MCAS-S Datapack for Alpine Bogs of the Australian Alps Bioregion

A worked example using the MCAS-S tool to map the coincidence of threats in the Australian Alps

DRAFT TUTORIAL

Prepared for demonstration to the Australian Alps Liaison Committee Alps Water and Catchments Reference Group meeting on 14 October 2014. The data included in this demonstration datapack is not final and should not be used for purposes beyond the demonstration and familiarising yourself with the potential of the MCAS-S tool.

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The aim of this users' guide is to describe the spatial data in the datapack and provide instructions on how the layers can be analysed and explored in MCAS-S for decision support. The instructions take the form of a worked example. You will need to download and install MCAS-S software to your desktop or laptop. The worked example then steps you through using MCAS-S and how to open an MCAS-S package to combine layers. This guide is not intended to be a comprehensive guide to using MCAS-S. For more detailed information on how to use MCAS-S, including how to format spatial data for input to MCAS-S, please see the ABARES website – www.abares.gov.au/mcass and User Guide (ABARES 2014). The report is an output of the Landscapes and Policy Research Hub.

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Glossary	
Alpine bog	In this manual the term 'alpine bog' refers to the EPBC listed Alpine *Sphagnum* Bogs and Associated Fens community.
ABARES	Australian Bureau of Agriculture and Resource Economics and Sciences
Information Panel	Left-hand panel in MCAS-S used to edit maps.
Input layer	Data layer contained within the Primary folder of an MCAS-S project.
Integrated data layer in MCAS-S	Any layer that combines data from >1 layer.
Mask	A type of data layer used in MCAS-S to restrict analyses (integration of maps) to a defined area.
MCAS-S	The Multi-Criteria Analysis Shell for Spatial Decision Support is a decision support tool designed specifically for non-GIS users to integrate spatial data.
MCAS-S Datapack	A series of folders and data layers organised and formatted ready for use in an MCAS-S project.
Multi-Way map	An integrated map layer created using the Multi-Way function to combine >2 input layers.
Overlay	A type of data layer used in MCAS-S as a visual reference. Overlays do not influence any calculations occurring in integrated maps.
Tip file	A small metadata record used to describe data layers exported from MCAS-S.
Two-Way map	An integrated map layer created using the Two-Way function to combine two input layers.
Viewer window	A pop-up window within in MCAS-S that shows the value of a pixel in a map plus values of all input layers to that map upon mouse hover over the pixel of interest. The viewer opens by default but if closed can be opened via the Edit tab.

1.0 The Freshwater Environment

The health or condition (ecological state) of aquatic ecosystems (rivers, lakes and wetlands) is a combined result of processes within the ecosystem and in the surrounding catchment (terrestrial environment). Land-use, catchment integrity, riparian vegetation condition, surface and ground water, geology and the intensity and frequency of disturbances all play a significant role in determining the structure of the physical environment of aquatic ecosystems and therefore, have a significant effect on aquatic biodiversity and the functioning of ecosystems such as bogs.

Making decisions about how to manage aquatic ecosystems in a changing climate is thus challenging because variation in climate can influence aquatic ecosystem condition via multiple pathways, many of which are poorly understood and indirect. Long-term changes in rainfall directly influence aquatic ecosystems through variation in surface run-off, sedimentation and erosion, but also indirectly impact aquatic ecosystems through, for example, changes in land and water management, tree growth and/or groundwater recharge.

1.1 The MCAS-S Tool

The Multi-Criteria Analysis Shell for Spatial Decision Support (MCAS-S), developed by the Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES) is a decision support tool designed specifically for non-GIS users to integrate spatial data.

The tool is free and users require little training to combine spatial data and assess results. It therefore has the potential to be a very useful decision support tool for freshwater ecosystem management because a range of spatial data can be easily integrated to explore potential futures or the effects of management decisions, even in workshop situations when data may be incomplete and decision making is by consensus. Here we show how we used the tool to explore spatial variability in threats, including climate change, in commonwealth listed alpine bogs and fens communities in the Australian Alps.

1.2 The Alpine Bogs MCAS-S Datapack

This users' guide and data package includes a MCAS-S Datapack containing spatial data relevant for identifying aquatic ecosystems at risk in the Australian Alps. The datapack consists of spatial data in a form that can be readily opened, displayed and interpreted using MCAS-S software and a worked example of an MCAS-S query (known as an MCAS-S 'project'). The aim of this users' guide is to describe the spatial data in the datapack and provide detailed instructions on how these data can be integrated and analysed within MCAS-S for decision support. The instructions take the form of a worked example. You will need to download and install MCAS-S software to your desktop. The worked examples then step you through using MCAS-S and how to open an MCAS-S package to combine layers.

However, this guide is not intended to be a comprehensive guide to using MCAS-S, nor to replace the program-specific user-guide. For more detailed information on how to use MCAS-S, including how to prepare spatial data for MCAS-S, please see the ABARES website - http://daff.gov.au/ABARES/Pages/data/mcass.aspx and User Guide (ABARES, 2011).

Installing MCAS-S Software

To use the datapack, you need to download and install the free MCAS-S software onto your computer.

1. Go to MCAS-S home page: www.abares.gov.au/mcass
2. Go to the right-hand side menu and click on **MCAS-S Tool**.
3. A new page opens with two download options –
    a. MCAS-S Version 3.1 installer (150MB)
    b. MCAS-S Version 3.1 user guide (10MB)
4. Download the installer (arrives zipped) then unzip. If you are new to MCAS-S, also download the MCAS-S user guide.
5. Once downloaded, follow prompts to install (requires 'Quicktime' to also be installed)
6. Register as a user

Unzip the MCAS-S Datapack

Before you start playing with our worked example, the next step is to extract the datapack from its zipped folder (right-click and unzip). If the datapack isn't unzipped correctly, MCAS-S will not be able to upload the spatial data and a red cross will appear in each map box instead of a map.

Now you are right to go!

Worked example: Mapping threats to alpine bogs in the Australian Alps Bioregion

2.0 About the worked example

This worked example steps you through how you might use MCAS-S to consider a query for mapping potential threats to Alpine Bogs in the Australian Alps Bioregion. We provide background information about the issue, sketch out the essential ‘means-to-end’ diagram, and then take you through a data combining exercise.

3.0 The Australian Alps Bioregion and the Alpine Sphagnum Bogs and Associated Fens community

The Australian Alps bioregion is a region of low mountains stretching some 375 km from Mount Baw Baw in Victoria to southern New South Wales (NSW) and the western margins of the Australian Capital Territory (ACT). The bioregion covers approximately 12,000 km^2 and more than 60% of this area is protected as statutory reserves under the relevant state legislation. The boundaries of the bioregion are roughly based on altitude and most of the bioregion is more than 1000 m above sea level (Figure 1).

The Alpine Sphagnum Bogs and Associated Fens community occurs throughout the Australian Alps bioregion and Tasmania, and is listed under the *Environmental Protection and Biodiversity Conservation Act 1999* (Threatened Species Scientific Committee, 2008). Alpine bogs are found in areas that generally have a positive water balance resulting from impeded drainage and/or good supply of groundwater. Example locations include along streams, valley floors and waterlogged slopes. Fens are semi-permanent to permanent pools of water often associated with bogs communities. Wetness, the source of water and the degree of pooling influences the types of vegetation that grow in an alpine bog. Bogs can often be identified by the presence of *Sphagnum* moss and shrub species such as *Richea continentis* and *Baeckea gunniana* or sometimes the rush *Empodisma minus* or *Carex* sedges; fens are more likely to be dominated by sedges and *Sphagnum* moss may be entirely absent (Threatened Species Scientific Committee, 2008).

