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Accounting for biodiversity in Life Cycle Impact Assessments of forestry and agricultural systems – the BioImpact metric

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Accounting for biodiversity in Life Cycle Impact Assessments of forestry and agricultural systems – the BioImpact metric

Prepared for

Forest & Wood Products Australia

by

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Executive Summary

Methods for incorporating biodiversity within a life cycle assessment (LCA) framework have to date been largely hindered by a lack of information on the relationships between land-use and biodiversity. In addition, no universal, appropriate metric for biodiversity at alternative scales is available. A method (hereafter referred to as "BioImpact") was proposed in Australia to address the issue of accounting for biodiversity impacts in LCA (Penman et al 2010). The approach relies on literature review and expert opinions through a series of questions which aim to encapsulate the main issues relating to biodiversity within a disturbance impact framework. The key aim of this project was to further develop and refine BioImpact, using four production systems in NSW: native forestry in the Eden region, plantation softwood timber production in the Hume region, and cropping and rangeland grazing systems in the central-western region. The approach used was a combination of literature reviews and direct expert input via surveys. The results were then compared with the use of species richness and net primary productivity (NPP) for the same production systems.

In this study we demonstrated that BioImpact could discern different biodiversity impacts for different land uses. Results were consistent with broad expectations regarding the relative scores of the four processes; i.e. the biodiversity impact of native hardwood production in Eden was significantly lower than that of land uses in other regions. The management of planted softwood forests in the Hume region resulted in similar biodiversity impacts to those of cropping/grazing systems.

Existing methods such as NPP and species richness were deemed inadequate in the assessment of how biodiversity responds to different disturbance impacts in the context of the forestry and agricultural production systems considered. Using NPP as a surrogate resulted in a pine plantation in Hume having a higher biodiversity value than native forests contained in national parks in the same region, and also a higher biodiversity value than the Eden native forests managed for hardwood timber production. Similarly, use of species richness as surrogate for biodiversity would have ranked cropping and grazing systems as having a higher biodiversity value than that of Eden and Hume managed forest systems.

Key advantages of BioImpact over alternative options available are that it is sensitive enough to discern impacts from different land uses, encapsulates different components of biodiversity (not just a single taxon) easily applied, and, transparent. BioImpact can be applied to any country – all that is required is access to literature and identification of experts.

The key benefit to the forest industry from this project is the demonstration of the applicability of a method that comprehensively and holistically assesses the biodiversity impacts of forestry operations. The default assumption in LCAs involving forest products is that the perceived biodiversity impacts from forestry operations negates other positive environmental outcomes (e.g. low greenhouse footprint, carbon sequestration). Through application of BioImpact this assumption can be explicitly tested.

The next steps are to apply BioImpact to a range of production systems covering different industries where biodiversity impacts are of concern in Australia and NZ. These scores would be used to populate a database that would be freely available to LCA practitioners. Continued support by the forest industry to the development of these datasets for different harvesting systems would be important for the widespread use of BioImpact in Australia, and to ensure that the biodiversity impacts of forestry in Australia are holistically assessed in LCAs.

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Introduction

Life Cycle Assessment (LCA) is a means of assessing the environmental impacts of a product from “cradle to grave”. The use of LCA in the quantification of the environmental impacts of products or production processes is becoming increasingly important. The “impact assessment” stage of LCA models impacts along mostly linear, deterministic, cause-effect chains by linking inventory items to so-called midpoint impact categories, such as global warming potential, ecotoxicity, and land use (Curran et al 2011). In an optional second step, the cause-effect chain is extended to final end points, which express impacts on three areas of protection: natural resources, human health, and ecosystem quality.

Although biodiversity is one of the main environmental impacts of concern, there are currently no globally appropriate means of assessing biodiversity within the LCA framework. Biodiversity and ecosystem diversity are site-specific and difficult to generalise into LCA (Grant 2009). Particular difficulties are related to the LCA framework itself, which require impacts to be generic in space, summed across time horizons, linked to a functional unit and free of interactions between impact pathways (Curran et al 2011). Existing methods do not allow for simultaneous measurement of a range of taxa (flora, mammals, birds, frogs and invertebrates) or the ecosystem services they underpin. There have been some attempts to incorporate biodiversity impacts into LCA, but there is no consensus on the most appropriate technique. Many of the early approaches used net primary productivity (NPP) as a surrogate for biodiversity (e.g. Hampicke 1991; Swan and Petterson 1991; Lindeijer 2000; Weidema and Lindeijer 2001). However, NPP is not a suitable surrogate for biodiversity worldwide with many systems having a negative relationship between biodiversity and productivity (Harden 1993; Huston 1993; Wardell-Johnson et al 2004). A number of studies have attempted a species-based approach using an estimate of diversity, primarily species richness (e.g. van Dobben et al 1998; Kollner 2000; Koellner and Scholz 2008; De Schryver et al 2010). This is problematic as species richness only considers one component of biodiversity, and species richness in one taxonomic group rarely relates to richness in other groups (see Michelsen 2007 for a review). In addition, for many areas the true species richness values are largely unknown (Oliver 2002) and attempting to estimate them would likely produce results with high levels of uncertainty.

Partly in recognition of the need for a robust approach to deal with biodiversity in LCAs, a land use assessment framework has recently been established by the United Nations Environment Programme (UNEP/Society of Environmental Toxicology and Chemistry – SETAC), initially through the early works of SETAC (Lindeijer et al 2002), then through the first phase of the UNEP-SETAC Life Cycle Initiative (Milà and Canals et al 2007) and more recently through the framework described by Koellner et al (2013). This framework aims to provide guidelines on global land use impacts on biodiversity and ecosystem services, through the development of a globally consistent life cycle inventory classification system. In this framework, key principles are suggested for the development of globally applicable methods. These include incorporation of impacts of land transformation and/or land occupation; whether impacts are reversible or permanent, and a measure of ecosystem quality change (either absolute or relative).

As part of this process, de Baan et al (2013) suggested an approach where species richness of different land use types was compared to a (semi) natural regional reference situation to calculate relative changes in species richness. The work focussed on occupation impacts, and the authors concluded that the approach may be used as a rough quantification of land use impact on biodiversity on a global scale. This methodology was further developed by Mueller et al (2014) in the assessment of milk production in Sweden. The work highlighted the fact that higher levels of direct land use cannot be assumed to lead to greater impacts on biodiversity. Coelho and Michelsen (2014) have proposed a globally applicable model for assessing land use impacts on biodiversity without the use of any taxa as indicators, using kiwifruit production in New Zealand as a case study. In their model, variables such as ecosystem scarcity, ecosystem vulnerability and impact on biodiversity were combined with a "deviation from naturalness" (hemeroby) factor. The authors detail several drawbacks with the method proposed, such as lack of reliable data to support the use of the variables proposed, and the simplistic linear approach associated with the use of hemeroby. The use of a functional diversity index for several taxonomic levels to calculate characterisation factors for land use impacts has been proposed by Souza et al (2014). This approach, based on a series of functional traits, aimed to capture the relationships between redundancy or complementarity between species and the functions they play. The authors describe the challenges in the availability and selection of appropriate functional traits for different taxa. The provision of characterisation factors for specific land use types, such as forestry and agriculture, is challenged by the lack of biodiversity data.

There are a number of existing metrics for measuring biodiversity that are commonly used in ecological research and monitoring programs. There is inherent conflict between the scale at which these biodiversity metrics and LCA attempt to calculate impacts. Biodiversity metrics are often designed to assess plots, sites or patches within a landscape and regional context where assessments can be made. In contrast, LCAs traditionally consider a much larger scale where the exact site of origin is typically of no interest.

Remote sensing of biodiversity metrics techniques has the potential to provide data suitable for incorporation into an LCA. These metrics require the comparison between areas affected by a process and an area considered natural or in a benchmark state. While comprehensive benchmarks have been developed for a number of areas in Australia, there are still vast numbers of ecosystems across the globe for which benchmarks do not exist. Even if notional benchmarks were applied, it is expected that if this method were adapted to a global scale, there would be a significant lag time and cost to acquire, process and analyse the remotely sensed data. In addition, the cost of this research may preclude its large-scale application within LCA.

In summary, to-date methods for incorporating biodiversity within an LCA framework have been largely hindered by a lack of information on the relationships between land-use and biodiversity and no universal, appropriate metric for biodiversity at alternative scales is available. Despite this, habitat alteration through land-use remains a primary threat to loss of biodiversity. For example, there is a generic public perception that forestry operations are typically detrimental to biodiversity values, but it is likely that biodiversity is significantly less impacted in well-managed, sustainable harvest operations than other land-uses that do not promote vegetation recovery. Without methods to account for biodiversity within the LCA framework, this misconception is unlikely to change. Similar problems are encountered when accounting for water usage and land use impact of primary production activities.

A method – here after referred to as "BioImpact" metric - was proposed to address the issue of accounting for biodiversity impacts in LCA (Penman et al 2010). BioImpact relies on literature review and expert opinions through a series of questions which aim to encapsulate the main issues relating to biodiversity within a disturbance impact framework. Using a series of semi-quantitative questions, biodiversity impacts are estimated for each taxonomic group (e.g. flora, mammals, diurnal birds, frogs and invertebrates) and then scaled to a single biodiversity measure that can be incorporated into LCA.

The key aim of this project was to develop and refine BioImpact by using four production systems in NSW: native forestry in the Eden region, plantation softwood timber production in the Hume region, and cropping and rangelands grazing in the central-western region. The approach used was a combination of literature reviews and direct expert input via surveys. The results were then compared with the species richness and NPP for the same production systems. We use these results to refine BioImpact, providing a potential pathway for widespread implementation of BioImpact and for making available the relevant databases.

Methodology

Three case study areas were used in this study. The areas selected were considered as representative of the four contrasting production systems: native forestry in Eden, NSW; plantation pine forestry in the Hume region of NSW, and cropping and grazing systems in the central-western region of NSW.

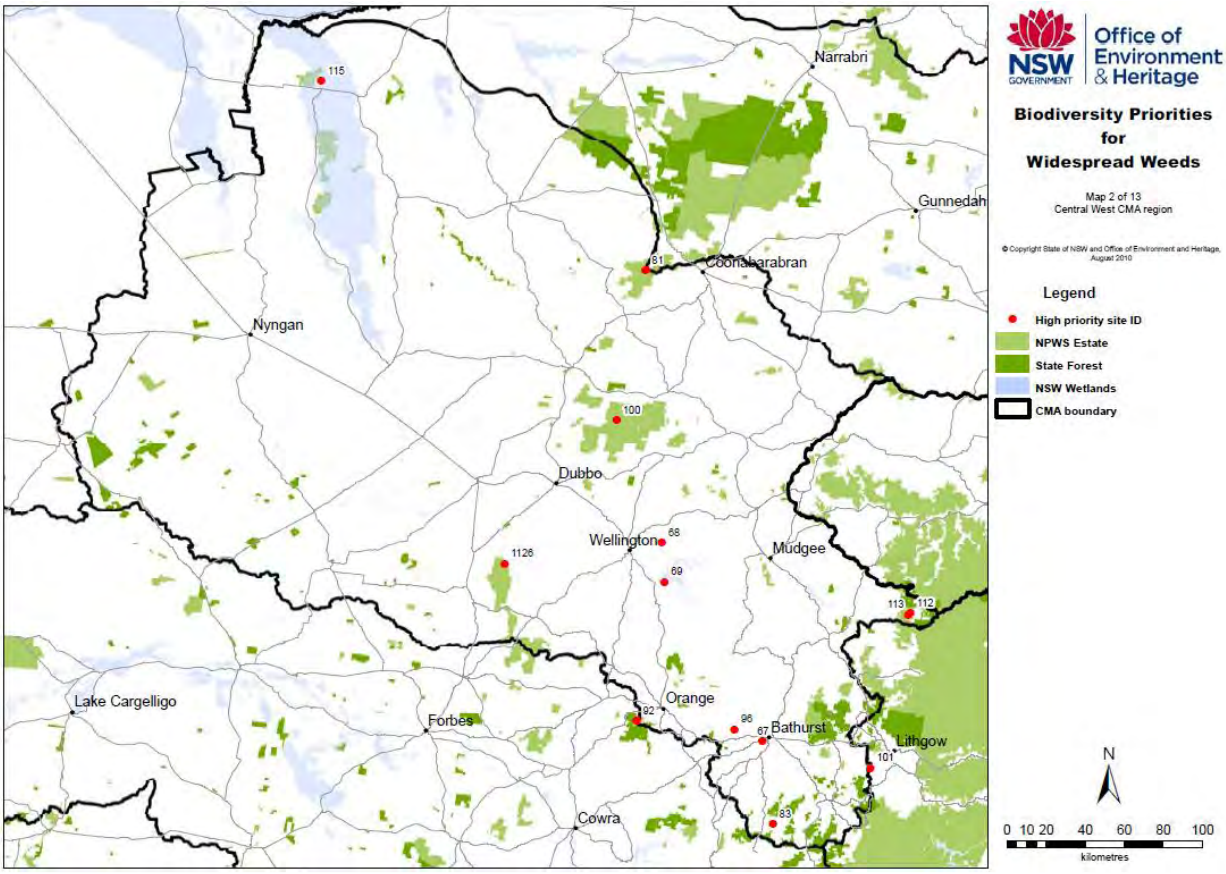
Case study areas

Central West Case study area – agricultural mixed (cropping, rangeland grazing)

Total area

The Central West region, as defined by Local Land Services, covers the central west slopes regions around Grenfell (-33° 51' 52.30" S 148° 09' 13.53"E) , Forbes (-33° 20' 47.93" S 148° 00' 47.25"E) and Wellington (-32° 33' 19.29" S 148° 56' 33.64"E) to the western plains of Nyngan (-31° 33' 30.02"S 147° 11' 43.52"E) and Coonamble (-30° 57' 08.83"S 148° 23' 19.27"E) Figure 1. The area includes the Lachlan, Macquarie-Bogan and Castlereagh catchments. Within this area, wetlands are a major feature, including the internationally recognised Macquarie Marshes.

Figure 1. Catchment Management Authority boundaries for the NSW central-west region.



According to Binks et al (2013), the region covers a total area of around 70.3 million hectares. The total land held by farm businesses and covered by the case study was estimated to be 5.6 million hectares in the Central West region in 2010–11. Agricultural land in the region is mainly used for grazing, which includes rangeland grazing (3.4 million hectares), and cropping (1.8 million hectares) with some forestry (12 974 hectares) also taking place. In addition, 209 745 hectares of land held by farm businesses was set aside for conservation (ABS 2012).

The Central West case study area has been apportioned based on the two most prevalent mixed agricultural systems, cropping/pasture and rangeland grazing. Grazing (71%) is the most significant land use, followed by broad acre cropping (17%). Production cropping systems are supported by evenly distributed winter and summer rainfall events. A large proportion of the area is dedicated to cereal crop production (88%), with 72% of cereal production being wheat). Cattle grazing is most prevalent in the region, followed by sheep grazing (Table 1).

Table 1. Number of farms in the Central-west region, by industry classification, 2010-11 (from Binks et al 2013)

	Central West region		New South Wales	
	no.	%	no.	%
Beef cattle	1,478	23	13,400	31
Mixed grains and livestock	1,199	19	4,138	10
Sheep	1,041	16	4,266	10
Mixed livestock	655	10	3,260	7
Grain growing	642	10	3,755	9
Other livestock	358	6	2,920	7
Fruit and nuts	245	4	2,895	7
Other crop growing	65	1	1,217	3
Other	740	12	7,618	18
Total Agriculture	6,424	100	43,470	100

Note: Where the estimated value of agricultural operations is more than $5000.

Source: Australian Bureau of Statistics

Tree cover across the upper Lachlan catchment is about 15% and about one third of remnant tree cover occurs as scattered paddock trees (Fisher et al 2010). Prior to the introduction of the Native Vegetation Act (2003), which restricted clearing of vegetation on farms, there were few restrictions on private land use.

A total of 172 threatened species occur or did occur within the Central West region (Table 2). Two plant species are presumed extinct, and a further 53 species are Endangered or Vulnerable. The Endangered Ecological Community (EEC) White Box, Yellow Box, Blakely's Red Gum Woodland have been severely cleared and degraded. It is found in five vegetation types in the Central West region, which, on average, have been cleared by more than 90% (Department of Environment, Climate Change and Water NSW 2010). The majority of large remaining tracts of native vegetation are found in national parks, nature reserves or state forests and travelling stock routes, as well as areas with soils considered unsuitable for cultivation (reserved areas are also predominantly on soils unsuitable for cultivation).

