	1
		Acacia aneura	mulga	2
		Acacia cambagei	gidyea	3
		Acacia harpophylla	brigalow	3
		Acacia oswaldii	boree	1
	Malvaceae	*Brachychiton populneus*	kurrajong	1
		Brachychiton rupestris	bottle tree	1
	Myrtaceae	*Backhousia subargentea*	ironwood	1
		Corymbia erythrophloia or *C. terminalis*	bloodwood	1
		Corymbia eximia or C. gummifera	bloodwood	1
		Eucalyptus acmenoides	white mahogany	1
		Eucalyptus albens	white box	2
		Eucalyptus bridgesiana	apple box	1
		Eucalyptus camaldulensis	river red gum	5
		Eucalyptus coolabah	coolabah	2
		Eucalyptus crebra	narrowleaf red ironbark	1
		Eucalyptus largiflorens	black box	2
		Eucalyptus macrorhyncha	red stringybark	1
		Eucalyptus microcarpa	grey box	1
		Eucalyptus populnea	poplar box	1
		Eucalyptus salmonophloia	salmon gum	2
		Leptospermum spp.	ti-tree	1
		Syncarpia glomulifera	turpentine	1
	Pinaceae	*Pinus radiata**	Monterey pine	1
	Rutaceae	*Flindersia maculosa*	leopardwood	1

Note: some taxa vary in size from tall shrubs to trees depending on location

Actinopterygii					**23**
	Anguillidae	*Anguilla*	*Anguilla australis* and/or *A. reinhardtii*	eel	4
	Mugilidae		Possibly *Myxus petardi* or *Mugil cephalus*	mullet	2
	Percichthyidae	*Maccullochella*	*Maccullochella* sp.	Brisbane River cod	1
		Macquaria	*Macquaria ambigua*	golden perch	1
			Macquaria australasica	Macquarie perch	1
Amphibia					**1**
	Anura			frogs	1
Aves					**72**
	Acanthizidae	*Acanthiza*	*Acanthiza uropygialis*	chestnut-rumped thornbill	1
	Alcedinidae	*Dacelo*	*Dacelo leachii*	blue-winged kookaburra	1
			Dacelo novaeguineae	laughing kookaburra	9
	Artamidae	*Cracticus*	*Cracticus nigrogularis*	pied butcherbird	1
			Cracticus tibicen	Australian magpie	5
			Cracticus torquatus	grey butcherbird	1
	Cacatuidae	*Cacatua*	*Cacatua galerita*	sulphur-crested cockatoo	2
	Campephagidae	*Lalage*	*Lalage tricolor*	white winged triller	1
	Casuariidae	*Dromaius*	*Dromaius novaehollandiae*	emu	9
	Columbidae	*Geophaps*	*Geophaps scripta*	squatter pigeon	1
	Estrilididae	*Taeniopygia*	*Taeniopygia guttata*	zebra finch	2
	Gruidae	*Grus*	*Grus rubicunda*	brolga	2
	Maluridae	*Malurus*	*Malurus melanocephalus*	red backed fairy wren	1
	Megapodiidae	*Alectura*	*Alectura lathami*	Australian brushturkey	1
		Leipoa	*Leipoa ocellata*	malleefowl	1
	Monarchidae	*Grallina*	*Grallina cyanoleuca*	magpie-lark	1
	Otididae	*Ardeotis*	*Ardeotis australis*	Australian bustard	2
	Pelecanidae	*Pelecanus*	*Pelecanus conspicillatus*	Australian pelican	1
	Psittacidae	*Melopsittacus*	*Melopsittacus undulatus*	budgerigah	1
		Polytelis	*Polytelis anthopeplus*	regent parrot	1
		Psephotus	*Psephotus pulcherrimus*	paradise parrot	1
Eutheria					**56**
	Leporidae	*Lepus*	*Lepus timidus**	European hare	1
		Oryctolagus	*Oryctolagus cuniculus**	European rabbit	55
Insecta					**3**
	Apidae	*Apis*	*Apis mellifera**	honey bee	1
Malacostraca					**1**
	Palaemonidae	*Macrobrachium*	*Macrobrachium australiense*	freshwater prawn	1
Marsupialia					**51**
	Dasyuridae	*Dasyurus*	*Dasyurus geoffroii*	western quoll	1
		Phascogale	*Phascogale tapoatafa*	brush-tailed phascogale	1
		Sminthopsis	*Sminthopsis crassicaudata*	fat tailed dunnart	1
	Macropodidae	*Lagorchestes*	*Lagorchestes hirsutus*	rufus hare-wallaby	1
		Macropus	*Macropus eugenii*	tammar wallaby	1
			Macropus fuliginosus and/or *M. rufus*	grey/red kangaroos	6
			Macropus giganteus	eastern grey kangaroo	2
		Petrogale	*Petrogale lateralis*	black-footed rock wallaby	1
	Myrmecobiidae	*Myrmecobius*	*Myrmecobius fasciatus*	numbat	1
	Peramelidae	*Isoodon*	*Isoodon obesulus*	southern brown bandicoot	1
	Phalangeridae	*Trichosurus*	*Trichosurus vulpecula*	brush-tailed possum	6
	Phascolarctidae	*Phascolarctos*	*Phascolarctos cinereus*	koala	3
	Potoroidae	*Bettongia*	*Bettongia lesueur*	burrowing bettong	1
	Thylacomyidae	*Macrotis*	*Macrotis lagotis*	bilby	1
	Vombatidae	*Vombatus*	*Vombatus ursinus*	common wombat	1
Reptilia					**7**
	Agamidae	*Ctenophorus*	*Ctenophorus* sp.	comb-bearing dragons	1
	Crocodylidae	*Crocodylis*	*Crocodylis johnsonii*	freshwater crocodile	1
	Varanidae	*Varanus*	*Varanus* spp.	monitors	1