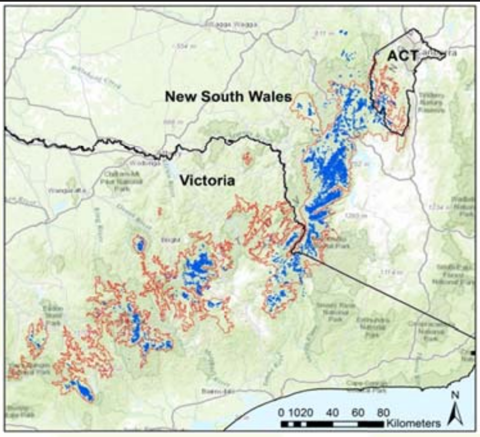

Figure 1 Map of the Australian Alps bioregion (v.7; red) and alpine bogs (blue). Map includes state borders (black) and topographic base data from ESRI (© OpenStreetMap contributors, and the GIS User Community). Bioregion data from the Australian Government Department of Environment, 2012.

Another key feature of the community is the presence of peat, partially decomposed plant material that has accumulated because of waterlogged conditions over thousands of years (Charman, 2002). The presence of peat, its depth and state of decomposition are all key features of the ecological community because these features have a large influence on water holding capacity and fluctuations within the wetlands and therefore have a large influence on plant community composition (Charman, 2002). Thus, while the presence and amount of peat is the direct result of supply of plant material from above, the listed community would not exist if not for the peat below. This is important because any processes or factors that influence the peat layer will have significant implications for the listed community.

While the community is abundant; more than 11,000 individual bogs of varying size are mapped in the Australian Alps bioregion. Most examples of the community are situated on reserved land (Threatened Species Scientific Committee, 2008), the community is under threat because of its restricted geographical extent, small size of individual patches (often more than 1 ha) and its vulnerability to impact because of the necessity for sources of water and peat which lead to distinct hydrological function. The existing bogs are at their climatic limit of distribution which is defined by levels of evapotranspiration in the hottest month (Whinam *et al.*, 2003) Given the periods and climatic conditions required to support peat accumulation, once peat is lost it cannot be restored. Restoring the water holding capacity and internal hydrology of disturbed peats may take up to 30 years (Whinam *et al.*, 2010). The negative prognosis is very alarming because the number of threats to peat and the listed community are multiple and include:

1. Past and future fire regimes. Fire is not a key recruitment process for ecosystem function in alpine bogs (Department of the Environment, 2014). Much of the bioregion has been burnt in mega-fires occurring over the last 10-15 years. Mega-fires are expected to be more frequent under climate change.
2. Climate change: Climate projections from the Landscapes and Policy Hub Climate Futures team suggest that parts of the alps will be significantly less favourable for alpine bog flora and peat accumulation. However, the implications and specific details are unclear (*see* Department of the Environment, 2014).
3. Domestic livestock can disturb peat and impact on water drainage.
4. Range expansion and population increase of pest species that have the ability to disturb peat and impact on water drainage for example horses, deer and pigs.
5. Range expansion of invasive flora that have the potential to displace alpine bog species and influence water drainage, for example willows.

A challenge for managers working in the Australian Alps is to determine where these threats are likely to occur and coincide within the landscape. Threat coincidence is particularly important not just because of the cumulative effects of multiple impacts but because of the high potential for these threats to interact and result in far greater impacts than when occurring in isolation. Examples of potential interactive effects include:

1. Mega-fires may favour the range expansion of pest species through increased bare ground and altered bog chemistry.
2. Feral animals disturb peat creating drainage incisions that dry peat and make it vulnerable to rapid decomposition particularly under changing climate.

Further complications exist for alps managers attempting to make bioregion-wide management decisions. Given the small size and number of alpine bogs located across the alps it is impractical to physically assess them all and impossible (and potentially damaging) to assess the status of the peat layer beneath the surface. Vulnerability of bogs is generally determined by a visual assessment of the extant vegetation community and the lack of consistency among the vegetation classification systems for alpine bogs across the different state/territory jurisdictions overlapping the bioregion in the past, has made this a challenge. Whilst much work further defining these communities has been undertaken for the vegetation community Recovery Plan (Department of the Environment, 2014), there is no spatial layer to help define the 'state' of bogs across these areas.

This MCAS-S Datapack attempts to make a first pass at mapping the coincidence of current and future threats to the listed alpine bogs community by providing spatial data on threats and by providing a worked example of how this data can be combined with in the MCAS-S platform. Alps-wide datasets are uncommon because of differences in data collections across the alps jurisdictions, and for this project, we have identified existing and relevant datasets and included these. When not possible we have combined datasets collected across jurisdictions. Much of this work collating and preparing spatial data was conducted by the Landscapes and Policy Hub Freshwater Ecosystems and Bioregional Futures teams and Anita Wild (Wild Ecology) with funding assistance from the Department of the Environment and Australian Alps Liaison Committee. Many of the base data sets have been provided by relevant state agencies including the Office of Environment and Heritage, Parks Victoria and Environment and Planning ACT. The contribution of individual researchers is also acknowledged. We imagine that the tool will become more useful as new alps-wide datasets are created and made available. Given this we have also provided instructions on how new layers can be prepared and added to the datapack (Appendix 10.1).

4.0 Aim

To identify examples of the EPBC Act listed Alpine Sphagnum Bogs and Associated Fens community within the Australian Alps bioregion that are currently, or in the future, likely to be exposed or vulnerable to multiple threats under climate change and range expansion of pest species.

5.0 Data layers

A complete list of input data layers available for analysis to date is shown in Table 1. The input layers are grouped into two types:

- Threat – Variables that have the potential to directly impact the ecological condition of alpine bogs.
- Vulnerability – Variables that have the potential to increase the vulnerability of alpine bogs to impacts from threats.

Table 1 Base data layers available for the Alpine bogs threats analysis. For more information, see metadata records for each layer.

Data layer	Layer type	File name	Data source	Description	States/Categories	Justification for inclusion in the Alpine Bogs Datapack
Gridded groundwater inflows (remote sensing layer)	Vulnerability	groundwater\groundwater	Atlas of Groundwater Dependent Ecosystems: gridded remote sensing layer produced by SKM & CSIRO and distributed by the Australian Bureau of Meteorology. Protected by a Creative Commons Attribution Licence (http://creativecommons.org/licenses/by/3.0/au/).	Layer indicating likelihood (rating 1-10) that landscape is accessing a source of water in addition to rainfall based on rainfall data, dry-season water-use, surface water, vegetation and spectral response	10 states (1-10): 1= landscape is least likely to be accessing an additional water source and is are more likely to rely solely on rainfall. 10= landscape is most likely to be using an additional source of water, such as groundwater.	Alpine bogs with a greater diversity of water inflows (i.e. including ground and surface water inflows) will be less susceptible to dry spells and other impacts e.g. fire.
Fire history (since 2000)	Vulnerability	Fire history\firehistory	Grant Williamson- Vegetation & Fire - Landscapes and Policy Hub. Based on a fire history layer obtained from the Victorian Department of Sustainability and Environment	This layer shows the number of times various areas of the Australian Alps have been burnt by fire since the year 2000.	3 states: 1= burnt once 2= burnt twice 3=burnt three times	Alpine areas that have been previously burnt or are in burnt country are more vulnerable to impacts from climate change and invasive species. Contraction of *Sphagnum* cover from past fire impacts and change in state to *Empodisma* fen or sod tussock grassland (Whinam, 1995) results in more-flammable areas.