Other EEC's include Artesian Springs Ecological Community, Brigalow within the Brigalow Belt South, Nandewar and Darling Riverine Plains Bioregions; Carex Sedgeland of the New England Tableland, Nandewar, Brigalow Belt South and NSW North Coast Bioregions; Coolibah-Black Box Woodland in the Brigalow Belt South, Cobar Peneplain and Mulga Lands Bioregion; Fuzzy Box Woodland on alluvial Soils of the South Western Slopes, Darling Riverine Plains and Brigalow Belt South Bioregions; Inland Grey Box Woodland in the Riverina, NSW South Western Slopes, Cobar Peneplain, Nandewar and Brigalow Belt South Bioregions; Myall Woodland in the Darling Riverine Plains, Brigalow Belt South, Cobar Peneplain, Murray-Darling Depression, Riverina and NSW South Western Slopes bioregions.

Of all faunal groups, the conservation concern of birds is the greatest, with a total of 59 listed under the Threatened Species Conservation Act 1995. Six mammal species are presumed extinct with a further 29 either endangered or vulnerable. Key threatening processes listed for species under conservation concern include: changes in fire regimes and water flows, habitat degradation (loss and fragmentation of habitat, isolation of populations, loss of hollow bearing trees); competition and disease transmission by Feral Pigs; predation by the European Red Fox and Feral Cats and dogs; introduced species, invertebrate damage (locust plagues). The main foci for the region are the clearing of native vegetation (remnant vegetation) and invasive native species (i.e. invasive native scrub or the thickening and encroaching native trees and shrubs).

Table 2. The number of species listed under the Threatened Species Conservation Act 1995 or Fisheries Management Act 1994 that occur or did occur in the Central West region. The categories reflect different levels of extinction risk ('critically endangered' indicates the highest risk, and 'vulnerable' the lowest) (Department of Environment, Climate Change and Water NSW 2010).

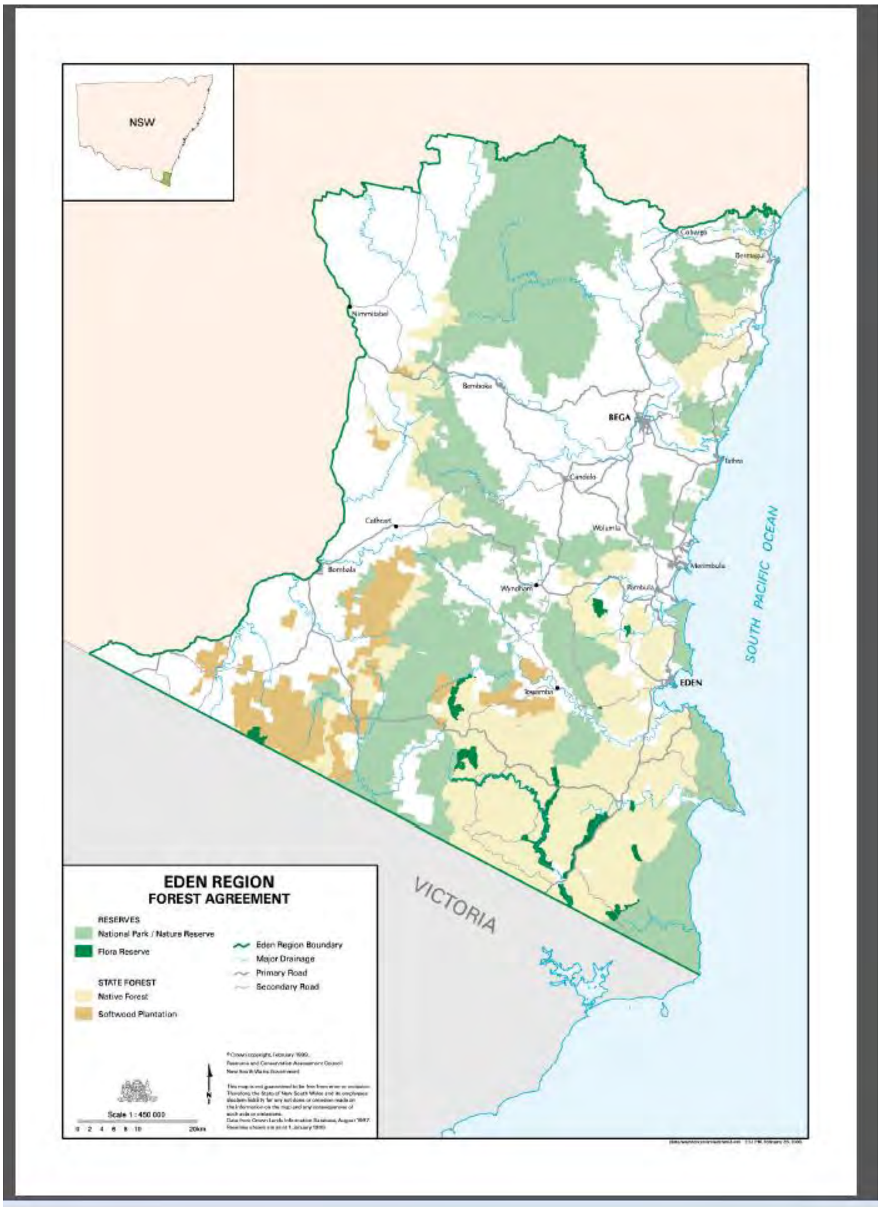
	Presumed extinct	Critically endangered	Endangered	Vulnerable	Total
Fauna					
Mammals	6	0	5	24	35
Birds	0	1	14	44	59
Amphibians	0	0	6	3	9
Reptiles	0	0	3	5	8
Fish	0	0	2	1	3
Invertebrates	0	0	3	0	3
Flora					
Plants	2	0	21	32	55
Algae	0	0	0	0	0
Fungi	0	0	0	0	0
Regional total	**8**	**1**	**54**	**109**	**172**
State total	**76**	**21**	**549**	**409**	**1055**

Eden Case study area – native hardwood production

Total Area

This case study is defined by the Eden sub-region area covered by the Eden Regional Forest Agreement (RFA) (Figure 2). The Eden RFA area covers about 800 000 hectares (the Forestry Corporation of NSW (FCNSW) estate totals 2 million hectares) and extends from Bermagui (-36° 25' 45.31"S 154° 04' 33.73"E) and Nimmitabel (-36° 28' 08.97" S 149° 10' 20.95"E) in the north to Delegate (-37° 02' 37.83" S 148° 56' 30.05"E) and Cape Howe (-37° 30' 24"S 149° 58' 45.00"E) in the south with the southern boundary along the NSW/VIC border. The Eden sub-region area considered in this study covers 167,023 ha (Table 3).

Figure 2. Map of the Eden region as defined in the Eden RFA



Approximately two thirds of the region is forested. Most of this is public forest, either designated as state forest (25 per cent of the total area) or national park (32 per cent). Together, national parks and state forests total 452 000 hectares.

The Eden RFA constitutes three regional districts under management by the FCNSW: the Eden sub-district (region covered in this study); the Narooma District south of the Bega River including the Murrabrine, Murrah, Bermagui, Mumbulla and Tanja Forests; and the eastern part of the Bombala District including a mix of softwood and hardwood forests. This study deals with the Eden sub-district component of the Eden RFA region (Table 1). The softwood forests in this area have been included in the Hume/Pine plantations case study literature.

There are a broad range of vegetation types in the area. Temperate wet eucalypt forests predominate, with scattered temperate rainforest. Old growth stands (approximately 70,000 ha in the whole Eden region, and 1486 ha in State Forests (Forests NSW 2005)), occur in a mosaic of mature and young forests. Coastal heath, salt marsh and floodplain wetlands can be found in the region.

Table 3. Key data for the Eden sub-district

Eden Sub region		
	Area ha	**Comment**
Gross Area	167,023	-
Formal Reserves	8,468	Flora Reserves (FMZ 1)
Informal Reserves	12,643	FMZ 2 and FMZ 3A
Mapped Harvest Exclusions	22,052	IFOA specified exclusions
Base Net Area	123,860	Mappable net area
Unmapped harvest exclusions	32,200	unmapped drainage, steep areas, non forest etc.
Unproductive forest	1,940	low quality forest
Old-growth forest	1486	Area of old-growth forests within state forests
Strategic Net Area	89,720	Used in forecasting models
Area harvested per year	1265	Mean of last five years
Area thinned per year	1130	Mean of last five years

About 3% of the State forest area or <1% of the total forested area is harvested each year for timber (Forests NSW 2005). However, < 1 % of the area of state forest is now old growth forest (though this would often exclude harvest exclusions on riparian zones) and this low proportion has resulted from extensive harvesting in the past and the transfer of significant portions into National Parks during the 1990s as part of the Eden Regional Forest Agreement.

Harvest in the Eden region is carried out using integrated harvest principles, where mixed-age stands dominated by a commercially mature overstorey are harvested to create regeneration opportunities through integrated harvesting of sawlogs and pulpwood with the retention of trees for future sawlogs, fauna habitat, seed trees, visual maintenance and soil and water protection (e.g. FCNSW 2013). Regionally-based IFOAs specify minimum measures to protect threatened species and their habitat from activities associated with timber harvesting across the public forest estate. Major environmental features are protected from harvesting and these include rainforest, high conservation value old growth forest, habitat trees and riparian habitats. Protection of these broad areas is supplemented with species-specific measures that identify key aspects of habitat for different species. Pre-harvest surveys for particular threatened species are undertaken to guide the identification of key habitat and subsequent protection measures. This process is outlined in the Eden region's IFOA (http://www.epa.nsw.gov.au/forestagreements/EDENagreement.htm). Further information on the management of the Eden forests can be found at the Ecologically Sustainable Forest Management (EFSM) for the Eden region (Forests NSW 2005).

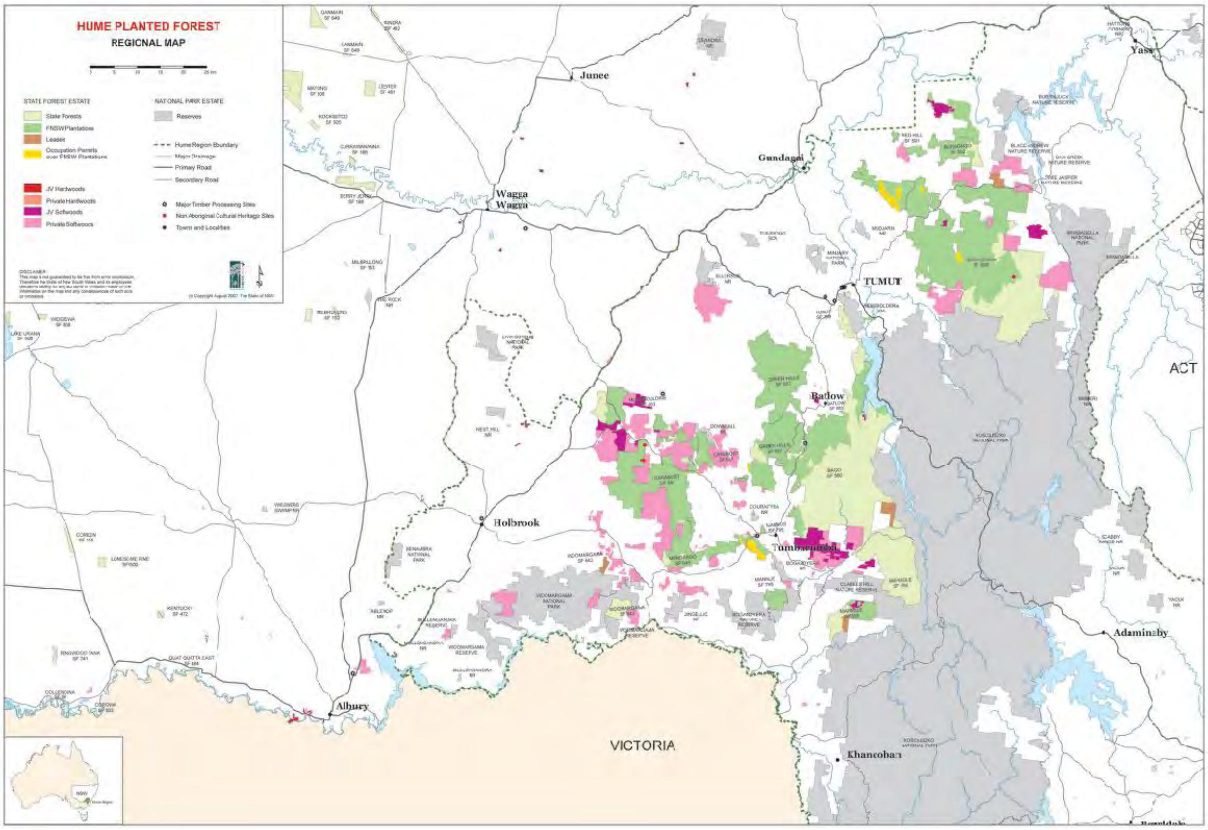
Hume Case study area – plantation softwood production

Total area

The Hume case study area is defined as the pine plantation (softwood) estate extending from the township of Tumut (-35° 17' 21.65"S, +148° 13' 16.51"E) to the north east and south west (Figure 3). The FCNSW manages over 89,000 ha of planted State forests within the Hume

Region under an ESFM plan (Forests NSW 2008). In addition there are 4,350 ha of joint venture plantation managed by the FCNSW on private land. Privately owned plantation on freehold land across the south west slopes, mostly adjacent to or in close proximity to FCNSW plantings totals approximately 35,000 ha (Forests NSW 2008). Of these, Hume Forests Limited currently owns and manages approximately 14,000 stocked ha of freehold plantations in the Tumut/Tumbarumba and Oberon Regions of NSW.

Figure 3. Map of the Hume region including the planted forest state



The Tumut Sub-region consist of planted forests in a mosaic with native forests and cleared and semi-cleared lands. State forests cover 8% of the Tumut sub-region and 16% of the forested landscape. Planted forests comprise 42% of State forest (Forests NSW 2008). Retained areas of remnant vegetation exist within the state owned plantings. Across the state of NSW this amounts to about 15 % of the land area of pine plantations (Forests NSW 2008). These remnant patches are predominantly in major drainage corridors or where biodiversity values have been identified and since 1982 native forest has not been cleared during harvest or plantation establishment (Forests NSW 2008). By 1990 this policy had extended to exclude any clearing of significant patches of native vegetation (Forests NSW 2008).

Where FCNSW becomes aware that plantation operations are likely to have an impact on “Unique or Special Wildlife Values”, field inspections must be undertaken, recovery plans considered and prescritpions to manage the species must be developed as part of the determination process. Planted forest areas within State forests are equivalent to IUCN category IV and values may be protected by:

•protecting natural ecosystems in riparian habitat that has been excluded from establishment;

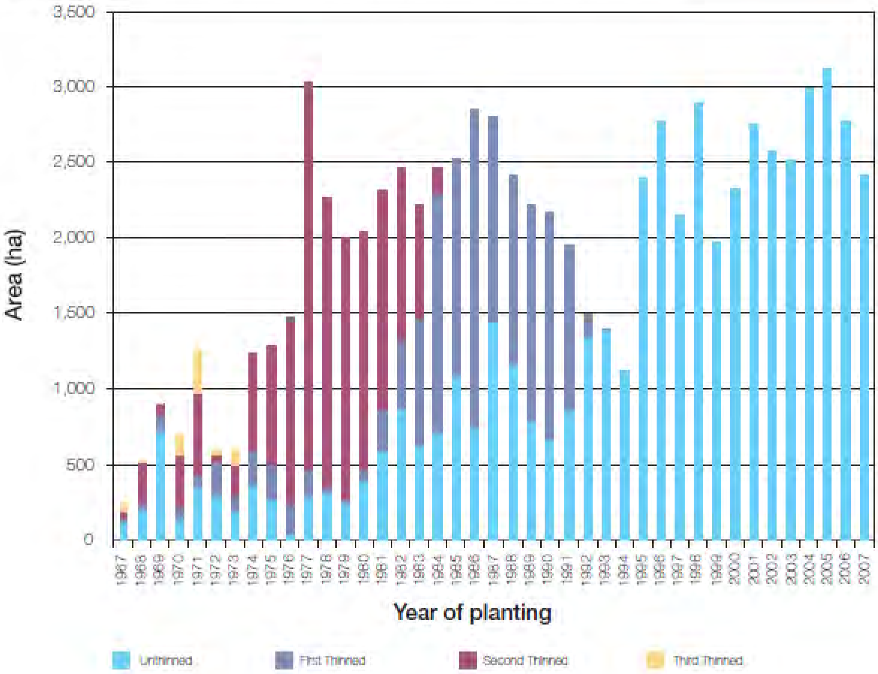
•excluding disturbance from identified extreme erosion and water pollution hazard;

•modifying the nature, intensity or timing of operations in an area, eg FMZ 3b or in catchments for limestone cave systems, and

•excluding disturbance from those elements of habitat or cultural heritage protected by application of prescriptions contained in the P&R Code.