Table S3. Accounts of population collapse (extirpation and near-extirpation) and mass mortality (by area and number) across major taxonomic groups and major families. Categories for E, NE and Ma are: 1) < 10km, 2) 10 - <100 km and 3) >100 km). Categories for the Mn category are 1) 10^2-10^3, 2) 10^4-10^5, and 3) 10^6+.

		Extirpation (E)		Near-Extirpation (NE)			Mass mortality (area) (Ma)			Mass mortality (number)(Mn)			Total
		2	3	1	2	3	1	2	3	1	2	3	
Actinopterygii							11	1	2	4			18
	Anguillidae						2	1		1			4
Aves		2	1	1	5	8	4	6	3	11			41
	Alcedinidae			1	3	1		1		1			7
	Casuariidae					1	1	2		1			5
	Psittacidae	1				1				1			3
Eutheria													
	Leporidae			1	10	3	2	5	4	12	1	7	45
Marsupialia		1	7		1	6	1	3	5	5			29
	Macropodidae		1		1	2	1	1		1			7
	Peramelidae		1						1	1			3
	Phalangeridae					2		1		1			4
	Phascolarctidae	1						1		1			3
	Potoroidae		1						4	1			6
Forbs								1					1
Insecta					1	1							2
Reptilia						2		1	2				5
Grasses													
	Poaceae				1			10	4				15
Short shrubs					3	5		14	3				25
	Chenopodiaceae				2	4		9	3				18
Tall Shrubs					1		4	7	5	2			19
	Fabaceae				1		3	7	4	2			17
Trees				2	1	1	9	21	11	4			49
	Casuarinaceae						1	1	2				4
	Cupressaceae			1			2	1		1			5
	Fabaceae						1	2	3				6
	Myrtaceae			1			4	8	1				14
Mixed animals					5	5	1						11
Mixed animals and plants								1					1
Mixed plants								4					4
Mixed woody plants				1	1		1	6	1				10
Grand Total		**3**	**8**	**5**	**29**	**31**	**33**	**80**	**40**	**38**	**1**	**7**	**275**

Table S4. Results of generalised least squares linear model analysis of relationships between magnitude or duration of drought (D_{CDM}, D_{CON}, R_{CON} and D_{SCO}; defined in *SI Appendix* Fig. S7) and mean annual impact site rainfall (P_{AV}, mm), location relative to areas infested by the European rabbit (*Oryctolagus cuniculus*) (RIA) and native terrestrial animal or plant group (Tgroup). F values (with residual degrees of freedom, rdf) for each predictor variable (DV) and predicted means (standard error) are provided; for P_{AV} means were evaluated at 130, 430, 740, 1000 and 1400 mm. Means are in the transformed scale where appropriate (D_{CDM}, D_{CON}, R_{CON} = square root transformed; D_{SCO} = untransformed). Three model types were used: FNS = all BIRs, non spatial; FS = all BIRs, spatial; RNS = only spatially unique BIRs, non-spatial; for details see *SI Appendix* SI Text. ^{M}P< 0.10, *P< 0.05, **P< 0.01, ***P<0.001.