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Data layer	Layer type	File name	Data source	Description	States/Categories	Justification for inclusion in the Alpine Bogs Datapack
Projected change in solar radiation (2100) This climate data has not yet been validated & adjusted against past (observed) data.	Threat	Climate\diff_sgnave19	Climate Futures - Landscapes and Policy Hub	Change in solar net radiation at ground (W/m^2). Calculated by subtracting the average value for 1960-1989 from the average value from 2070-2099.	Continuous variable binned to 5 states: 1= Decreasing (-4.5-0 W/m^2) 2= Increasing (0-5 W/m^2) 3= Increasing (5-10 W/m^2) 4= Increasing (10-15 W/m^2) 5= Increasing (15-20 W/m^2)	Solar radiation can inhibit moss growth and cause increased water evaporation in bogs (Good *et al.*, 2010). Evidence of summer bleaching of *Sphagnum* hummocks has been noted with reduced cover (Whinam & *Chilcott*, 2002)
Mean Summer net solar radiation (1980 to 2006)	Vulnerability	radiation\Net_radiation	Mean monthly radiation surfaces for Australia at 1 arc-second resolution by Jenet Austin, John Gallant, Tom Van Niel, CSIRO Land and Water Date: 19.03.2014	Predicted mean Summer (Dec-Mar) net radiation from 1980 to 2006. Predictions based on solar geometry, elevation, slope, aspect, albedo, cloud cover, air temperature, vapour pressure and vegetation cover.	Continuous variable binned to 3 states: 1= 0-10 MJ.m^{-2}.d^{-1} 2= 10-15 MJ.m^{-2}.d^{-1} 3= 15-20 MJ.m^{-2}.d^{-1}	Fine scale data (1 degree) on topography and past solar exposure can be used to identify which alpine bogs may be most susceptible to increased solar radiation in the future.
Projected change in daily rainfall (2100)	Threat	climate\diff_rnd24	Climate Futures - Landscapes and Policy Hub	Change in maximum precipitation rate in a time-step (mm/day). Calculated by subtracting the average value for 1960-1989 from the average value from 2070-2099.	Continuous variable binned to 5 states: 1= -22 to -20 mm 2= -20 to -19 mm 3= -19 to -18.5 mm 4= -18.5 to -17 mm 5= -17 to -15.5 mm	Declines in rainfall may impact bog vegetation and hydrology.

Table 1 Base data layers available for the Alpine bogs threats analysis. For more information, see metadata records for each layer.

Data layer	Layer type	File name	Data source	Description	States/Categories	Justification for inclusion in the Alpine Bogs Datapack
Projected change in max Temp (2100)	Threat	climate\diff_tmax	Climate Futures - Landscapes and Policy Hub	Change in maximum temperature (K). Calculated by subtracting the average value for 1961-1990 from the average value from 2070-2099.	Continuous variable binned to 5 states (positive values – increasing temperature): 1= 3-3.5 Kelvin/ °C 2= 3.5-3.8 Kelvin/ °C 3= 3.9-4.3 Kelvin/ °C 4= 4.3-4.7 Kelvin/ °C 5= 4.7-5.1 Kelvin/ °C	Higher temperatures will influence plant growth and may be too high for some bog taxa. Higher temperatures (in association with winds) also result in higher rates of evaporation and evapotranspiration of water from alpine bogs. Evapotranspiration in the hottest month is the current limiting factor for *Sphagnum* peatlands (Whinam *et al.*, 2003).
Land-use	Threat	landuse\landuse	Derived from the National scale land use version 4 (2005-06) produced by ABARES - http://data.daff.gov.au/anrdl/metadata_files/pa_luav4g9abl07811a00.xml . Date of access 22/09/2014	Land-use data produced for the year 2005-2006. The land-use categories in the original data were grouped into 6 broad land-use states. Categories 1 & 2 were land-use types thought to have no environmental impact on alpine bogs, Category 3, minimal impact on alpine bogs and Categories 4-6 included land-use types most likely to be associated with impacts to alpine bogs e.g. forestry or grazing by domestic livestock.	6 states 1= Conservation and natural environments 2= Water 3= Production from relatively natural environments 4= Intensive uses 5= Dryland agriculture and plantations 6= Irrigated agriculture and plantations	Alpine bogs in areas reserved for food or wood production may be impacted by domestic livestock and/or modifications to hydrology. There are few alpine bogs in classes 4, 5 and 6.

Table 1 Base data layers available for the Alpine bogs threats analysis. For more information, see metadata records for each layer.

Data layer	Layer type	File name	Data source	Description	States/Categories	Justification for inclusion in the Alpine Bogs Datapack
Flammability	Vulnerability	vegetation\Flammability	Freshwater Ecosystems - Landscapes and Policy Hub. Layer derived from bog vegetation mapping from data of NSW OEH, Parks Victoria See also Shannon, 2011.	Degree of flammability depending on the vegetation community ('shrubbiness') within the bog. Bog mapping is a composite of many sources from across the Australian Alps bioregion. *Sphagnum* bogs occur in multiple categories depending on altitude (montane, alpine or sub-alpine). Numerous shrub species within bogs contain volatile oils or retain much dry material, increasing their flammability (e.g. many myrtaceous species. are known to be highly flammable due to a high content of oils).	5 states (lowest to highest): 1= Carex fen (NSW/ACT); Alpine fen (Vic); Sedgeland (Vic); *Poa hiemata* tussock grassland (Vic). 2= *Empodisma moor* (NSW/ACT); Alpine bogs (Vic); Relic bogs (Vic); Alpine peatland (Vic); Null (no data) values. 3= Alpine *Sphagnum* shrub bog (NSW/ACT); Wet alpine heathland (Vic); Wet alpine heath (Vic). 4= Sub-alpine *Sphagnum* shrub bog (NSW/ACT); Kunzea heathland (Vic). 5= Montane *Sphagnum* shrub bog (NSW/ACT).	Alpine bogs containing larger proportions flammable plants are more likely to be impacted by fire and carry fire within the bogs even if peat layers are moist (P. Zylstra pers comm.). Fire impacts on both plants and peat substrates have been found to be more severe in bogs that have a high density of shrubs (Shannon, 2011).
Habitat suitability for horses	Threat	Horses\habitat_suit	Dan Brown – Parks Victoria	Predicted suitability of habitat for horses (expressed as density of horses or carrying capacity (K)) based on ecological vegetation classes.	3 states: Poor = estimated K is 1 horse/km^2 Moderate=estimated K is 4 horses/km^2 Good= estimated K is 6 horses/km^2	Alpine bogs located within vegetation classes that attract horses or that are likely to have a high abundance of horses are more likely to be used by horses and impacted.