According to the ESFM plan for the Hume region, silvicultural thinning operations are designed to maintain forest health and optimise the growth of trees capable of producing sawlogs during later harvesting operations. The age and silvicultural condition of commercial radiata pine stands in the Hume region (as at December 2007) is shown in Figure 4 (Forests NSW 2008). Based on site conditions, optimal silviculture and the existing age class distribution the forests within Hume Region have a potential to grow at between 13 m^3/ ha and 25 m^3/ ha each year with an annual average of approximately 18 m^3/ ha. The plantations are clearfelled at harvest.

Figure 4. Age and silvicultural condition of commercial radiata pine in the Hume region



Notes: The graph includes data for radiata pine plantations on State forest, radiata pine joint ventures on State forest and radiata pine joint ventures on private land managed by Forests NSW
The total net stocked area of plantation varies daily based on the balance between forest harvesting and plantation establishment activities. The figures quoted above were correct as at December 2007.

In the ESFM for the Hume region (Forests NSW 2008), a more detailed description of how biodiversity issues are considered in the management of the softwood planted forests is included.

BioImpact Development

BioImpact is primarily based on the response to a series of questions that aim to capture key biodiversity concepts within a disturbance impact framework (Penman et al 2010). In order to develop a complete set of questions to be used, an initial 'concepts' survey was carried out using a broad set of 26 questions (Appendix 4). These questions were based on ecological concepts considered important in the assessment of biodiversity and disturbance impacts by project members. With a global focus in mind, Ecological Societies from Australia, New Zealand, Canada, United States, Japan, China, Britain and Europe were contacted via ecological network email lists and the Concept survey questions answered using an online survey interface (Survey Monkey).

Ecologists were asked to rate their answers on a scale of importance (Major, Minor, Not and unknown). Ecologists were also asked to identify in what country they primarily worked in relation to biodiversity conservation, to give an estimate in years as to how long they had been active in biodiversity conservation and their current role in relation to biodiversity.

From the global survey results, we distilled a list of five Key Concepts that were identified as being essential to incorporate into an LCA assessment of biodiversity. A total of 16 preliminary questions were then created during an initial internal project workshop to address this list of Key Concepts. These questions were subsequently presented to a group of ecologists during a one day workshop in Melbourne at the Royal Melbourne Institute of Technology (RMIT). While this workshop was not originally planned, the project members felt it prudent to further validate the draft assessment questions with a broader range of ecologists not linked to the project.

The workshop was structured as follows:

1. Presentation of what is Life Cycle Assessment – definitions, examples, uses,
2. Presentation of LCA and biodiversity: how did the current project begin; why incorporate biodiversity into an LCA framework; an introduction and evaluation of current methods in the literature; and an introduction to the current studies method and case studies
3. Impact on biodiversity: participants were asked to first rate five production processes in order of impact on biodiversity from least impact to greatest impact. Production processes included: Native Forestry in the Eden Region (Regional Forest Agreement area) NSW; Pine Plantation Forestry (*Pinus radiata*) in the Hume Plantation Estate NSW; Cropping/Pasture Agriculture in the Central West Local Land Services (LLS) area, NSW; Rangeland grazing Agriculture in the Central West Local Land Services (LLS) area, NSW; and Open cut coal mining in the La Trobe Valley, Victoria.
4. Participants were then systematically taken through each of the 16 questions. Each question was presented and discussed. Any clarification surrounding that question was then provided. Participants then individually scored that question on the scale provided for that question.
5. At the completion of all the questions, scores were totalled. Participants were then asked to compare their initial impact rating of the process with this new rating.
6. Discussion surrounding questions concluded the workshop

From the Melbourne Workshop, the 16 questions were further refined and a list of questions and associated explanations were developed (Table 4). These final questions, which numbered 19 (some questions were divided into a), b), etc.), were identified as relating to disturbance impacts on different taxonomic groups across all study areas.

BioImpact application
The literature review, which was the first critical step in the implementation of BioImpact, focused on studies of biodiversity within the following three areas: the Eden Forest Region (Native species forestry), Hume Region (Pine plantation forestry) and Central Western New South Wales (Agriculture). The Central West Agriculture was further divided into two groups focused on 'cropping/pasture' or 'rangeland grazing'. The review consisted of over 90 peer-reviewed publications. Acquisition of literature is ongoing and it is expected that additional papers will be continually added to the initial database as they become available.

A paper was included in the review if it:

a) was within a case study area,
b) considered fauna and/or flora of that area, and
c) was relevant to one or more of the 16 questions

Flora and fauna included 12 broad taxonomic groups: bryophytes (hornworts, liverworts and mosses), lichens, fungi (including pathogenic fungi), vascular plants, invertebrates, amphibians, reptiles, ground mammals, large to medium mammals, arboreal mammals (not including bats),

bats and birds. A list of all species by taxonomic group is included in Appendix 1. Papers discussing the production system from outside the study area were included if a taxonomic group was not adequately represented by papers from within the case study area.

Literature was reviewed against each of the 19 questions for each study area (Table 4).

Table 4. Nineteen questions (Questions 1a through to 13d), developed from the Key Concepts and Melbourne Workshop. Appendix 2 details the explanations that accompanied the questions

Question	**Response Range**
Question 1. What is the immediate loss of species diversity as a direct result of the process? **a. compared to a benchmark state (e.g. pre-1750 vegetation) appropriate for the region in question**[1] 1 Compare this question to a benchmark state. For an international audience, defer to 'naturalness'. Definitions for these terms are found in the question summary above.	+10 = total loss, 0 = no change, -10 = total improvement
Question 1. What is the immediate loss of species diversity as a direct result of the process? **b. compared to the land-use immediately prior to the process in question**[2] 2 Land-use prior to the process is not considered to be of a benchmark state; for example in the forestry context it may be a mid-succession stage or second rotation crop, and for agriculture it may be annual cropping rotation or seasonal	+10 = total loss, 0 = no change, -10 = total improvement
Question 2. To what extent does species diversity recover? **a. between the primary disturbance events induced by the process or within 50 years since disturbance for processes that are non-cyclic disturbance events (e.g. mining) (When the process is not new, but is continuing the same existing process in that area)**[1] 1 for example, in the forestry context, this means second rotation in regrowth, clearfall of an existing plantation and for agriculture, a second year of cropping.	+10 = total loss, 0 = no change, -10 = total improvement
Question 2. To what extent does species diversity recover? **b. when the process has been newly established on existing, mature native vegetation**[2] 2 for example in the forestry context, logging of old growth, or where forest has been cleared for plantations establishment, and for agriculture clearance of remnant vegetation.	+10 = total loss, 0 = no change, -10 = total improvement
Question 3. To what extent does the process alter natural disturbance regimes?	+ 10 = No recovery, 0 = Total recovery
Question 4. To what extent does the disturbance increase the impacts of invasive predators?	+10 = total loss, 0 = no change, -10 = total improvement
Question 5. To what extent does the disturbance increase the impacts of invasive plants?	+10 = total loss, 0 = no change, -10 = total improvement
Question 6. To what extent does the disturbance increase the impacts of herbivorous and invertebrate pest populations?	+10 = total loss, 0 = no change, -10 = total improvement

Question	Response Range
Question 7. To what extent does the disturbance increase the impacts of pathogens?	+10 = total loss, 0 = no change, -10 = total improvement
Question 8. To what extent does the process affect connectivity of native vegetation across the region?	+10 = total loss, 0 = no change, -10 = total improvement
Question 9. To what extent does the process alter habitat structure? **a. compared to a benchmark state (e.g. pre-1750 vegetation) appropriate for the region in question[1]** [1] Compare this question to a benchmark state. See summaries for definition of pre-1750 benchmark state. For an international audience defer to 'naturalness' under this summary (references included).	+10 = total loss, 0 = no change, -10 = total improvement
Question 9. To what extent does the process alter habitat structure? **b. compared to the land-use immediately prior to the process in question[2]** [2] Land-use prior to the process is not considered to be of a benchmark state; for example in the forestry context it may be a mid-succession stage or second rotation crop, and for agriculture it may be annual cropping rotation or seasonal pasture grazing	+10 = total loss, 0 = no change, -10 = total improvement
Question 10. To what extent does the process reduce the resilience of the system – capacity to absorb stochastic disturbance – flood, fire, drought?	+10 = total loss, 0 = no change, -10 = total improvement
Question 11. To what extent does the disturbance have a negative impact on keystone species?	+10 = total loss, 0 = no change, -10 = total improvement
Question 12. Will the process result in at risk species becoming eligible for IUCN listing or upgrading existing listings under IUCN?	**Response range: 1 = YES, 0 + NO**
Question 13. Does the process affect threatened species or endangered ecological communities? **a. – an individual threatened species?**	+10 = total loss, 0 = no change, -10 = total improvement
Question 13. Does the process affect threatened species or endangered ecological communities? **b. – an endangered ecological community?**	+10 = total loss, 0 = no change, -10 = total improvement
Question 13. Does the process affect threatened species or endangered ecological communities? **c. – more than one threatened species?**	+10 = total loss, 0 = no change, -10 = total improvement
Question 13. Does the process affect threatened species or endangered ecological communities? **d. – more than one endangered ecological community?**	+10 = total loss, 0 = no change, -10 = total improvement

Question	Response Range
ADDITIONAL QUESTIONS TO BE ANSWERED USING A GIS or existing information	
A. What is the regional extent of the process? **Explanation** This question refers to the proportional coverage of the process over the total area of the bioregion for the 'time to recovery'. Bioregions are described as "relatively large land areas characterised by broad, landscape-scale natural features and environmental processes that influence the functions of entire ecosystems" (Thackway and Cresswell 1995). There are currently 89 bioregions recognised in Australia. Examples include the Sydney Basin, New England Tablelands, Cape York Peninsula and Tasmanian Southern Ranges.	
B. To what extent does the process increase fragmentation of native vegetation coverage within the region? **Explanation** Habitat fragmentation is a term used for the process that alters the structure and function of an ecosystem such that the ability of an organism to adapt and modify is reduced or there are discontinuities in an organism's favoured environment. Habitat fragmentation is a separate issue to habitat loss (Fahrig 2003). Habitat loss increases fragmentation. Fragmentation may cause low amounts of habitat loss e.g. roading in forested areas, however the associated fragmentation effect is large e.g. edge effects, isolation/separation (Didham 2010). Habitat fragmentation may occur through natural causes (e.g. fire, climate change) or through human activity. Where landscapes have been altered by human influence, the change usually occurs at a rate faster than natural events and involves the disintegration of continuous habitats, into smaller, disjunct and more isolated habitats. Fragmentation includes edge effects, changes in patch shape, reduced patch area, patch isolation, and alterations in the land-use types in the landscape.	
C. To what extent has the native vegetation in the region been cleared? **AND/OR** **What is the proportion of land-clearing in the bioregion of interest?**	

Each individual paper was considered against a question and subsequently given a score (if applicable), based on the scale (response range in Table 4) associated with that question. The data relating to scores and references were then stored in a database.

Online survey of ecological experts

A list of ecological experts from each of the case study areas was made after discussion with project members. An ecological expert was defined as a person who has been active in the study area and who has published and presented substantial work on a particular taxonomic group(s) over 5 years. A total of 42 experts were identified. Each expert was individually contacted via email. No individual was aware of who was participating in the survey and all responses were anonymous. An online survey interface (Survey Monkey) was used to distribute the survey to ecologists. All listed experts were emailed with the survey URL and a brief description of the project. Experts were asked to identify which case study area they were answering questions to and to rate on a scale of 1 (no expertise) to 6 (greatest expertise) their expertise in the taxonomic groups. Experts were then lead through each question by way of introducing the question and a brief explanation of the question (see Appendix 2). A timeframe of 2 weeks was given for completion of the survey. This time frame was extended to mid-January as a consequence of the time frame ending close to Christmas and New Year.

Preliminary analysis of data found large variation in answers to some questions. In order to clarify these answers, all experts on the list were contacted via email a second time. Each expert was asked if they could answer questions relating to the survey, whether they answered the survey or not (due to anonymity this was not known). Responses were used to further inform the survey. The final format of the questions is shown in Appendix 2. The questions were refined based on feedback received and the experience of conducting the survey itself.

Literature and survey biodiversity scoring

Each region was analysed separately. After scoring papers, a biodiversity score for that question was created. For example, for Question 1a Eden Native Forestry, from each taxonomic group the mean, standard deviation, maximum, minimum and 95% confidence interval of raw scores were calculated from the different papers per taxon. Mean, standard deviation, maximum, minimum and 95% Confidence interval of all taxonomic groups were then averaged to give a Biodiversity score for Question 1a Eden Native Forestry. This process was repeated for each question for each case study.

Once biodiversity scores were generated for each question, these were initially separately added to give a final biodiversity score for each region. The same process used for the literature data was followed separately to create biodiversity scores from the survey data.

Two further methods were used to create a total biodiversity score for each region. Firstly, the survey and literature scores for each questions were averaged into the one dataset and a final biodiversity score generated by the method used for separate literature and survey data sets (i.e. adding or multiplying individual scores to obtain a total score). Secondly, using the literature data set as a base, any gaps in the literature were filled in with survey data, where the latter was available. Once again a final biodiversity score was calculated as described above for the other methods.

Net primary productivity (NPP)

The NPP of the three production systems was derived taking the CSIRO NPP model (Haverd et al 2013) as the reference data set. The data included long-term average annual Bios2 (Haverd et al 2013) NPP values over the period 1990-2002. For Central West NSW, cropping and grazing were combined due to the lack of reliable spatial information on areas of rangeland grazing relative to cropping enterprises.

From that original resource a number of shape files were extracted, which represented the boundaries for each of the production systems included in this study. The mean NPP (grassy layer, woody layer and a combined woody and grassy layer) and standard deviation for each of the production systems and their reference benchmarks were derived.

The Eden shapefiles were derived as follows:

1) EDEN_REGION.shp: This shapefile covers the entire Eden region

2) EDEN_NP.shp: This shapefile includes only national parks within the Eden region

3) EDEN_SF.shp: This shapefile includes state forests within the Eden region excluding all the following plantation types:
   Planted forest Softwood
   Native Forest Plantation
   Planted Forest Hardwood
   Softwood Joint Venture
   Hardwood Joint Venture
   Planted Forest Salinity Trial
   Planted Forest Native Protection
   Private Hardwood Plantation

The Hume shapefiles were derived as follows:

1) HUME_REGION.shp: This shapefile covers the entire Hume region

2) HUME_NP.shp: This shapefile includes only national parks within the Hume region.

3) HUME_SOFTWOOD.shp: This shapefile includes the following types within the Hume region:
   Private Softwood Plantations
   Planted forest Softwood
   Softwood Joint Venture

The Central West shapefiles were derived as follows:

1) Central_West_Region. shp: This shapefile covers the entire catchment management authority region, without the national parks and state forest layers.

2) Central_West_NP.shp: This shapefile covers the total area of national parks within the entire catchment management authority region.

Species Richness

The Atlas of Living Australia (ALA) (www.ala.org.au) was interrogated to generate species richness data for each of the case study areas. For Central West the boundaries for the catchment management authority area were used, and all species data for this area downloaded. For Hume and Eden regions a shapefile was uploaded via the spatial portal and all species data was selected and downloaded. Using shapefiles for National Park and State Forest/Softwood plantations, Eden and Hume spatial data were clipped to species data for that region and divided into a) whole region, b) national park and c) state forest/softwood plantation. For each data set, species data per taxonomic group were generated. As for NPP, it was not possible to generate individual species lists for cropping and grazing areas in the central west region, as a GIS layer that separates cropping from grazing enterprises was not available. Thus, the central-west area excluding national parks and state forests was taken as representative of a combined cropping/grazing layer.

Results

Key Concepts survey

Two hundred and sixty-seven individual responses were received from 20 countries, dominated by Australia, the United States, New Zealand and Canada (Figure 5). Responses from Ecological Societies agreeing to distribute the URL for the survey were received from Australia, New Zealand, United States and Canada. The email sent out was in English, and this may have had an influence on distribution to countries where English is not the primary language.