	Model		Effect			RIA		Tgroup		P_{AV}				
DV	Type	rdf	P_{AV}	TGroup	RIA	Inside	Outside	Plant	Animal	130	430	740	1000	1400
D_{CDM}	FNS	295	41.67***	0.01	8.03	2.25 (0.13)	2.65 (0.05)	2.58 (0.07)	2.59 (0.07)	2.18	2.54	2.91	3.22	3.70
	FS	295	4.16*	0.13	1.24	2.44 (0.20)	2.55 (0.09)	2.56 (0.09)	2.51 (0.10)	2.30	2.51	2.72	2.91	3.19
	RNS	151	5.31*	0.01	0.01	2.50 (0.17)	2.52 (0.08)	2.52 (0.09)	2.51 (0.12)	2.31	2.51	2.72	2.90	3.18
D_{CON}	FNS	289	3.34^{M}	6.29*	13.87***	5.06 (0.24)	6.14 (0.10)	6.19 (0.13)	5.71 (0.14)	6.33	6.00	5.66	5.38	4.94
	FS	289	1.73	0.04	0.19	5.72 (0.40)	6.03 (0.20)	5.98 (0.20)	5.97 (0.20)	6.30	6.01	5.72	5.47	5.08
	RNS	147	2.93^{M}	1.57	4.19*	5.34 (0.35)	6.18 (0.16)	6.17 (0.18)	5.79 (0.24)	6.46	6.05	5.62	5.27	4.72
R_{CON}	FNS	289	10.94**	5.34*	21.24***	8.83 (0.43)	11.17 (0.18)	11.16 (0.23)	10.36 (0.24)	11.91	10.91	9.89	9.02	7.70
	FS	289	8.02**	0.84	0.47	10.08 (0.66)	10.94 (0.35)	10.82 (0.34)	10.77 (0.34)	11.98	10.94	9.86	8.96	7.57
	RNS	147	14.02***	0.96	8.14**	9.38 (0.59)	11.32 (0.27)	11.15 (0.30)	10.65 (0.41)	12.43	11.01	9.56	8.34	6.45
D_{SCO}	FNS	275	4.14*	2.37	0.03	50.53 (3.9)	52.41 (1.71)	54.46 (2.17)	49.55 (2.24)	56.53	52.75	48.86	45.59	40.56
	RNS	136	0.97	0.08	0.54	48.39 (5.50)	52.80 (2.57)	51.47 (2.84)	52.84 (3.89)	56.14	52.30	48.33	45.01	39.89

Table S5. Mean (standard error) of magnitude and duration of drought (*D_{CDM}*, *D_{CON}*, *R_{CON}* and *D_{SCO}*; defined in *SI Appendix* Fig. S7) prior to mortality for native plants, animals, and the European rabbit (*Oryctolagus cuniculus*) across all BIRs (all areas) and both inside and outside of rabbit-infested areas (RIA).

		D_{CDM}	D_{CON}	R_{CON}	D_{SCO}
All areas	Native animal	7.23 (0.40)	34.54 (1.79)	111.46 (5.83)	51.72 (2.66)
	Actinopterygii	5.45 (0.96)	32.30 (6.10)	86.98 (16.79)	50.80 (6.79)
	Aves	8.07 (0.69)	30.07 (2.92)	119.26 (9.85)	49.64 (4.19)
	Marsupialia	6.86 (0.75)	30.90 (2.66)	99.60 (8.27)	54.31 (5.34)
	Native plant	6.93 (4.32)	40.86 (1.97)	136.25 (6.32)	56.93 (2.66)
	Grasses	6.44 (1.15)	36.75 (5.40)	135.97 (19.97)	57.31 (7.62)
	Low shrubs	6.44 (0.96)	38.35 (5.38)	128.50 (17.23)	48.39 (6.64)
	Tall shrubs	6.09 (0.79)	44.30 (4.56)	154.68 (16.21)	63.09 (6.48)
	Trees	8.09 (0.58)	39.87 (2.93)	126.88 (8.56)	57.26 (4.02)
	Oryctolagus cuniculus	4.13 (0.36)	25.43 (2.92)	68.70 (7.04)	35.87 (4.24)
Outside RIA	Native animal	7.51 (0.43)	34.33 (1.70)	112.30 (5.79)	53.23 (2.74)
	Native plant	7.20 (0.41)	42.30 (2.21)	142.19 (7.09)	57.74 (3.06)
Inside RIA	Native animal	4.58 (0.53)	36.42 (9.68)	103.71 (27.40)	37.75 (9.53)
	Native plant	5.89 (0.87)	35.39 (4.27)	113.77 (13.40)	53.86 (5.28)
	Oryctolagus cuniculus	3.85 (0.33)	21.30 (2.54)	58.18 (5.54)	30.24 (4.09)