Table 1 Base data layers available for the Alpine bogs threats analysis. For more information, see metadata records for each layer.

Data layer	Layer type	File name	Data source	Description	States/Categories	Justification for inclusion in the Alpine Bogs Datapack
Palatability to horses	Vulnerability	vegetation\Palatability	Freshwater Ecosystems - Landscapes and Policy Hub	Degree of palatability depending on the vegetation community within the bog. Bog mapping is a composite of many sources from across the Australian Alps bioregion (Vic, NSW & ACT), some data are up to 20-30 years old (e.g Victorian data collated by Arn Tolsma from numerous studies). Vegetation mapping in NSW/ACT was mire-specific and recent (2012).	3 states (highest to lowest): 1= Alpine fen (Vic); Sedgeland (Vic); *Poa hiemata* tussock grassland (Vic), Carex fen (NSW/ACT). 2=Alpine bogs (Vic), Relic bogs (Vic); Alpine peatland (Vic); *Empodisma moor* (NSW/ACT) ; Null (not data) values. 3=Wet alpine heathland (Vic); Wet alpine heath (Vic); Kunzea heathland (Vic); alpine and sub-alpine; montane *Sphagnum* bogs (NSW/ACT).	Alpine bogs containing greater proportions of vegetation that is palatable to horses are more likely to be impacted by horses. Horse exclusion plot studies have shown that horses have a high preference for some sedge (*Carex*) species (Wild and Poll 2012) such as those in fen communities Horses will still use and seek bogs with lower proportions of palatable species in search of water (J. Whinam and J. Shannon pers. comm.)
Threats animals	Threat (composite)	CurrentDistrib_threats\Threats_ani	Bioregional Futures & Freshwater Ecosystems - Landscapes and Policy Hub. Composite layer from data of NSW OEH, Parks Victoria, Atlas of Living Australia	Combined map of all feral animals (except foxes) likely to impact alpine bogs (pigs, deer & horses).	5 states: 0= No threats 1= Pigs or deer 2= Horses or pigs & deer 3= Horses & pigs or deer 4= Horses, pigs & deer	Layer includes current distribution on all exotic animals known to impact alpine bogs. See description of layers for individual species for more detail.

Table 1 Base data layers available for the Alpine bogs threats analysis. For more information, see metadata records for each layer.

Data layer	Layer type	File name	Data source	Description	States/Categories	Justification for inclusion in the Alpine Bogs Datapack
Threats plants	Threat (composite)	CurrentDistrib_threats\Threats_weeds	Bioregional Futures & Freshwater Ecosystems - Landscapes and Policy Hub. Composite layer from data of NSW OEH, Parks Victoria, Atlas of Living Australia	Combine map of all weeds likely to impact alpine bogs (hawkweed, broom, willows, blackberries & ox-eye daisy)	5 states: 0= No threats 1= Hawkweed, broom, blackberry OR ox-eye daisy 2= Willows OR any 2 other species 3= Willows & 1 other species OR 3 species (none willow) 4= Willows & 2 other species	Layer includes current distribution of all exotic plants understood to act as transforming weeds known to establish or impact alpine bogs. See description of layers for individual species for more detail.
Pigs (current distribution)	Threat	CurrentDistrib_threats\pigs	Bioregional Futures & Freshwater Ecosystems - Landscapes and Policy Hub. Composite layer from data of NSW OEH, Parks Victoria, Atlas of Living Australia	Locations where feral pigs have been observed.	3 states -9999 = No data -888 = Area searched and no pigs observed 0 = Area searched and pigs observed	Pigs are a significant problem in ACT & NSW, they damage alpine bog soils and vegetation by wallowing and digging which can lower water tables and exacerbate drying of peat layers (Department of the Environment, 2014).
Deer (current distribution)	Threat	CurrentDistrib_threats\deer	Bioregional Futures & Freshwater Ecosystems - Landscapes and Policy Hub. Composite layer from data of NSW OEH, Parks Victoria, Atlas of Living Australia	Locations where feral deer have been observed.	3 states -9999 = No data -888 = Area searched and no deer observed 0 = Area searched and deer observed	Increasing threat with increased range noted recently. Impact alpine bog soils and vegetation through trampling, wallowing and browsing (Department of the Environment, 2014).

Table 1 Base data layers available for the Alpine bogs threats analysis. For more information, see metadata records for each layer.

Data layer	Layer type	File name	Data source	Description	States/Categories	Justification for inclusion in the Alpine Bogs Datapack
Foxes (current distribution)		CurrentDistrib_threats\foxes	Bioregional Futures & Freshwater Ecosystems - Landscapes and Policy Hub. Composite layer from data of NSW OEH, Parks Victoria, Atlas of Living Australia	Locations where foxes have been observed.	3 states -9999 = No data -888 = Area searched and no foxes observed 0 = Area searched and foxes observed	Impacts other natural values of bogs including native frogs, fish and crayfish in some areas (Department of the Environment, 2014).
Horses (current distribution)	Threat	CurrentDistrib_threats\horses	Bioregional Futures & Freshwater Ecosystems - Landscapes and Policy Hub. Composite layer from data of NSW OEH, Parks Victoria, Atlas of Living Australia	Locations where feral horses have been observed.	3 states -9999 = No data -888 = Area searched and no horses observed 0 = Area searched and horses observed	Alpine bog soils and *Sphagnum* are susceptible to hoof damage which can lead to desiccation, soil erosion (Good, 1992) altered vegetation composition and hydrological processes (Wild *et al.*, 2012) and can impact on water retention (Department of the Environment, 2014).
Hawkweed (current distribution)	Threat	CurrentDistrib_threats\hawkweed	Bioregional Futures & Freshwater Ecosystems - Landscapes and Policy Hub. Composite layer from data of NSW OEH, Parks Victoria, Atlas of Living Australia	Locations where orange hawkweed (*Heiracium aurantiacum*) has been identified and usually controlled.	3 states -9999 = No data -888 = Area searched and no hawkweed observed 0 = Area searched and hawkweed observed	Can form dense populations over large areas (Morgan, 2000).
Broom (current distribution)	Threat	CurrentDistrib_threats\broom	Bioregional Futures & Freshwater Ecosystems - Landscapes and Policy Hub. Composite layer from data of NSW OEH, Parks Victoria, Atlas of Living Australia	Locations where English/Scotch broom (*Cytisus scoparius*) has been identified and usually controlled.	3 states -9999 = No data -888 = Area searched and no broom observed 0 = Area searched and broom observed	Although not commonly a weed of bogs, English broom is highly invasive and can outcompete native species (Odom *et al.*, 2005) and can result in increased fuel loads in adjacent areas.

Table 1 Base data layers available for the Alpine bogs threats analysis. For more information, see metadata records for each layer.