The majority of responses came from those working in an academic capacity, followed by ecological consultants and student researchers (Figure 6). Sixty-six respondents filled out the comments section at the end of the survey. These comments (Appendix 5) were taken into consideration when considering the responses to the survey questions, greatly assisting the formulation of a more refined list of questions.

From the concepts survey, a list of five key concepts was developed:

1) Connectivity, fragmentation, isolation, gene flow
2) Interactions
   - Invasive species
   - Natural disturbance regimes
3) Anthropogenic disturbance regime impacts
   - Frequency, duration, intensity, extent, recovery x frequency, succession
4) Habitat structure, ecosystem function, resilience
5) Threatened communities and species

Figure 5. Number of respondents from each country.

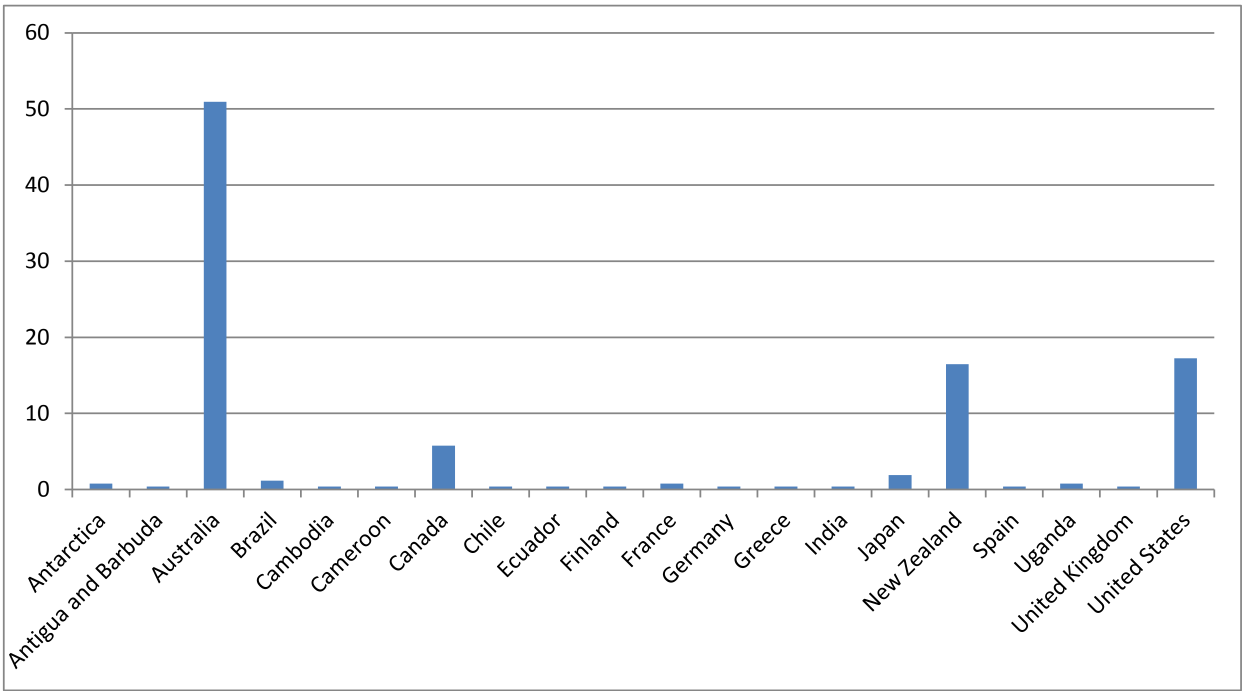
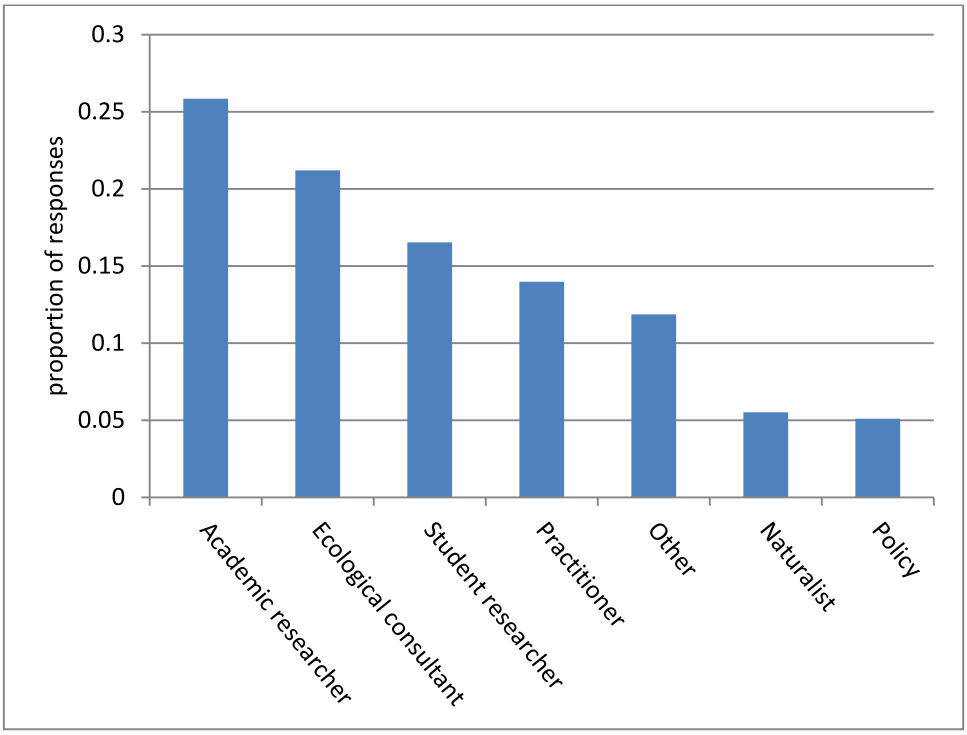


Figure 6. Profession of Respondents



Questions were developed to address the range of issues covered by these concepts. The 16 questions were subsequently workshopped with a group of ecologists from RMIT. Feedback from this process refined questions. Questions were removed from the original list when it was suggested that a GIS could generate the data in question. These questions became Questions A, B and C.

Table 5. Summary of literature scoring in the Central West Cropping/Pasture case study. Numbers shown in the columns represent the scores allocated to each scientific paper. Where multiple papers share the same score in the same taxonomic group, the number of papers for that score is shown in superscript (e.g. -1^2 = two papers have been scored in a particular taxonomic group as -1). Gaps in literature are highlighted with grey shading.

	Bryophytes	Lichens	Vascular plants	Fungi	Invertebrates	Frogs	Reptiles	Ground mammals	Large/ medium mammals	Arboreal mammals	Bats	Birds
1a	6^1	6^1	$0^1,7^2,8^1$	8^1	$-2^1, 0^1,7^1$	8^1	9^1	8^1	4^1	9^1	$8^1,9^1$	$8^1,9^1$
1b	3^1	3^1	$6^1,5^1$	8^1	$8^1,2^1$	6^1	7^1	9^1		8^1	$8^1,2^1$	$8^1,7^1$
2a	$6^2,7^1,9,^1$											
2b	$6^2, 9^1,7^2$											
3	$3^2,5^1,6^2 8^1$											
4									9^1			
5	7^1	7^1	$2^1 8^1$						6^1			
6			8^1						9^1			
7									2^1			
8	$3^1,5^2,6^3 7^1 8^1$											
9a	7^1	7^1	9^1		$4^1,6^2$	9^1	7^1	7^1	8^1		$6^1 5^1 8^1$	$4^1 9^1$
9b	3^1	3^1	6^1		$3^1 4^1$	5^1	9^1	4^1	6^1	9^1	$2^1 5^1 6^1$	4^2
10	6^1											
11						8^1	8^1	8^1			7^1	8^1
12	1^4											
13a	0^1	0^1	6^1	0^1	1^1	5^1	5^1	$6^1,7^1,8^1$	$4^1,8^1$	4^1	$4^1,6^1$	5^2
13b			8^1									
13c	0^1	0^1	$6^1,8^1$	0^1	1^1	5^1	5^1	$6^1,7^1,8^1$	$4^1,8^1$	4^1	4^1	5^1
13d			8^1									

Table 6. Summary of literature scoring in the Central West Rangeland grazing case study. Numbers shown in the columns represent the scores allocated to the each scientific paper. Where multiple papers share the same score in the same taxonomic group, the number of papers for that score is shown in superscript (e.g. -1^{2} = two papers have been scored in a particular taxonomic group as -1). Gaps in literature are highlighted with grey shading.

	Bryophytes	Lichens	Vascular plants	Fungi	Invertebrates	Frogs	Reptiles	Ground mammals	Large/ medium mammals	Arboreal mammals	Bats	Birds
1a	4^{1}	$4^{1}8^{1}$	$-2^{1}4^{1}5^{1}6^{1},7^{1},8^{1},9^{2}$		$-3^{1}1^{1},5^{2}$	6^{1}	$3^{2}7^{1}$	6^{1}		6^{1}	$5^{1}7^{1}$	$7^{2},8^{1},9^{1}$
1b	3^{1}	$3^{1}5^{1}$	$-2^{1},4^{1},5^{3},6^{1}$		3^{1}	4^{1}	$3^{1}5^{1}$	7^{1}		4^{1}	$^{11}7^{1}$	$5^{1},7^{2}$
2a	$2^{1},3^{1},4^{2}, 5^{2}6^{2}, 7^{1}$											
2b	$7^{7},8^{1},9^{2}$											
3	$4^{1},5^{3},6^{4}7^{2}$											
4									9^{1}			
5	$5^{1}6^{1}$	$5^{1}6^{1}$	$4^{1}6^{2}8^{1},9^{1}$									
6			$2^{1}5^{1}8^{1}$		$-2^{1},3^{1}$							
7					3^{1}							
8	$2^{1}3^{1},5^{5,}6^{2}8^{1},9^{1}$											
9a	5^{1}	5^{1}	$5^{2}6^{1}7^{1}8^{1}$		$4^{1}5^{1}$	$4^{1}6^{1}$	5^{2}	5^{1}	8^{1}	5^{1}	0^{1} $3^{1}5^{1}$	$5^{2}6^{1}$
9b	3^{1}	3^{1}	$3^{2}4^{2}5^{1}6^{1}$		$2^{1}3^{1}$	$4^{1}7^{1}$	4^{1}	6^{1}		6^{1}	0^{1}, $1^{1},5^{2}$	$6^{1},5^{2}$
10	$5^{2},6^{2}$ 8^{1}											
11			8^{1}		8^{1}							
12	1^{3}											
13a	0^{1}	0^{1}	6^{1}	0^{1}	1^{1}	5^{1}	5^{1}	6^{1}	4^{1}	4^{1}	$4^{1},6^{1}$	$3^{1},5^{1},7^{1}$
13b	7^{1}		8^{1}								4,6	
13c	0^{1}	0^{1}	6^{1}	0^{1}	1^{1}	5^{1}	5^{1}	6^{1}	4^{1}	4^{1}		$5^{1},7^{1}$
13d			8^{1}									

Table 7. Summary of literature scoring in the Eden Native Forestry case study. Numbers shown in the columns represent the scores allocated to the each scientific paper. Where multiple papers share the same score in the same taxonomic group, the number of papers for that score is shown in superscript (e.g. -1^2 = two papers have been scored in a particular taxonomic group as -1). Gaps in literature are highlighted with grey shading.

	Bryophytes	Lichens	Vascular plants	Fungi	Invertebrates	Frogs	Reptiles	Ground mammals	Large/ medium mammals	Arboreal mammals	Bats	Birds
1a			2^3	2^1	$2^1,1^1,2^1$	$3^1,4^1$	3^1	$2^1,3^3$	2^1	$-1^1,2^3,3^2,4^2$	2	$2^2,3^2,4^1$
1b			2^3	$4^1,5^1$		1^2			$2^1,4^1$	$2^2,4^2$	2^1	$2^2,3^2,5^1$
2a	$0^2,1^2,2^2,3^4$											
2b	$1^5,2^2,3^4, 4^4$											
3	$0^2,2^3,3^2,4^2,5^4,6^1$											
4									7^1	$0^1, 1^1$		0^3
5			0^5									
6					0^1							
7						4^1						
8	$0^1,2^34^1,5^37^{12}$											
9a			5^3		5^1	3^1	3^1	$2^1,5^1$	5^1	3^1	5^1	$2^1,4^1$
9b			1^3		1^3	$0^2, 1^2,6^1$	1^1	1^2	1^1	$0^1,1^1$	2^1	$0^1,4^2$
10	$0^1,1^2,3^3$											
11			1^2		0^1						2^1	8^1
12												
13a			0^4			$3^4,4^1$		$0^1,7^1,8^1$	7^1	7^1	6^1	$7^1,8^1$
13b												
13c			0^4			$3^4,4^1$		$0^1,4^2,7^1$	7^1	7^1	7^1	$7^1,8^1$
13d												

Table 8. Summary of literature scoring in the Hume Pine plantation case study. Numbers shown in the columns represent the scores allocated to the each scientific paper. Where multiple papers share the same score in the same taxonomic group, the number of papers for that score is shown in superscript (e.g. -1^2 = two papers have been scored in a particular taxonomic group as -1). Gaps in literature are highlighted with grey shading.

<table>
<tr><th></th><th>Bryophytes</th><th>Lichens</th><th>Vascular plants</th><th>Fungi</th><th>Invertebrates</th><th>Frogs</th><th>Reptiles</th><th>Ground mammals</th><th>Large/ medium mammals</th><th>Arboreal mammals</th><th>Bats</th><th>Birds</th></tr>
<tr><td>1a</td><td>0^1</td><td></td><td></td><td></td><td>7^1</td><td></td><td></td><td></td><td>$0^1,5^1$</td><td></td><td></td><td>$2^1,7^1$</td></tr>
<tr><td>1b</td><td></td><td></td><td></td><td></td><td></td><td></td><td>$0^3,5^1$</td><td>3^1</td><td>0^1</td><td>5^2</td><td></td><td>$0^1,2^1,4^1$</td></tr>
<tr><td>2a</td><td colspan="12">$0^3,1^1,3^2,4^1,5^5,6^6,7^1,8^1,10^1$</td></tr>
<tr><td>2b</td><td colspan="12">$6^1,9^1$</td></tr>
<tr><td>3</td><td colspan="12">$6^2,7^1,8^1$</td></tr>
<tr><td>4</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td>$5^1,7^1$</td><td>7^1</td><td>$3^2,4^1$</td><td></td><td>3^1</td></tr>
<tr><td>5</td><td></td><td></td><td>7^1</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>6</td><td></td><td></td><td></td><td></td><td>2^1</td><td></td><td></td><td></td><td></td><td>-1^1</td><td></td><td></td></tr>
<tr><td>7</td><td></td><td></td><td></td><td></td><td>0^1</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>8</td><td colspan="12">2^1, $3^1 4^1$, $6^1,8^2$</td></tr>
<tr><td>9a</td><td>7^2</td><td></td><td></td><td></td><td>$0^1,6^1$</td><td>6^1</td><td>4^1</td><td>$5^1,6^2$</td><td></td><td>5^1</td><td></td><td>7^1</td></tr>
<tr><td>9b</td><td>7^2</td><td></td><td></td><td></td><td>$0^1,7^1$</td><td>3^1</td><td>7^1</td><td>$5^1,7^1,8^1$</td><td>6^1</td><td>$4^1,5^1$</td><td></td><td>$1^1,6^1,7^1$</td></tr>
<tr><td>10</td><td colspan="12">$2^2,5^3,7^2$</td></tr>
<tr><td>11</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td>1^1</td></tr>
<tr><td>12</td><td colspan="12">$0^6,1^2$</td></tr>
<tr><td>13a</td><td></td><td></td><td></td><td></td><td></td><td>$3^1,8^1$</td><td></td><td></td><td></td><td></td><td></td><td>$3^1,10^1$</td></tr>
<tr><td>13b</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>13c</td><td></td><td></td><td></td><td></td><td></td><td>$3^1,5^1$</td><td></td><td></td><td></td><td></td><td></td><td>$3^1,9^1$</td></tr>
<tr><td>13d</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

Literature Review

There were a total of 95 papers reviewed. This included 27 papers for Central West (12 for cropping/pasture and 15 for rangeland grazing), 38 papers for Eden, and 30 for Hume. These are summarised in Tables 5-8. There are an additional 96 papers that may be relevant for the study areas, but which are not yet reviewed in detail. It is expected that this list will change and be refined with future developments in the study.

The majority of papers focused on birds, regardless of case study area. Vascular plants are well studied in Eden and Central West agriculture regions, but only one study is listed for Hume Pine Plantations. There were fewer studies for the lesser known taxonomic groups, in decreasing order: amphibians, reptiles, invertebrates, bryophytes, lichens, fungi. Ground mammals are less studied in the Agricultural area compared to Native Forest and Pine Plantation. Studies considering amphibians were most numerous in Native Forests.

Literature revealed that the predominant key threatening process amongst all regions was 'land clearance' or 'vegetation clearance'. This mostly referred to clearing native vegetation/semi-grazed land/remnant vegetation for agriculture (cropping/grazing/pasture) or pine plantation forestry (pine) (Table 9). Remaining threatening processes differed for each case study region. For Agriculture, 'invasive species' was a major key threatening process. Native forestry was mostly identified with the threatening processes of 'fire frequency', 'logging' and 'habitat loss'. 'Fragmentation', which can be linked with 'land clearance', was also a high threatening process for agriculture and native forests only. Processes such as 'disease' and the 'removal of structural complexity' appeared low on the list because they were represented by a specific group e.g. frogs/disease; bryophytes/removal of structural complexity.

Table 9. Key threatening processes identified within each case study area.

Agriculture	Pine Plantation	Native Forests
Extremely common (appeared in ~50% of papers)		
Land clearance	Land clearance	Land clearance
Invasive species		Fire frequency
		Logging
		Habitat loss
Very common (appeared in ~20% of papers)		
Fragmentation		Fragmentation
Habitat loss		Predation
Logging		
(Moderately common (appeared in ~ 15% of papers)		
Grazing frequency		grazing frequency
Fire frequency		
Least common (appeared in ~10% of papers)		
Predation	Removal of structural complexity	Disease
Roading		
Erosion		

Central Western New South Wales – Agriculture (cropping/rangeland grazing)

A total of 15 studies were reviewed. Land clearance, invasive species, fragmentation and habitat loss were a major focus. A range of biodiversity components were covered by the examined literature (Table 5). Few studies relating to bryophytes, lichens, fungi, frogs, ground mammals and arboreal mammals could be sourced. The main studies focused on birds and vascular plants.

Studies mainly rated land clearance as the main threatening process to biodiversity. Land clearance came in a range of guises: the conversion of native vegetation to cropping; conversion of semi-natural vegetation to cropping.

Studies in the agricultural region tended to be more landscape incorporating than studies within other regions. These studies also tended to incorporate more than one component of biodiversity. Bridle et al (2009) looked at biodiversity (invertebrates, vascular plants, birds) on a national scale.

Unlike other regions, bryophytes and lichens are well studied in the present region, but not individually. Instead they are treated as a functional group termed 'biological crusts'. The literature reviewed is only a small portion of what has been published. Biological crusts were studied in conjunction with other components of biodiversity e.g. vascular plants. Virtually no studies were found for fungi.

Central West Rangeland grazing

Of the 19 papers reviewed, a significant number of studies focused on bats and birds (Table 6) (Fischer et al, 2010a, Fischer et al, 2010b, Kavanagh et al 2005, Law and Chidel, 2006, Lentini et al 2012). It should be noted that Kavanagh et al 2005, Law and Chidel (2006) and Lentini et al (2012) are studies from just outside the Central West area. Vascular plants were analysed together with invertebrates (e.g. Oliver et al 2006 included invertebrates and trees).

The decline of scattered trees in paddocks was highlighted and their importance emphasised (Fischer et al 2010a). Similarly to the Hume region, studies were related to fragmentation in the landscape, the presence of remnant vegetation in a landscape of grazing and cropping. Kavanagh et al (2005) is similar to Lindenmayer et al (2008) where both studies have had a broad taxonomic focus. Kavanagh et al (2005) looked at a broad regional area around Albury – Wodonga, and assessed the effect of eucalypt plantings on birds, bats, arboreal marsupials, terrestrial mammals, reptiles and amphibians. Both these studies listed habitat loss and land clearance as major negative impacts on biodiversity.

A review of 'faunal response to revegetation in agricultural areas of Australia' was published by Munro et al (2007). The review included 27 studies and found that birds were the most studied group, with 9 studies considering multiple groups. Bird studies were a major component of this literature review. The review by Munro et al (2007) gives a good overview of the biodiversity studies in agriculture in Australia.

Eden region – Native Forestry

A total of 38 studies were reviewed and tabulated (Table 7, Appendix 6). The majority of studies considered arboreal marsupials (e.g. studies on the threatened Yellow Bellied Glider (Binns and Kavanagh, 1990a, Binns and Kavanagh, 1990b, Braithwaite, 1983, Braithwaite et al, 1988, Braithwaite et al, 1983, Goldingay and Kavanagh, 1993, Kavanagh, 1987). Vascular plant papers were also predominant, primarily due to the 'Eden Burning Management Area' and flora surveys of State Forest (Penman et al, 2011, Penman et al, 2008a and b, Penman et al, 2009). These papers documented the changes in understorey vascular plant species richness and abundance, over a period of 15 years, under various logging and burning disturbance regimes. Papers focusing on birds, ground mammals and frogs were common; those on birds were mainly concerned with threatened species (e.g. Kavanagh, 1996, Wintle et al, 2005). Papers on frogs were dominated by studies of the giant burrowing frog *Heleioporus australiacus,* a listed threatened species (Penman et al, 2006, Penman et al, 2008, Penman et al, 2005). Studies incorporating fungi were few (Claridge et al, 1993, Jumpponen et al, 2004). Fungi was inherent within a study focused on ground dwelling mammals (Claridge etal 2008). Mycological studies included those that covered the Eden region and extended into East Gippsland. Bryophytes and invertebrates papers were hard to find. No bryophyte or lichen papers were found for the study area; there is one bryophyte paper listed from East Gippsland but it basically only included a species list (Chesterfield 1996). Invertebrates were inherent in studies of birds. Invertebrate studies were rare (Anderson et al 2009). Other studies were found, but were outside the study area (e.g. studies in native forest elsewhere on the east coast of New South Wales). Genetic diversity was not covered in any papers reviewed. Disease (chytrid fungus) was listed as a threatening process for amphibians.

The majority of studies were related to modification of native vegetation, specifically impacts of integrated logging (saw logs and woodchips) on native forest. Land clearance, fire frequency, logging and habitat loss were all identified as key threatening processes for biodiversity in the Eden Native Forest region. Studies incorporating the Eden Burning and Logging Management Area are a good reference for vascular plant ecology and different burning and logging regimes. Data from these studies is based on long term monitoring (1986 – 2002) and a replicated study design (Penman et al, 2009, Penman et al, 2008). Time to recovery was able to be estimated due to the long-term nature of the study.

A few studies included more than one component of biodiversity (Binns and Kavanagh, 1990a, Binns and Kavanagh, 1990b, Catling and Burt, 1994, Kavanagh and Webb, 1998) and one of these also included long term data (Kavanagh and Webb 1998). The latter study analysed the effects of variable-intensity logging on mammals, reptiles and amphibians from 1983 – 1992. The data from this paper provided good information on time to recovery for a range of flora and fauna, including threatened species.

Hume region – Pine Plantation.

A total of 30 studies were reviewed and tabulated (Table 8). A large number of studies covered birds, reptiles (more specifically, lizards) and arboreal mammals (more specifically, possums and gliders). Studies were available for three terrestrial mammal species: Agile antechinus *Antechinus agilis* (Banks et al, 2005a,b), Bush rat *Rattus fuscipes* (Peakall et al, 2006) and Common wombat *Vombatus ursinus* (Rishworth et al, 1995). Three studies relating to invertebrates covered beetles (Stone et al, 2010; Schmuki et al, 2006) and millipedes (Car, 2010). Bryophytes, frogs and macropods were considered by one or two papers each. Studies were lacking for the lesser known taxonomic groups – lichens and fungi. Vascular plant studies were virtually absent.

The majority of the studies were related to habitat fragmentation, specifically the fragmentation of native forest within a landscape matrix of *Pinus radiata* plantation. A representative example is Lindenmayer et al (2008), which is a long-term quanitative study with a broad taxonomic focus, covering terrestrial and arboreal mammals, birds and lizards. Between 1998 and 2005, a range of ecological methods were employed in plantation compartments of different age classes and unfragmented native forest (control), capturing fragmentation at a landscape level. The experimental design in such studies enables tracking of faunal responses in remnant patches of native forest as the plantations reaches maturation. This study and others by Lindenmayer et al are part of the "Tumut Fragmentation Experiment".

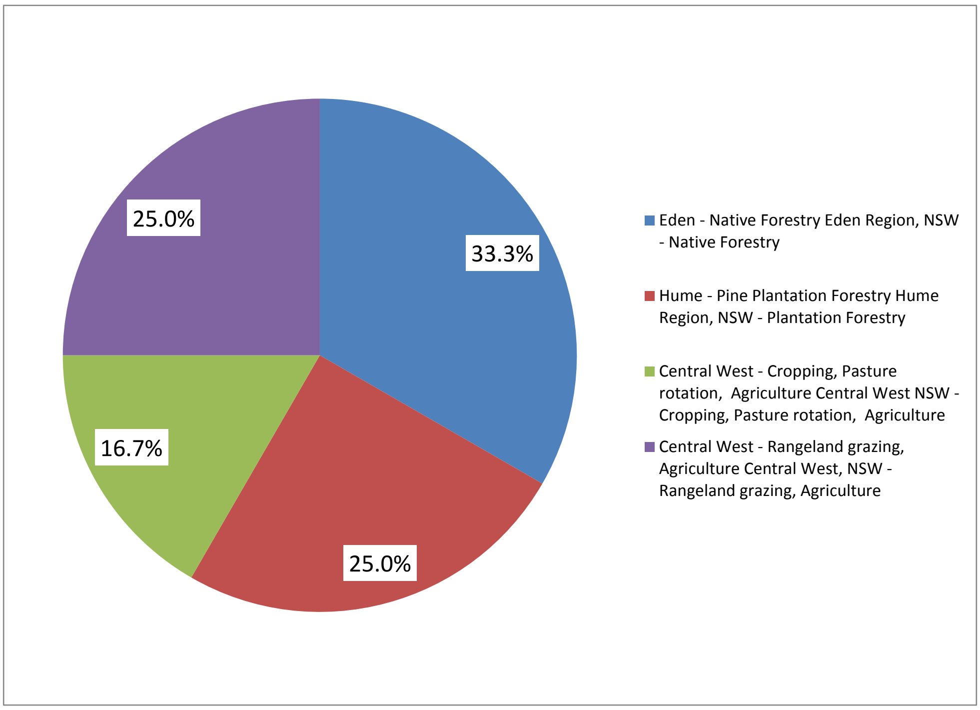
No studies were found considering fungi or lichens or bats. Both lichen and fungi groups are difficult taxonomically and few specialists exist. For example, bryophytes were studied, and although it would have been logical to include them in the same study, it was considered 'too hard' (E. Pharo per comm. 2013). Genetic diversity was only covered by one study, in which reduced dispersal in male *A. agilis* due to habitat fragmentation was supported (Banks et al, 2005b). Likewise, land conversion was only covered by one study (Lindenmayer et al, 2001 – grazing land converted into pine plantation), as the rest used established plantations as study sites, relying on data captured from nearby unfragmented (continuous) native forest as a comparative control. The impacts of harvest or invasive species (possibly promoted by landscape changes) are not assessed in any of the available literature. No studies were found considering threatened ecological communities and few considering threatened species (Lindenmayer et al, 2008 – Speckled warbler *Pyrrholaemus sagittatus* and Brown treecreeper *Climacteris picumnus*; Parris and Lindenmayer, 2004 – Northern corroboree frog *Pseudophryne pengilleyi*).

Survey data

A total of 24 people out of 43 responded to the majority of the survey. Responses were received primarily via the online survey, with a few extra via email and over the telephone. Twenty-five people responded online. Eight of the 25 online respondents did not attempt to answer any questions. These eight were excluded from analyses. Of the remaining online respondents (17), one did not indicate "Region" or "Expertise" but could be allocated to these criteria from their answers and so their data was retained. Two additional respondents answered questions via email; one of these answered for all four case study areas, thus the total email response was '5'. Two additional respondents answered questions for the first time during the second round follow up survey (telephone). Therefore the total number of 'respondents' was 24. The Eden case study had the highest number of responses (33%), followed by Hume and Central West rangeland grazing (25%), (Figure 7).

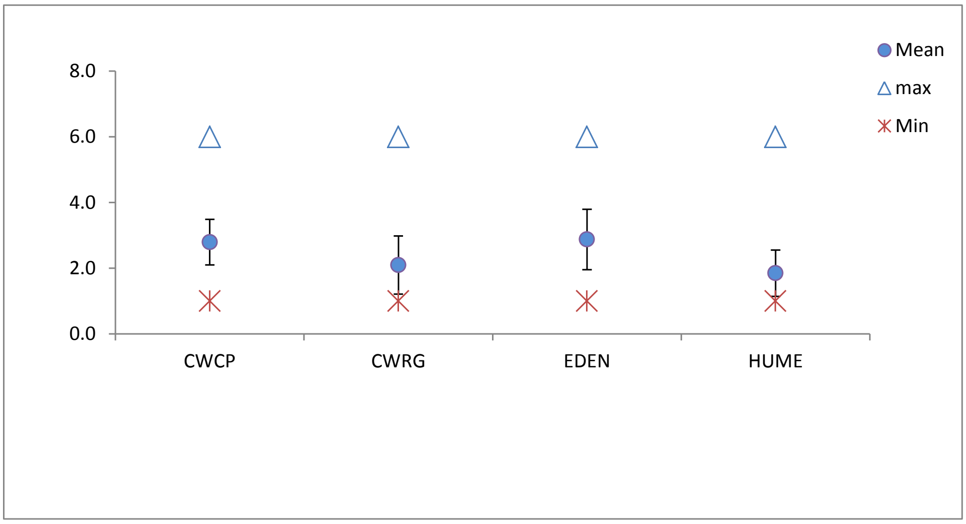
The second follow up email asking for further clarification of answers was able to gain a response from nine experts. A further four experts were willing to respond to the follow up survey, however no suitable arrangement could be found to facilitate this within the timeframe allowed.

Figure 7. Response to survey by region



Overall, there was even representation of taxonomic expertise for each study area (Figure 8). Eden scored highly in expertise for most taxonomic groups. All regions scored low for the lesser known groups: invertebrates, bryophytes, lichens, and fungi (see Appendix 3).

Figure 8. Expertise by case study area. Y axis = Range of expertise in a taxonomic group (1 = no expertise; 6 = greatest expertise). Mean = sum of all values divided by the count of values. Max = maximum score; Min = minimum score; error bars show 95%CI. CWCP = CentralWest Cropping/Pasture; CWRG = CentralWest Rangeland Grazing; Eden= Eden Region Native Forestry; Hume = Hume region Pine Plantation Forestry.



Questions 13b and 13d were excluded from analyses. Little to no data was received for these questions irrespective of case study area and whether data was recorded from the survey or the literature.