Data layer	Layer type	File name	Data source	Description	States/Categories	Justification for inclusion in the Alpine Bogs Datapack
Willow (current distribution)	Threat	CurrentDistrib_threats\willows	Bioregional Futures & Freshwater Ecosystems - Landscapes and Policy Hub. Composite layer from data of NSW OEH, Parks Victoria, Atlas of Living Australia	Locations where willows has been identified and usually controlled.	3 states -9999 = No data -888 = Area searched and no willows observed 0 = Area searched and willows observed	Willows are ecosystem 'engineers' and can alter hydrology of bogs and dry them out from increased evapo-transpiration.
Blackberries (current distribution)	Threat	CurrentDistrib_threats\blackberries	Bioregional Futures & Freshwater Ecosystems - Landscapes and Policy Hub. Composite layer from data of NSW OEH, Parks Victoria, Atlas of Living Australia	Locations where blackberries have been identified and usually controlled.	3 states -9999 = No data -888 = Area searched and no blackberries observed 0 = Area searched and blackberries observed	Potential emerging threat as climate warms and the potential range expands and blackberries persist in higher-altitude and exposed areas.
Ox-eye daisy (current distribution)	Threat	CurrentDistrib_threats\oxdaisy	Bioregional Futures & Freshwater Ecosystems - Landscapes and Policy Hub. Composite layer from data of NSW OEH, Parks Victoria, Atlas of Living Australia	Locations where ox-eye daisy has been identified and usually controlled.	3 states -9999 = No data -888 = Area searched and no ox-eye daisy observed 0 = Area searched and ox-eye daisy observed	Potential emerging threat. Capable of spread into burnt native vegetation (Department of the Environment, 2014, McDougall *et al.*, 2013)

6.0 Means–to–end diagram

A means-to-end diagram is the important first step in scoping out the problem you are trying to consider. The means-to-end diagram shows how the input layers relate to one another and how they will be combined.

Our means-to-end diagram in Figure 2 shows how the different input layers can be combined in an MCAS-S analysis to assess threats to alpine bogs. This is the design described in this worked example described below and is available for download (see Sections 7.0 - 9.0).

We recommend that a means-to-end diagram be completed for any MCAS-S analysis to ensure model structure is appropriate to the project aims. Within MCAS-S, each of the boxes in Figure 2 is a stand-alone map that can be exported to GIS or Google Earth™ or saved as an image.

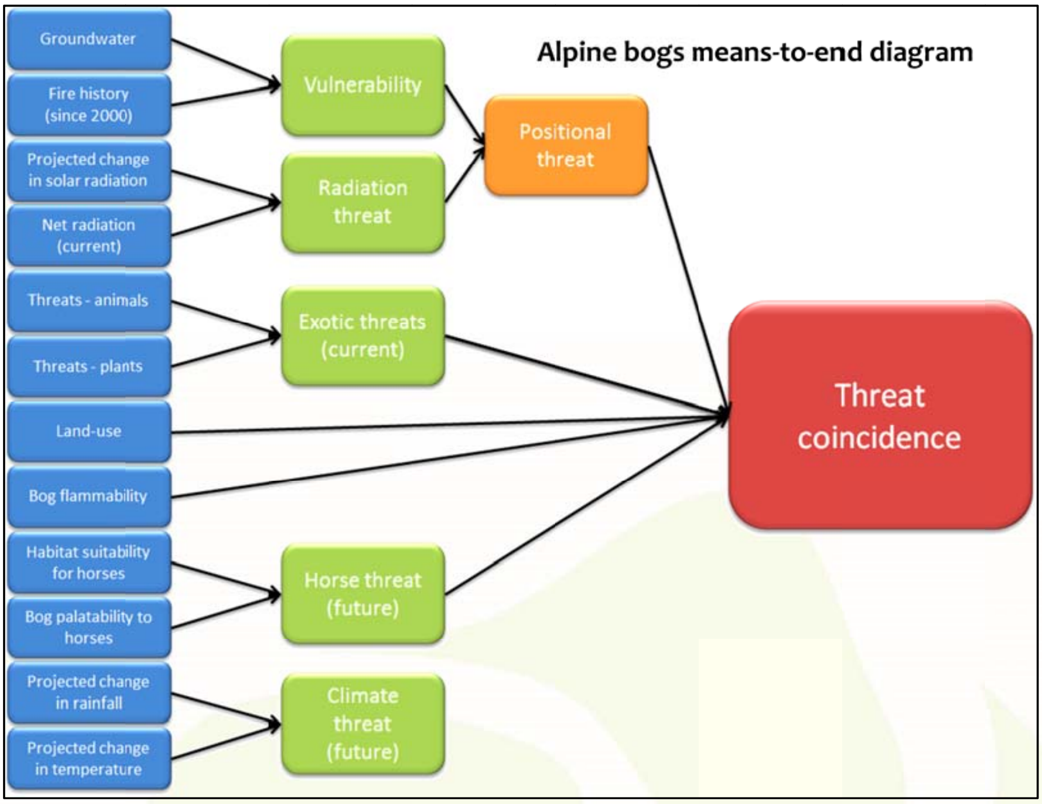


Figure 2 Means-to-end diagram for the Alpine Bogs Threats model, analysis and datapack. Dark blue boxes represent the input nodes and all other boxes represent different levels of spatial data integration. The red box represents the final integrated product, a map illustrating the location of alpine bogs predicted to be most at threat.

7.0 MCAS-S package structure

The Alpine Bogs MCAS-S Datapack consists of two MCAS-S project files and a set of three MCAS-S data folders. The project files are AlpineBogs.mcas and AlpineBogs_blank.mcas. AlpineBogs.mcas contains the completed worked example described in this document. AlpineBogs_blank.mcas contains links to the data used in the worked example but the workspace is blank so that users can select and combine the layers from scratch.

The three data folders are Data, History and KML (see Table 2). The 'Data' folder contains all of the input data layers necessary for the alpine bogs threats analysis. The 'Data' folder includes four sub-folders: Primary, Classified, Overlay and Mask. Most of the input data layers for this analysis are located in the 'Primary' sub-folder. We have also added some useful overlays and masks to their respective sub-folders. Some folders are initially empty but these should not be deleted, as MCAS-S will write to these folders for various operations

Table 2 MCAS-S folder structure and descriptions (adapted from MCAS-S User-Guide; ABARES, 2011)

Level 1	Level 2	Description
Data	Primary	Gridded input layers: e.g climate data, distribution of threats, groundwater (see Table 1).
	Classified	Gridded data exported from MCAS-S by user (initially empty).
	Overlay	Line or point data used for visual reference only: Alpine bogs, The Australian Alps bioregion (IBRA) and National Park and state/territory borders.
	Mask	Gridded data used to restrict the area of analysis: Alpine bogs, The Australian Alps bioregion (IBRA), National Parks, and alps_mask-9999.
History		Cached project files (initially empty).
KML		GoogleEarth™ (*.kml) files exported from MCAS-S[1] (initially empty).

[1] Note at time of publication there was a maximum resolution (1000*1000 cells) for viewing MCAS-S layers in Google Earth™. To view files at a finer resolution in Google Earth™ the user must export the layer from MCAS-S and convert to *.kml in an alternative application. Google Earth™ will render a lower resolution version but this does not adequately represent individual alpine bogs.

8.0 Worked example

To gain the most from the worked example, open the MCAS-S file in your unzipped folder, and follow what we do in the text by having a play on the MCAS-S screen.

Open the file: AlpineBogs.mcas

8.1 Input data layers

The file AlpineBogs.mcas contains a worked example using most of the input layers provided in the Alpine Bogs MCAS-S Datapack (Figure 3). This worked example is based on the model structure shown in the means-to-end diagram in Figure 2.

The input layers are arranged around the outer edges of the screen and are the smallest maps shown. In the default version of the analysis the maps are un-masked so that you can see the full extent of each and how the extents vary. We recommend that before you interpret the results of this or your own threat analysis that you mask the maps to individual alpine bogs (see Section 8.4). Map areas coloured by a grey and white checkerboard pattern are areas of no data. In the original input data files these layers are identified by the value '-9999' (default no data value for MCAS-S). Some of the input layers contain only data for individual bogs, which are small and numerous (for example 'Bog flammability'), you will need to look closely to see the data in these layers. To zoom into a layer change the interface magnification (first option on map menu bar above the right-hand side workspace (Figure 4)), double click on a map (Esc to exit), or right click and then select 'Show in Google Earth'.

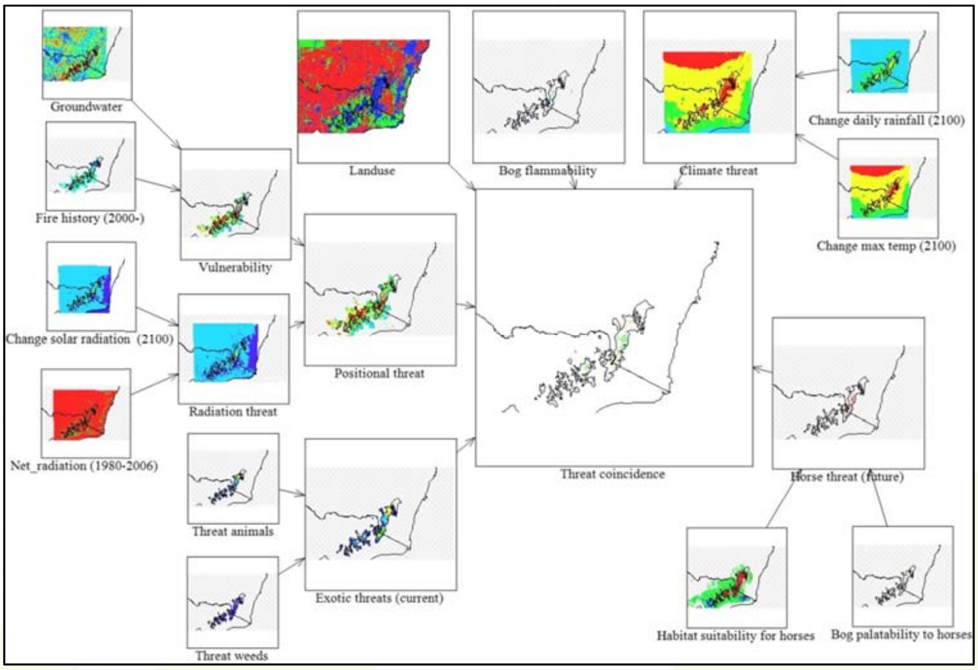


Figure 3 Image of the Alpine Bogs MCAS-S model. Input layers are the smallest maps and the largest map is the most integrated map illustrating the coincidence of threats to alpine bog communities (low to high threat level in all maps: blue-green-yellow-orange-red).

Familiarise yourself with the different input layers by clicking on each individually and then viewing information about the number, colours and titles of different states within the map layer in the left-hand Information Panel. At this point it will also be useful to review the information about the different input layers in Table 1.

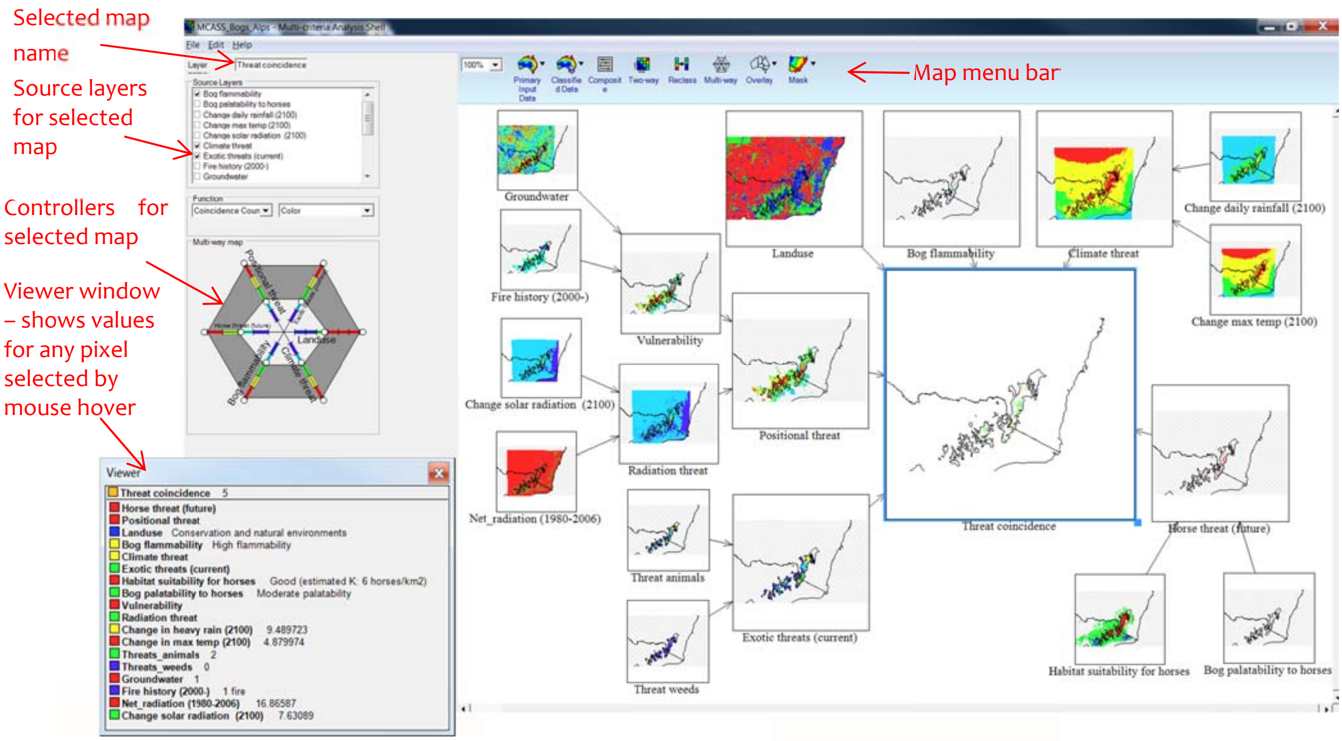


Figure 4 Layout of the graphical user interface of MCAS-S. Layers are shown in the right-hand side workspace and can be modified using options available in the left-hand side interface panel. Select the layer of interest (here 'Threat coincidence') and available options will appear in the Interface Panel. A mouse hover over a pixel of interest will result in the Viewer Window displaying the names and values of the pixel in the selected layer and in any layer used in the calculation of the selected layer.