Total Biodiversity Impact Scores

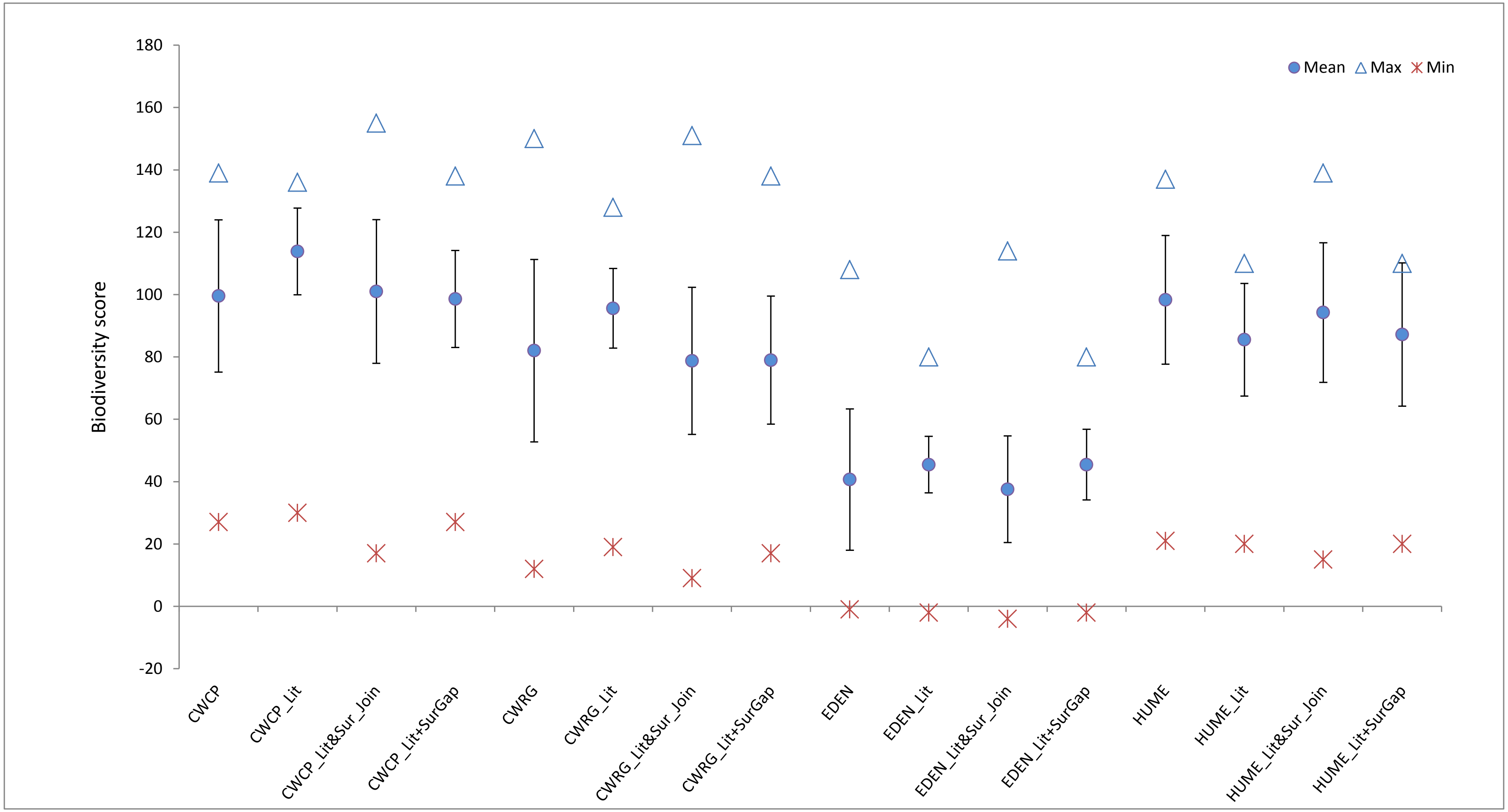
The distribution of scores for individual questions per case study area is shown in Appendix 7. Biodiversity scores were added together to give a total score for each region (Figure 9).

Figure 9 shows the four methods utilised to derive a biodiversity score using an additive method of summing across questions. CWCP, CWRG, EDEN and HUME show the mean and 95% confidence intervals for the survey data only. The suffix of 'Lit' indicates only literature data is used; 'Lit&Sur_join' indicates where survey and literature data has been combined for a case study area; 'Lit+SurGap' indicates where survey data has been inserted where gaps (no data) existed after the literature review.

Irrespective of method, biodiversity impact scores for CWCP, CWRG and Hume were highest, with Eden having the lowest biodiversity impact scores (Figure 9). All four methods show little variation in the mean biodiversity score. However, when using literature alone, for all apart from Hume the mean is greater than other methods, and the confidence interval bands are tighter (Figure 9). When considering literature alone, the mean biodiversity impact score for CWCP is highest, followed by CWRG, Hume and Eden (Figure 9).

Scores for each individual question can be found in Appendix 7. CWCP had a mean biodiversity impact score demonstrating a lower than expected impact on biodiversity. For many other questions (Appendix 7) CWCP and CWRG scores were often at either end of the scales or mirroring each other, which may explain the lack of a more marked difference in the mean biodiversity scores shown in Figure 9. The invertebrates appear to respond differently to these processes compared to all other taxonomic groups (Appendix 7.).

Figure 9. Added mean, maximum and minimum biodiversity score per region for survey data (CWCP, CWRG, EDEN, and HUME), Literature only (Lit), literature data plus survey together (CWCP_Lit&Sur_join, CWRG_ Lit&Sur_join, EDEN_ Lit&Sur_join and HUME_ Lit&Sur_join) and literature data plus survey data inserted where no literature existed (CWCP_Lit+SurGap, CWRG_Lit+SurGap, EDEN_Lit+SurGap and HUME_Lit+SurGap). CWCP (Central West cropping/pasture agriculture); CWRG (Central West rangeland grazing agriculture); Eden (Native species forestry) and Hume (Pine plantation forestry). Error bars show 95%confidence interval..



Net Primary Productivity (NPP)

The NPP values derived for each production system included in this study are shown in Table 10. The values are broken down into "grassy NPP" and "woody NPP". The woody NPP values were higher than the equivalent "grassy NPP" values, with the exception of the central west area when all national parks and state forests were excluded (Table 10).

The managed forests in both Eden and Hume regions have a higher NPP than their equivalent counterparts in national parks (Table 10). The total NPP for the national parks in the central west region was only slightly higher than the NP for the central west area when all state forests and national parks were excluded (Table 10).

Table 10. NPP values for each production system.

NPP ($gC/m^2/yr$)				
Region	**Sub-region**	**GRASSY NPP Mean (SD)**	**Woody NPP Mean (SD)**	**Total NPP Mean (SD)**
Eden	***Eden_total area***	0.536 (0.17)	1.739 (0.29)	2.275 (0.24)
Eden	***Eden_State Forests***	0.464 (0.07)	1.929 (0.21)	2.393 (0.20)
Eden	***Eden_National Parks***	0.502 (0.14)	1.800 (0.21)	2.302 (0.13)
Hume	***Hume_total area***	0.911 (0.39)	1.061 (0.49)	1.973 (0.29)
Hume	***Hume_Softwood***	0.487 (0.21)	1.926 (0.41)	2.414 (0.24)
Hume	***Hume National Parks***	0.504 (0.24)	1.446 (0.43)	1.950 (0.32)
Central West	***CMA excluding National Parks and State Forests***	0.981 (0.51)	0.606 (0.37)	1.587 (0.60)
Central West	***Average of National Parks in CMA***	0.674 (0.33)	1.037 (0.45)	1.710 (0.44)

Species richness

The number of species per taxonomic group and number of records per taxonomic group, by case study area, are shown in Figures 10, 11 and 12 and Table 11.

Table 11. Number of species per taxonomic group and number of records per taxonomic group, by case study area. Eden: Eden Region,; Hume: Hume region; CW: Central West region; NP: National Park,; SW = Softwood Plantation; SF: State Forest; Total: total number of records or species; R: records

	Bryophytes	Bryophytes_R	lichen	lichen_R	Vascular plants	Vascular plants_R	Fungi	Fungi_R	Invertebrates	Invertebrates_R	Amphibians	Amphibians_R	Reptiles	Reptiles_R
EDEN	206	893	144	438	2395	242748	102	477	1816	6978	34	3926	53	6616
HUME	334	3046	151	864	2826	155362	49	108	1903	16521	40	4470	87	4475
CW	165	587	231	731	3132	153005	79	120	2063	9808	43	3980	146	7491
EDEN_NP	103	276	72	144	1556	118308	64	263	261	760	23	357	34	881
HUME_NP	229	1719	88	405	1534	53781	20	55	872	4428	24	2479	57	2045
CW_NP	70	174	109	229	1732	45170	14	17	363	2230	27	434	86	1510
EDEN_SF	94	163	30	49	793	45680	41	97	355	515	25	1532	27	721
HUME_SW	13	19	7	12	537	3691	3	3	77	179	11	333	25	158
CW_SF	24	29	16	18	1170	4449	7	7	111	248	19	106	57	297

	Ground Mammals	Ground Mammals_R	Large medium mammals	Large medium mammals_R	Arboreal Mammals	Arboreal Mammals_R	Bats	Bats_R	Birds	Birds_R	Total	Total_R
EDEN	21	10027	15	19959	11	14140	23	3559	362	118712	5182	428473
HUME	23	2719	16	3090	12	1950	23	4004	336	271565	5800	468174
CW	30	2151	17	3441	10	961	27	2997	489	285586	6432	470858
EDEN_NP	21	1252	14	2298	11	2083	20	1310	357	16794	2536	144726
HUME_NP	17	1513	14	1459	11	703	24	2479	251	24254	3141	95320
CW_NP	16	538	14	974	9	733	22	1214	310	45495	2772	98718
EDEN_SF	20	6540	13	13686	11	10363	17	1511	231	32432	1657	113289
HUME_SW	11	80	9	71	8	85	10	51	181	3694	892	8376
CW_SF	11	142	13	196	8	770	22	450	238	9640	1696	16352

Table 11 also shows the recordings of occurrences of a species, for that area. For example, in the Eden Region there were 206 species of bryophyte present. There were 806 recordings, showing the number of recordings taken to generate the species list of 206. Likewise, for Eden Region there were 362 bird species present and 11872 occurrences were recorded to generate a list of 362 species. The total number of recordings and the total number of species per taxonomic group were highest for CW compared to Hume and Eden (Table 11). Eden had the lowest number of recordings and number of species (Table 11) – the opposite result to that show in Figure 3, where Eden had the lowest biodiversity impact scores, regardless of the approach used.

The taxonomic groups with the most species are vascular plants, invertebrates and birds (Figure 10). Of these, it is clear that vascular plant records are proportional to the number of species present. However, there is disproportionate representation for birds where recordings of occurrences far outweigh the number of species recorded, and invertebrates where the opposite is true (Figure 10).

Figure 10. Species richness per region per taxonomic group. Appendix _ lists species within groups. '_rec' indicates the number of records downloaded from the ALA for that taxonomic group.

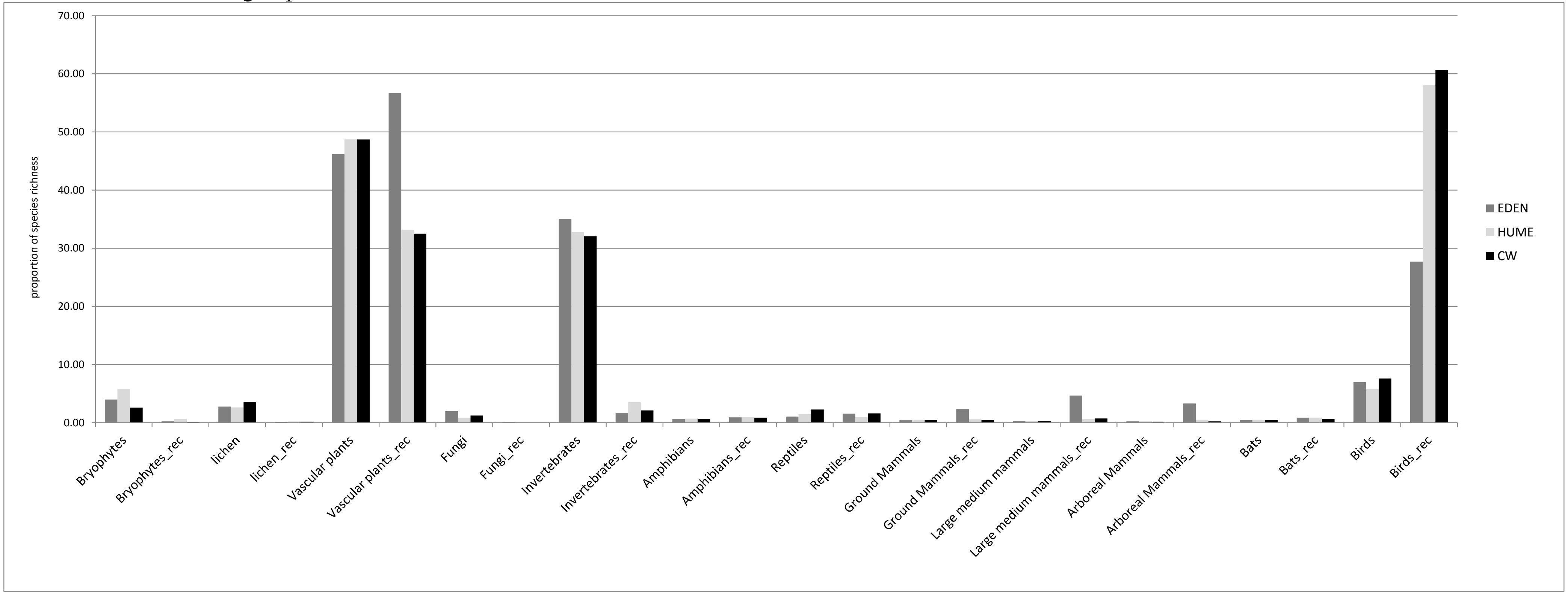


Figure 11. Species richness per region: National Parks area per taxonomic group. Appendix 1 lists species within groups. '_rec' indicates the number of records downloaded from the ALA for that taxonomic group

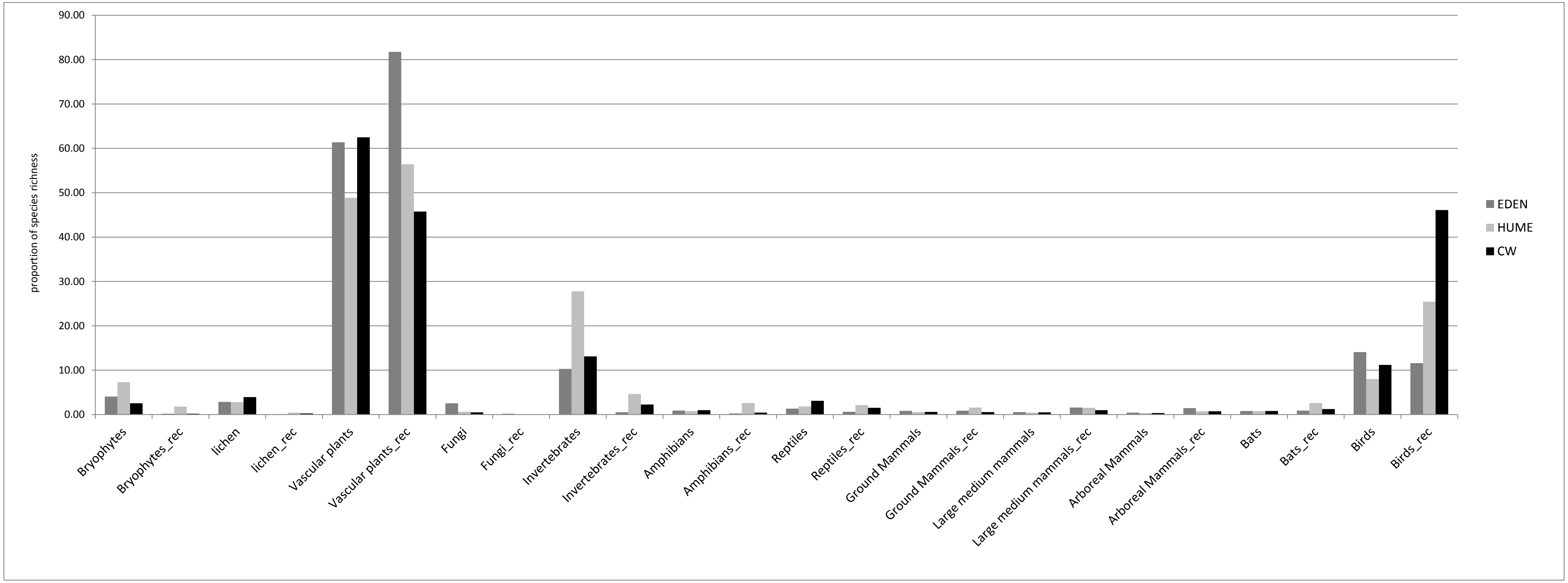
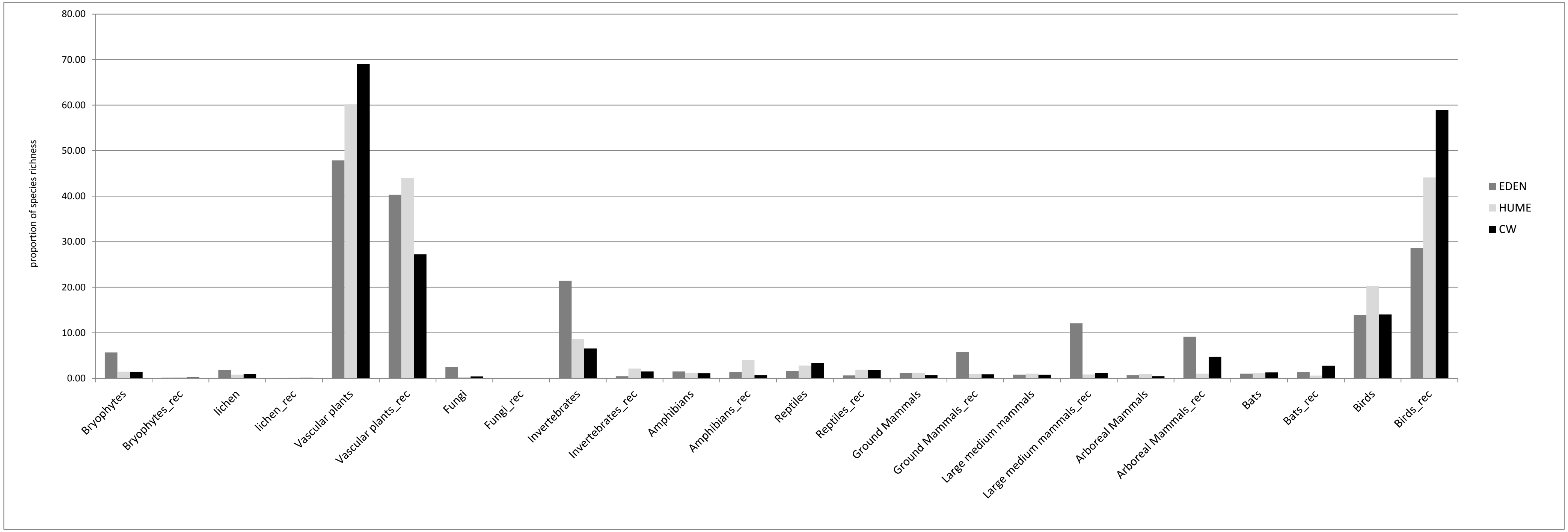


Figure 12. Species richness per region: State forest/Softwood area per taxonomic group. Appendix 1 lists species within groups. '_rec' indicates the number of records downloaded from the ALA for that taxonomic group.