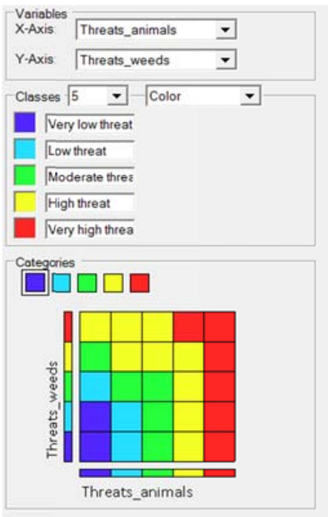
Struggling with MCAS-S?

The Landscapes and Policy Hub have produced several datapacks for MCAS-S some of these work through much simpler worked examples than the Alpine Bogs worked example. If you are new to MCAS-S you may find it easier to work with one of these before attempting this worked example. The Tasmanian Midlands Refuges worked example would be a good start. The MCAS-S user-guide also contains a sample project and ABARES also offer training sessions for small groups, see - http://daff.gov.au/ABARES/Pages/data/mcass.aspx

8.2 Integrated data layers

Any layer that combines data from more than one layer is considered an integrated data layer. In this MCAS-S Datapack all but the final integrated data layer ('Threat coincidence' - see Section 8.3) were produced by the 'Two-Way' tool on the map menu bar. The Two-Way tool combines two input layers into a single composite, the user can then define how the layers are combined simply by changing colours on a grid displayed in the Interface panel (Figure 5).

Figure 5 Appearance of the Interface Panel for a Two-Way integrated layer. In this example data layers for exotic animals and weeds are combined to create a map of exotic threats. States within the composite map are defined by the number of classes using a drop-down menu and coloured using the below class descriptions. To modify how the layers are combined change the colour of cells in the lower grid by selecting a colour under 'Categories' and then clicking on the grid cells that need to change to that colour.



To view or modify how layers have been combined click on the integrated layer and view/change information in the Interface panel. Within MCAS-S, a mouse hover over a pixel of interest on an integrated layer will result in the Viewer Window displaying the names and pixel-values for all of the layers that influence the selected integrated map.

8.3 Threat coincidence

The largest integrated data layer labelled 'Threat Coincidence' is the main output from this datapack and has been created using the 'Multi-Way' tool on the map menu bar. With this tool more than 2 layers can be combined to produce an integrated map. The Threat Coincidence layer combines three Two-Way integrated layers and three input data layers. The layers can be combined in several ways: mask, coincidence count or composite. The Threat coincidence map uses the coincidence count function which counts the number of layers that satisfy the criteria set in the below Multi-Way map controllers or 'radar-plot' (Figure 6). The mask function highlights all areas that satisfy all of the criteria set in the radar-plot and the composite function scales and combines data layers into a single map. Note, it is better to use the actual Composite tool on the map menu bar if you are interested in this function as there are more options for how to scale and combine the layers – see the MCAS-S manual.

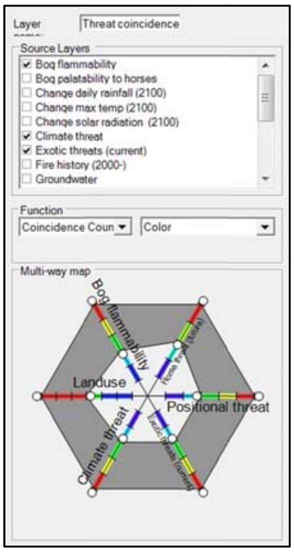


Figure 6 Appearance of the Interface Panel for a Multi-Way integrated layer. In this example, six data layers mapping threats are combined into a single data layer that maps the coincidence of these layers (using a count). A pixel is included in the coincidence count if its state (defined by colour) is selected for inclusion. Each arm of the radar-plot represents the states of a single layer and the white circles are sliders used to select/deselect states (grey areas are selected and included in the count). Users can add/remove layers by checking boxes on the Source Layer section and select/deselect states by shifting the radar-plot sliders using a left-mouse click. For all the layers used in this datapack the colour scheme from dark blue, light blue, green, yellow to red represents an increase in threat level or vulnerability. In the default version of the datapack and as shown here the coincidence count, includes the higher levels of threat and vulnerability for each source layer. The Viewer window can be used to understand the colour scheme in the radar-plot as well as the levels of threat coincidence as a mouse hover over a pixel of interest in the Threat Coincidence layer will reveal the descriptions, colours and values for all source layers.

8.4 Overlays and masks

The Alpine Bogs MCAS-S Datapack contains a number of overlay and mask files.

The overlay layers included are alpine bogs, The Australian Alps bioregion (IBRA; Department of Environment, 2012), national parks and states, these can be added to the maps displayed on screen and are a useful visual reference. Overlays do not influence any of the calculations occurring in the model. Any line or point data can be added to the overlay folder and viewed in MCAS-S, however it is important that the projection of this data matches the projection of the raster layers in our datapack (GDA1994; see also Appendix 10.1).

Several mask layers have been included in the datapack; Alpine bogs, The Australian Alps bioregion (IBRA), national parks and 'alps_mask-9999'. All but the 'alps_mask-9999' mask will restrict any analyses to a defined area. This can be useful because it will also increase the zoom level of the maps shown in the map workspace. The 'alps_mask-9999' mask actually extends to the full extent of the workspace. Its purpose is not to restrict the analysis but to act as a template for any new layers created in MCAS-S (See Section8.8).

To add/remove a mask– select the 'Mask' tab on the Map menu bar and then check/uncheck the relevant box. It is a good idea to mask (restrict) any analyses to the input layer that has the smallest extent so that you know that all of the output/integrated layers that you observe include data from all input layers (important for Two-Way and Multi-Way analyses which will only show the area where all layers intersect). In this worked example we recommend you turn on the alpine bogs mask to interpret threat coincidence because this mask matches the extent of the flammability and palatability input layers and limits the analysis to the actual areas of interest (individual bogs).

8.5 Modifying state thresholds, number of states, or layer colour schemes

Clicking on any layer within the worked example will allow you to view details and modify the layer using the left-hand Information Panel (Figure 4). Many of the options within the Information Panel can be altered including the layer name, colour scheme, the number, limits and colour of classes and the names of the categories or classes within each layer.

8.6 Modifying integrated layers

There are several options within MCAS-S for integrating layers. Details for how to alter these options can be found in the MCAS-S User Guide (ABARES, 2011 -Section 6: Explore and Combine data).

You can change the number of states and their colours for a selected map by making alterations at the Interface Panel (see Figures 6 and 7 for examples). Other ways of modifying the final result are to:

- Delete layers - right click, then delete. Note you cannot undo a delete! You'll need to drag the map back in from the Primary Input Data tab if you make an error.
- Change the input layers for and existing integrated data layer – Modify connections by changing the input layers on the Information Panel or by modifying how the layers are integrated (e.g. by creating a 'Composite' map using this option on the Map menu bar (instead of a Two-Way or 'Multi-Way) and selecting and completing either 'Manual', 'Function' or 'AHP weighting' options to combine layers.
- Add layers from the primary folder – Click and drag layers from the 'Primary Input Data' tab.
- Create new integrated layers- Click and drag from either the 'Composite', 'Two-Way', 'Reclass' or 'Multi-Way' tabs to create a new blank map. Create connections by selecting input layers on the Information Panel.

8.7 Viewing results

Larger versions of your input and integrated data layers can be viewed simply by double-clicking (Esc to exit) on the layer of interest or by adjusting the zoom function in MCAS-S. You can also export layers for use in other applications. The available options for exporting are accessed via a right-click on the layer of interest and include:

1. Show in Google Earth: Note at time of publication there was a maximum resolution (1000*1000 cells) for viewing MCAS-S layers in Google Earth™. To view files at a finer resolution in Google Earth™ the user must export the layer from MCAS-S (see 3 below) and convert to *.kml in an alternative application. Google Earth™ will render a lower resolution version but this will not adequately represent some individual bogs.
2. Save image: Allows you to save the map, legend and/or histogram of the layer of interest.
3. Export: Creates a GEOTIFF or ASCII file of the layer and saves it to the Data\Classified. This procedure requires the creation of a small metadata file known in MCAS-S as a tip file. See Appendix 10.2 for details on completing a tip file metadata record.

8.8 Modifying or creating new input layers (in an alternative program eg ArcGIS)

We highly recommend that you attend an MCAS-S training workshop or consult with a GIS expert before attempting to modify or create new input layers.

All of the input layers have been created from existing resources, and categorised as outlined in Table 1. Modifying or creating new input layers will require some GIS expertise. The original layers must be obtained from the source outlined in Table 1, converted to raster format, and modified so that they have the same projection and extent as the data layers within this datapack. Similarly, for any new layer you choose to create. The easiest way to do this is to create the raster with the environment settings set to the 'alps_mask-9999' layer contained within the 'Mask' folder for this datapack. The settings for the layers in the datapack are also outlined in Appendix 10.1. Areas of no data must be set to a value of '-9999'.

9.0 Biological conclusions from the worked example

9.1 What we did

We used the MCAS-S Alpine Bogs Datapack to identify alpine bogs that are currently, or in the future, likely to be exposed or vulnerable to multiple threats under climate change and range expansion of pest species.

We included information on groundwater inflows, fire history, solar exposure, climate change, invasive species, land-use and vegetation characteristics (flammability and palatability).

We integrated the layers using very simple rules based on existing knowledge of threats and to ensure consistency with information provided in the Alpine Bogs Recovery Plan currently under review (Department of the Environment, 2014). The layers were integrated in MCAS-S using Two-Way and Multi-Way analyses.

9.2 What it told us

There was clear variation in threat levels across the bioregion. For example, alpine bogs near Cabramurra (NSW) had a low level of threat coincidence, and 25 km away a small number of bogs on the Snowy Plains (NSW) had a very high level of threat coincidence (Figure 7).

New South Wales had the greatest proportion of bogs with high or very high threat coincidence because:

- Climate change is projected to have the greatest impact on alpine bogs in the north-eastern parts of the alps (higher temperatures and solar radiation and less rainfall).
- Many bogs in this area were considered more vulnerable because of higher exposure to solar radiation, which may inhibit plant growth and increase evaporation.
- Horses, pigs and deer are all present through much of this area.
- Bogs in NSW tend to be more shrubby and were therefore thought to be more flammable.

In Victoria the Bogong High Plains region is noteworthy because of the extensive area of alpine bogs and the moderate to high level of threat. Threats identified here were climate change and horses.

A key feature that may decrease the impact of the above threats in this region is groundwater supply. The inferred groundwater inflows from the Atlas of Groundwater Dependent

Ecosystems were higher in the northern and eastern parts of the bioregion. However, groundwater inflows themselves are influenced by future rainfall, which is likely to decline under changing climate. We note also that the groundwater data used is inferred from remote sensing (satellite) data. Actual groundwater inflows have not been measured in sufficient detail across the region to be used in this analysis. Further research is required to validate whether these inferred flows reflect actual water available to alpine bog communities.

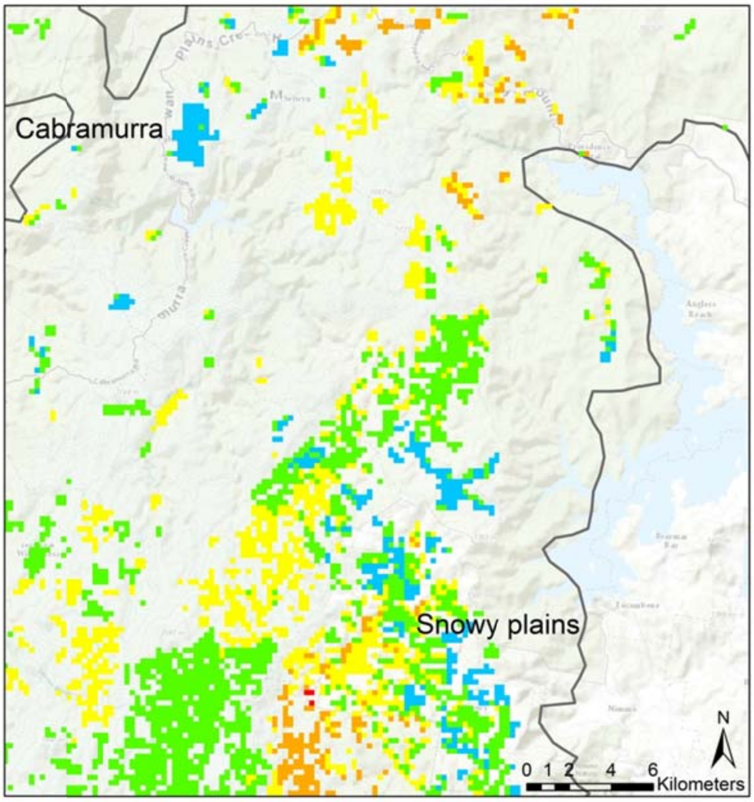


Figure 7 Map showing variability in inferred threat levels (threat coincidence) to bogs in parts of NSW. Threat level from low to very high: blue, green, yellow, orange and red. Map includes Australian Alps bioregion (v.7; black line) and topographic base data from ESRI (© OpenStreetMap contributors, and the GIS User Community). Bioregion data from the Department of the Environment.

10.0 Appendices

10.1 MCAS-S data layer specifications for the Australian Alps.

We recommend that you use the alps_mask-9999 layer (in the Mask folder) to set your GIS environment settings to ensure that layers match exactly.

Data layer/file specifications	*Australian Alps*
Coordinate reference system / projection	Map Grid of Australia Zone 55 (GDA 94) Projection: Transverse_Mercator
Northern extent	5459344.814849
Southern extent	5305344.814849
Eastern extent	604288.552916
Western extent	452788.552916
Recommended cell size	250-500
No data or null values	-9999

10.2 MCAS-S tip files (adapted from ABARES, 2011)

Field	Description	Example
Filename	Shortened version to display when mouse hovers over map	Bogs_threats
Description	More information on the data, including units if applicable	Threat coincidence for alpine bogs in the Australian Alps Bioregion
Custodian	Organisation that owns the data	University of Tasmania
Currency	Year	2014
Lineage	Processing completed on the data (for example, source, calculations, software/commands used)	Incorporates data on groundwater inflows, fire history, solar exposure, climate change, invasive species, land-use and vegetation characteristics (flammability and palatability)
Source	Source of the data	NERP- Landscapes and Policy Hub
Resolution (cell size)	Grid size of the raster data	500
Exclude masked regions?	Check box Yes/No	Yes
Mask value	Value for grid cells with no data	-9999

11.0 References

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