Discussion

In this section we aim to divide the discussion into different components; namely refinement and improvement from the survey and literature results; how BioImpact compares with NPP and species richness results for the same regions; key steps for the application of BioImpact; the application of Bioimpact in LCA and future directions. Given that the experience of applying our initial method led to considerable improvements that were subsequently incorporated into the final version, it is important to emphasise that the results tabulated and graphed in this report are not treated as final responses to the BioImpact metric.

Survey and literature results

In biodiversity literature, there are multiple reasons for bias towards particular groups: funding related to conservation (logging, land conversion); greater expertise on charismatic species; data relatively easier to collect than lesser known components of biodiversity (e.g. non-vascular plants); public and/or political pressure. For example bryophytes and lichens (biological crusts), two groups usually overlooked in many ecological studies, are well covered in the rangeland grazing systems of western NSW due to work by Eldridge et al (2006). One bryological study (Pharo and Lindenmayer, 2004; Pharo et al, 2009) is all that exists for pine plantation in Australia. Studies in the area of below ground fungi (e.g. mycorrhizal associations), are more focused on crop production than biodiversity. Mycological studies are often intermixed with those focused on ground dwelling mammals; studies on fungi (and potoroos) were found only for native forests. Likewise, invertebrate studies are entwined with bird studies. In both cases, for the most part, there is little to no biodiversity data on the lesser known group of these studies. Vascular plants are not necessarily well covered for all areas – e.g. only one study was found for vascular plants in the Hume region. This is primarily because vascular plant diversity is low in exotic pine plantations. Above ground fungi are rarely observed in the agricultural sector.

All the points above suggest that attempting to include all different taxa in the responses to the survey may be unrealistic from an empirical data, literature or even expert point of view, and may lead to biased and/or incomplete responses. Thus, in the final version of the questions included in BioImpact (Recommendations section below), the answers to most questions consider biodiversity as a whole, rather than focussing on individual taxon as a general rule. However, we recommend, where possible, that a broad base of experts specialising on different taxa are consulted when obtaining responses to the questions.

The biodiversity impact results for CWCP and CWRG were not as high as expected (Figure 3). Cropping/pasture disturbance, which was expected to score highly as a negative impact on biodiversity, was viewed as similarly negative with rangeland grazing across all methods, and slightly higher when literature alone was used. It was also expected more of a difference between the biodiversity impacts for the Hume region and cropping/rangeland grazing. The similarities in the results for CWCP and CWRG may be explained by the scoring for some questions. In Questions 1a and 1b respondents were asked to answer based on taxonomic groups. The invertebrates appear to respond differently to cropping/pasture and rangeland grazing processes compared to all other taxonomic groups, That is, some invertebrate groups respond positively to disturbance. Our literature review supports this opinion: Cunningham et al (2005) found little difference in species richness for Coleoptera (beetles), Lepidoptera (moths) and Hymenoptera (ants, bees and wasps) between remnant vegetation, cleared farmland and tree plantings. Similarly, survey respondents for Question 1a gave low values for large medium mammals in CWCP compared to CWRG, with the low values given the caveat by the respondent that ‘large mammals variable -some increase like grey roos, others decrease’. It was also apparent that some experts misinterpreted questions leading to erroneous scores. These unreliable responses and associated comments were of great assistance in refining BioImpact, especially the wording of questions, issues of spatial scale, and providing more guidance on scaling the scores for each question.

The biodiversity impact scores calculated for the Eden region from both the literature review and expert survey were clearly lower than for other production processes, unlike the NPP and species richness methods. This demonstrates the sensitivity of BioImpact for discerning differential impacts of land-use. The results for the Hume region from the literature and expert survey did not take into account the extent of remnant vegetation typically left along creek lines (15%, according to Forests NSW, 2008). That is primarily because the description of the production system in the Hume region that went to survey respondents did not make this as clear as it could have been. The overall biodiversity scores for the Hume region may have been lower if a clearer, more detailed description of the study area and process had been given to respondents.

The key objective of the use of the case studies selected here was to inform further development and refinement of the BioImpact. The use of these case studies highlighted many issues that have been addressed and reflected in the final set of questions listed below. The relative scores for the different production systems presented here reflect the use of BioImpact in a dynamic state of development. The use of the questions as presented below may have resulted in different scores for the different production systems, although we do not anticipate they would have changed drastically, as the concepts included are largely the same.

Comparison with NPP and species richness

The high NPP results for the forests managed for production compared to the equivalent national park areas reflects the higher productivity associated with the areas managed for commercial purposes. This also highlights the inadequacy of using NPP as a surrogate for biodiversity, as in this scenario, a pine plantation in Hume would have higher biodiversity value than native forests contained in national parks in the same region, and also a higher biodiversity value than the Eden native forests managed for hardwood timber production. The use of NPP as a surrogate for biodiversity has also proven inadequate for different ecosystems; for example, desert systems have low NPP, but extremely high diversity of many groups such as reptiles (e.g., Cogger 2000).

Use of species richness as a proxy for biodiversity in the case studies here would have ranked CW systems as having a lower biodiversity impact score than that of Eden and Hume managed forest systems. One main feature of the species richness data is the disproportion in species groups that have been recorded. It is obvious that the larger and taxonomically 'easy' species are the ones with the most recordings e.g. birds and vascular plants. However, invertebrates also make up a significant number of species from a region, with less recording effort resulting in more species. Curran et al (2011) conducted a review of the use of indicators to model biodiversity in LCA. They found serious conceptual shortcomings in the way models are constructed, with scale considerations largely absent, and a disproportionate focus on species richness. In addition, most available models are restricted to one or a few taxonomic groups and geographic regions (Curran et al 2011).

Another limitation of species richness is that ecologists often consider species composition to be a more important attribute when considering change to a system. For instance, it is feasible that species richness may not change when an ecosystem is altered, but the composition could change from sensitive, conservation-dependent species to widespread and common disturbance-adapted species. Our method attempts to deal with this by placing emphasis on changes in species composition (including the concept of evenness) rather than change in species richness alone. This is also reflected more recently in the direction taken by researchers away from those indicators as a proxy for biodiversity, and towards concepts such as the use of trait data to derive functional diversity (Souza et al 2103) and the incorporation of vulnerability and irreplaceability principles (Mueller et al 2014).

BioImpact application

The development of the biodiversity data required for a given production system needs to be undertaken by an experienced ecologist. This is because there are three key pre-requisites for the application of BioImpact: knowledge of where to find the relevant literature, capacity to extract key information, and knowledge of ecological networks useful in the identification of key experts.

The following practical steps are recommended for the application of BioImpact to derive biodiversity scores for production systems:

1) Carry out initial literature survey for region and production system in question (including "grey" literature)
2) If in the initial literature review gaps are identified, carry out a secondary literature survey for any literature available for areas with similar production systems and species composition, to be used as a proxy.
3) Expert consultation either remotely (e-mail, discussions via Skype) or via a workshop with selected experts. The specific structure of this step is ultimately the discretion of the person applying BioImpact. As a guide, we suggest that the consultation process could adopt the following structure:

    - Consult experts with a range of taxonomic expertise
    - Presentation of the scenarios with clear descriptions of the regions in question and system boundaries, including any mitigation measures that the process follows to minimise impacts on biodiversity
    - Ask experts to give their scores for all questions
    - Present the scores derived from the literature review process and expert input to the experts, to allow experts to reflect on their original response in the context of other responses.
    - Carry out a final scoring round to achieve consensus, if the scatter in the data is high. This also allows experts to revisit their original scores and change them if they have misinterpreted any particular question

4) Use the literature review to obtain scores for the different questions, complemented by expert input where literature is non-existent
5) Determine a total biodiversity score by adding the individual scores for each question

Key advantages and limitations of BioImpact

A key point of difference between BioImpact and other methods is the level of coverage of key ecological concepts for incorporating biodiversity into a disturbance framework. The following are considered to be key advantages of BioImpact:

- Easily applied by an experienced ecologist at national and global levels using existing literature and surveys of experts
- Robust – incorporates the strength of published literature as well as harnessing the direct, site-specific expert knowledge which is often not represented by available literature.
- It does not only focus on one indicator or taxa, but rather on a series of concepts, strengthening the final score.

- Scores are presented for each question, making it easy to identify "hot spots" for a given production system, and where practice / land management needs to improve.
- Transparent – all data included in a public database.
- Allows fair comparison between land use options using a consistent method.

We have also identified challenges associated with the use of BioImpact. Although this is unlikely to be the case for the vast majority of significant production processes included in LCAs, for some production systems and regions, the lack of extensive literature and limited expert knowledge may hinder the development of the required scores. In this instance, one option would be to seek, as a proxy, literature from similar regions and use expert advice from other ecologists in the same country. This would allow the scoring of the questions and would also highlight to the research community where obvious gaps in the knowledge are. The issue of lack of relevant empirical data is one of the key issues hindering the use of other proposed methods for assessing biodiversity impacts in LCA (e.g. de Baan et al (2013) and Coelho and Michelsen (2014)). Mueller et al (2014) proposed a weighting system based on absolute species richness, vulnerability and irreplaceability; however attempts to incorporate transformation impacts in addition to plant species richness data (occupation effects) were challenged by the lack of empirical data.

The costs associated with the development of the scores required for BioImpact have not yet been determined, as the activities in this project were primarily concerned with its development and refinement. Thus, this could be an impediment for its widespread application. Once BioImpact, in its final recommended format described below, is used in the development of biodiversity impact data for future LCAs, we will have a clearer idea of the time and costs involved. We estimate that carrying out the literature review, scoring the questions and seeking expert input would, require 5-8 weeks for a given production system. The development of data for a number of key production systems in one project would be beneficial, as economies of scale would mean that the average cost per production system would be lower.

Application in LCA

BioImpact allows integration of the scores within the context of a life cycle impact assessment, either as an add-on module to a LCA model, or potentially as core part of a LCA database. It may potentially also be used as a method to be applied after an initial, more simplistic method is applied and results are deemed inconclusive or unsatisfactory, although we suggest more simplistic methods are unlikely to produce meaningful results.

BioImpact can be implemented in an integrated fashion with LCI units as core part of a LCA database. The inventory data required by the method is achievable, as it is already part of existing practice, or could be with only minor adjustments. In this case, it may be appropriate to combine the biodiversity scores with a measure of land occupation or land transformation, as typically used in LCAs. For the case studies selected here, the relevant elementary flows may be:

1) For cropping and pasture: Transformation, mixed cropping and pasture;
2) For hardwood production: Occupation, Eden forest extensive;
3) For plantation softwood production: Transformation, Hume forest intensive

The units of land occupation and land transformation typically used are area*time, e.g. m^2a (square metre-years). Typically the long-term production average (e.g. 50,000 m^3 of timber / year), and the area required to produce the goods are the key parameters needed. Using as an example the forestry production systems included here, the land occupation and transformation units are included in Table 12 below (data supplied by the Forestry Corporation of NSW). However, this does not consider the total area of the operation required to be able to have a sustained yield per year, which is a key concept for considering overall impact on biodiversity. Thus, in Table 12 we also include a measure of the land occupation and transformation divided by the overall extent of the production process (which coincidentally for both regions is around 89,000 ha).The comparison of the area*time values between production systems that produce goods that do not necessarily perform the same function (e.g. native hardwood used for floorboards / high-value furniture cannot be replaced by plantation softwood timber) is not relevant, as they are not competing with each other. However if different regions produce goods that are used for the same purpose (e.g. plantation softwood timber from the Hume region of NSW compared to plantation softwood timber from the central tablelands of NSW), then the area*time values are directly comparable. If the softwood plantation has been established on a cleared native forest area, then the transformation impact of the activity as well as the intensity of production need to be taken into account. Native hardwood production, although more land-demanding, does not result in the transformation of the original landscape to the same degree as for plantation forestry. It can be argued that the transformation/occupation aspect and the concept of "production intensity" reflected in Table 12 below are already captured in several of the questions included in BioImpact. This reflects the complex nature of the task of "assessing" biodiversity – different concepts are intertwined.

Table 12. Land transformation and land occupation impacts due to native hardwood production in Eden and plantation softwood production in the Hume region.

Production system	Elementary flow	Area harvested / year (ha)	Volume harvested / year (m3)	m^2a ($m^2/m^3.year^{-1}$)	m^2a / total harvestable area ($m^2/m^3.year^{-1}$/'000ha)
Native hardwood; Eden	Occupation, Eden forest extensive	1260	220,000	57.5	0.64
Plantation softwood, Hume	Transformation, Hume forest intensive	3642	1,769,688	20.6	0.23

It may be possible though to explicitly link the concept of "production intensity" to the biodiversity score obtained as a result of BioImpact. Care would need to be exercised in doing so numerically to avoid awarding "production intensity" too much weight. Until a satisfactory numerical relationship can be worked out, we recommend the use of BioImpact as an "add-on module" to LCAs rather than being part of the LCI database of a product or production system.

Where to from now

One of the important considerations for wider use of BioImpact is public availability of data for a range of key production systems, in an accessible format. It is proposed here that the database containing the background information used to develop the scores, and the actual scores, be housed by the Australian Life Cycle Assessment Society (ALCAS). Discussions will be held with ALCAS senior management to gauge the feasibility of this approach.

As part of the dissemination strategy for this project, the following activities will take place in the next few months:

- A final report delivered to FWPA and made public at FWPA's website
- A webinar detailing key results of the project to key stakeholders / FWPA members
- Preparation of a manuscript for publication in the peer-reviewed International Journal of Life Cycle Assessment (IJLCA)

- Oral presentation at the upcoming NZ LCA conference
- Short workshop offered at the upcoming NZ LCA conference

In addition, discussions are under way to apply BioImpact in agricultural LCA projects currently being developed and/or proposed by researchers at NSW DPI. These opportunities will be pursued upon completion of this project.

As mentioned above, one of the items in the dissemination plan for this project is the preparation of a manuscript for submission to the IJLCA. For this manuscript, some aspects of the required work that were not comprehensively covered here will be included. These will include further work on the scoring system (e.g. potentially the introduction of a weighting system based on the idea that some questions should have a different weight to others; introduction of a multiplicative approach to combining scores). Some further work will be carried out in the development of the uncertainty analyses associated with the scores, and how to deal with data quality.

Conclusions

The following are key conclusions from the work undertaken here:

- Existing methods such as NPP and species richness were deemed inadequate in the assessment of how biodiversity responds to different disturbance impacts or processes in the context of the forestry and agricultural production systems considered.
- BioImpact captures the key concepts required for assessment of biodiversity implications and for inclusion in LCAs.
- The application of BioImpact in the context of the forestry and agricultural production systems included here resulted in scores that largely reflected expectations in how they would rank, with production of native forest hardwood in Eden having the lowest biodiversity impact score.
- Using biodiversity (species composition) as a whole as the basis for the responses to most questions rather than a taxon-specific approach was deemed preferable. This is due to a lack of specific literature and experts for many diverse but poorly known taxa, and this approach is reflected in the final set of questions recommended.
- The publication of scores for every question included in BioImpact allows the LCA practitioners to identify areas where practices and land use management could be improved for a given production system.

Recommendations

The following are key recommendations suggested by the project team as a pathway for further development and implementation of BioImpact:

- BioImpact should be used to populate a database that would be freely available to LCA practitioners, beginning with the case studies considered in this report.
- Further support for a project to populate a database with a number of key production systems for AUS and NZ where biodiversity impacts are of concern. This would lower the average cost of study per production system.
- Application of BioImpact for current LCA projects (e.g. NSW DPI agricultural LCAs)
- Investigate further the options and opportunities associated with the process of integrating BioImpact in LCA systems.

The revised set of questions that we recommend to be used in future assessments of production systems is included below.

Definitions
Benchmark A benchmark is a reliable point against which a change can be quantified and studied. For Australian vegetation, a benchmark state would be vegetation with somewhat little modification and disturbance by humans. The introduction of modern technology i.e. the arrival of Europeans is taken as a 'starting point' for vegetation comparison (referred to here as 'pre-1750 vegetation') and while it doesn't exclude the reality of aboriginal disturbance, it accepts aboriginal influence on ecosystems as being 'natural' (Mackey et al. 1998, Machado 2004). A benchmark state can also be considered to be equivalent to the concept of 'naturalness', which is sometimes used in the literature (Machado 2004; Aplet and Cole 2010). Aplet, G.H and Cole, D.N. 2010 The trouble with naturalness: Rethinking park and wilderness goals. In Beyond Naturalness: rethinking Park and Wilderness stewardship in an era of rapid change. Island Press, Washington, DC. Machado, A. 2004. An index of naturalness. Journal for Nature Conservation 12: 95-110 Mackey, B. G., Lesslie, R. G., Lindenmayer, D. B., Nix, H. A., & Incoll, R. D. 1998. The role of wilderness in nature conservation. Canberra: The School of Resource Management and Environmental Science, The Australian National University.
Disturbance event A cyclic or singular stage of a process that has an impact on the natural state of an ecosystem.
Invasive A term used to describe the ecological impact of a species or population: the effect(s) it may have on the environment it has migrated to and the process(es) it has interrupted/changed.
Keystone species A species that has a disproportionately positive effect on ecosystems relative to either their low abundance or limited spatial occupancy.
Natural disturbance regimes A pattern of disturbance events that shape an ecosystem over a long time.
Naturalness A state that has not been influenced and/or made by humans or technology.
Process A primary production system in a defined geographical region.
Recovery The ability of an ecosystem or population to return to a state where a stable structure, function and identity are achieved. The 'time to recovery' can be a measure of resilience.
Resilience The capacity for an ecosystem to absorb stochastic disturbance, such as flood, fire and drought.
Species composition The effective number of different species that are represented in a community.

For description of the processes, see case study descriptions in the methods section.

Questions 1a and 1b.
If the process is implemented on benchmark vegetation or has been in the last 50 years answer Q1 a. If the process has been on-going for more than 50 years answer Q1b.

If the process is implemented on a mix of benchmark and existing ongoing land-use, then answer for the scenario of greatest prevalence in that region.

NOTE - The spatial scale to consider is the management unit directly affected by the process. For example for forestry this may be one or a group of adjacent compartments or in agriculture a whole or part of a farm. When this is not clear a default area of 1,000 ha, which reflects the extent of a local landscape, should be considered an appropriate scale for assessment.

Question 1a. Compared to a benchmark state[1] (e.g. pre-1750 vegetation) appropriate for the region in question, what is the *immediate change in* biodiversity (not simply a change in species richness or relative abundance, but change in composition or evenness is important) as a direct result of the process (disturbance)? 1 A benchmark state for Eden region might be undisturbed old growth forest; for pine plantation pre-existing forest or woodland/grassland; for cropping/pasture and/or rangeland grazing it might be remnant woodland vegetation. For an international audience, defer to 'naturalness'. Definitions for these terms are found in the definitions summary above.	Response Range: +10 = total transformation of species composition from benchmark; +5 = 50 % transformation of species composition, 0 = no change in species composition.
Question 1b. Compared to the land-use immediately prior to the process in question, what is the *immediate change* in biodiversity (not simply a change in species richness or relative abundance, but change in composition or evenness is important) as a direct result of the process (disturbance)[2]? 2 Land-use prior to the process is not considered to be of a benchmark state; for example in the forestry context it may be a mid-succession stage or second rotation crop, and for agriculture it may be annual cropping rotation or seasonal	Response Range: +10 = total transformation of species composition from benchmark; +5 = 50 % transformation of species composition, 0 = no change in species composition.

Explanation

Species composition is the effective number of different species that are represented in a community and the relative abundance of species (). It also related to evenness, which quantifies how equal two communities are numerically. Species richness is a simple count of occurring species, and is used in biodiversity studies more often than composition (Ma 2005). Species composition is more complex, looking at relative distribution of species. For instance, species richness may remain identical after a paddock is replaced by a pine plantation, but the composition of the species is likely to be different (e.g. changes in the proportion of threatened species). An example related to an individual species would be the response of greater gliders to the establishment of a pine plantation; the species does not colonise pine stands, but remains in the plantation estate by persisting in remnant patches of native forest (Pope et al 2004). Even if the abundance of the species does not change within remnant patches, its overall abundance across the estate has declined and its distribution within estate is reduced.

A benchmark is a reliable point against which a change can be quantified and studied. For Australian vegetation, a benchmark state would be vegetation with somewhat little modification and disturbance by humans. The introduction of modern technology i.e. the arrival of Europeans is taken as a 'starting point' for vegetation comparison and while it doesn't exclude the reality of aboriginal disturbance, it accepts aboriginal influence on ecosystems as being 'natural' (Mackey et al 1998, Machado 2004). It should be noted that the pre-1750 benchmark state is being used at a regional level, not site specific level. This distinction is important for biodiversity conservation because for example at a site level there will be vegetation communities that are no longer existent due to changes in conditions (changes in fire regime, salinity etc.) even though they may have been there previously or vegetation communities that are devalued in favour of pre-existing native vegetation, where the latter is no longer optimal for biodiversity conservation. LCA is focused on biodiversity in relation to a production process rather than its prevalence in remnants/specific sites of native vegetation. The concept of naturalness is one recognised at an international scale and is used to describe a state that has not been influenced and/or made by humans or technology (Machado 2004). In this respect, naturalness may be equated with pre-1750 vegetation.

References

Ma, M. 2005. Species richness vs. evenness: independent relationship and different responses to edaphic factors. Oikos 111(1): 192-198.

Machado, A. 2004. An index of naturalness. Journal for Nature Conservation 12: 95-110.

Mackey, B. G., Lesslie, R. G., Lindenmayer, D. B., Nix, H. A., & Incoll, R. D. 1998. The role of wilderness in nature conservation. Canberra: The School of Resource Management and Environmental Science, The Australian National University.

Pope, M.L., Lindenmayer, D.B. and Cunningham, R.B. 2004. Patch use by the greater glider *Petauroides volans* in a fragmented forest ecosystem. I. Home range size andmovements. Wildlife Research 31: 559-568.

Questions 2a, 2b and 2c.

If the process is implemented within the last 50 years on benchmark vegetation answer Q2 a. If the process has been on-going for more than 50 years answer Q2b. If the process is new, but is implemented on land cleared of native vegetation answer Q2c. If the process is implemented on a mix of benchmark and existing ongoing land-use, then answer for the scenario of greatest prevalence in that region.

> NOTE - The spatial scale to consider is the management unit directly affected by the process. For example for forestry this may be one or a group of adjacent compartments or in agriculture a whole or part of a farm. When this is not clear a default area of 1,000 ha, which reflects the extent of a local landscape, should be considered an appropriate scale for assessment.

Question 2a. Consider that the process has been newly established on existing, mature, native vegetation. To what extent does biodiversity (species composition) *recover to benchmark levels before the process is repeated*[3]? 3 See definitions for a description of 'benchmark'. For an international audience, defer to 'naturalness'. Descriptions for these terms are found in the explanation for Question 1. Consider for example in the forestry context, logging of old growth, or where forest has been cleared for plantations establishment, and for agriculture clearance of remnant vegetation.	Response Range : + 10 = 100% positive total recovery of biodiversity, +5 = 50% recovery, 0 = no change.
Question 2b. Consider that the process is not new, but is continuing in the same area[4]. To what extent does biodiversity (species composition) *recover to pre-disturbance (as opposed to benchmark) levels before the process is repeated?* 4. by continuing we mean between the primary disturbance events induced by the process or within 50 years since disturbance for processes that are non-cyclic disturbance events (e.g. mining). For example, in the forestry context, this means second rotation in regrowth, clearfall of an existing plantation and for agriculture, a second year of cropping.	Response Range : + 10 = 100% positive total recovery of biodiversity, +5= 50% recovery, 0 = no change.
Question 2c. Consider that the process has been newly established on cleared land (minimal native vegetation). To what extent does existing biodiversity (species composition) *recover to benchmark*[5] *levels before the process is repeated*? 5 See definitions and Question 1 explanation for a description of 'benchmark'.	Response Range : + 10 = 100% positive total recovery of biodiversity, +5 = 50% recovery, 0 = no change.

Explanation

Following disturbance, an ecosystem develops from a simple stage of organisation to something more akin to a complex community over generations (this process follows ecological succession). The time required for an ecosystem or population to return to a state where a stable structure, function and identity are achieved can be described as the '*time to recovery'* or a measure of resilience. Threatened species management and conservation biology have an extensive history of species focused recovery plans, aimed at mitigating the decline of a species. The species-based approach has also been applied at the landscape scale in the emergent field of ecological restoration, which aims at accelerating the recovery of a system. Clearly different taxa will have different trajectories and time to recovery from a disturbance. For the present question we are focusing on the extent of species composition recovery for a taxon or population between disturbance events induced by the process, within a region. For part (a) above, the disturbance event may alter the pre-disturbance/baseline level and establish a new level (Fig. 1). Subsequent impact may further alter that new level and influence the extent to recovery to pre-disturbance/baseline level. In a moderate system, natural succession trajectories facilitate recovery e.g. remnant components not destroyed by a disturbance.

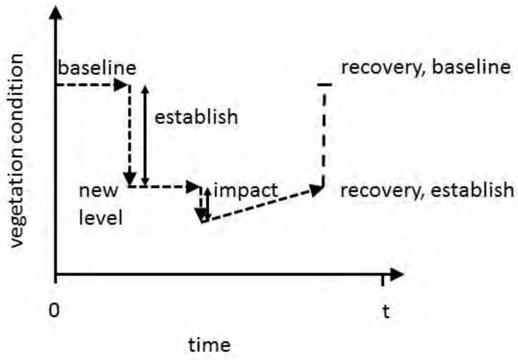


Fig. 1. Illustration of the extent of recovery of a system after disturbance.

Question 3. To what extent does the process alter natural (abiotic) disturbance regimes?	Response Range: + 10 = TOTAL change in disturbance regime, + 5 = 50% change in disturbance regime, 0 = no change in disturbance regime

Explanation

The concept 'natural disturbance regime' describes a pattern of disturbance events that shape an ecosystem over a long time. For many ecosystems (e.g. forests, grasslands), events such as changes in species diversity (e.g. feral predator impact), structure (e.g. land clearing) or function (e.g. alternate fire regime) are viewed as a shift from a natural disturbance regime. Humans have been at the heart of altering many natural systems: fire frequency; fire intensity; fire suppression; insect and pathogen outbreaks; flooding regimes; logging. Disruption of the natural disturbance regime may alter ecosystems resilience to environmental change and function. For example: Does the process increase the risk of fire or alter fire regimes; Are flooding regimes altered (e.g. through damming of rivers and irrigation).

Question 4. To what extent does the process (disturbance) reduce the resilience of the system – capacity to absorb stochastic disturbance – flood, fire, drought?	Response Range: + 10 = 100% reduction in resilience of total biodiversity due to the impact of the process, + 5 = 50% reduction in reduction in resilience of total biodiversity due to the impact of the process, 0 = no change, -10 = major benefit to biodiversity and 100% increase in resilience due to the impact of the process.

Explanation

Disturbance of significant magnitude or disturbance that continues for an extended period can place pressure on an ecosystem that pushes it beyond a threshold, resulting in a regime shift. This capacity of an ecosystem to counter or to absorb the disturbance and recover to an extent that function and structure are maintained is termed resilience. Disturbance may include stochastic events such as fire, flood and drought. Biodiversity has been found to increase resilience of ecosystems from stochastic disturbance or damaging human interference. The resilience of an ecosystem is considered in environmental policy and management e.g. development must consider the impact upon threatened ecosystems and/or species (NSW Threatened Species Conservation Act 1995)

Question 5. To what extent does the process (disturbance) increase the impacts of invasive predators?	Response Range: Scored against taxonomic groups: +10 major impact on biodiversity,+5 = moderate impact, +2 = minor impact, 0 = no impact and -10 = a major benefit to biodiversity?

Explanation

The term "invasive" is used to describe the ecological impact of a species or population: the effect(s) it may have on the environment it has migrated to and the process(es) it has interrupted/changed. An invasive predator is a carnivorous species that is described as occurring beyond an acknowledged historical distribution as a result of human activities. The damage caused by an invasive predator may threaten valued environmental, agricultural or other social resources. Native species may have responded to predator pressure through modifying behaviour or morphology to facilitate escape or avoid detection. Invasive predators can have a severe effect on the population size of native species, where native species have not developed defence mechanisms against the new invader/predator. They have been reported to be two times more harmful to prey populations than native predators (Salo et al 2007) and are implicated in the extinction of many species. Disturbances such as land clearing have created islands of habitat; small refuges for prey populations, while altered habitat extent and complexity can affect the movement and activity of introduced predators. Is the habitat altered in such a way to change levels of predation (e.g. by increasing the abundance and activity of ferals)? etc. These factors heighten the potential for stochastic loss at the patch scale, all in an environment where habitat loss and fragmentation are highly likely (Salo et al 2007, Fischer et al 2006).

References

Fischer, J., Lindenmayer, D.B., and Manning, A.D. 2006. Biodiversity, ecosystem function, and resilience: ten guiding principles for commodity production landscapes. Frontiers in Ecology and the Environment 4: 80–86.

Salo, P., Korpimäki, E., Banks, P.B., Nordström, M. and Dickman, C.R. 2007. Alien predators are more dangerous than native predators to prey populations. Proceedings of the Royal Society Series B 274: 1237-1243.

Question 6. To what extent does the process (disturbance) increase the impacts of invasive plants?	Seek experts in this area and ask for input to this question. Scored against taxonomic groups. Response Range: + 10 major impact on biodiversity; + 5 moderate impact, 0 no change, -10 major benefit to biodiversity

Explanation

As a result of human activities, many plant species have become invasive, that is, these species occur beyond their accepted normal distribution and cause significant damage, which in turn compromises resources such as agriculture and forestry. Invasive plant species (weeds) have been described as the second greatest threat to biodiversity, after habitat loss (humans). Invasive species modify the environment they invade. They displace native species and change burning patterns. In the agricultural region they assist in degrading habitat and arable land e.g. shallow rooted invasive annual grasses don't take up as much water as native perennial grasses, resulting in increased deep drainage, acidification and salinity (Hughes et al 2006). Activities by humans, domestic stock and invasive animals (e.g. rabbits) have contributed to creating conditions favourable to invasive plant growth, dispersal and persistence.

References

Hughes, J.D., Packer, I.J., Michalk, D.L., Dowling, P.M., King, W.M., Brisbane, S., Millar, G.D., Priest, S.M., Kemp, D.R. and Koen, T.B. 2006. Sustainable grazing systems for the Central Tablelands of New South Wales. 4. Soil water dynamics and runoff events for differently-managed pasture types. Australian Journal of Experimental Agriculture 46: 483-494.

Question 7. To what extent does the process (disturbance) increase the impacts of a) herbivores and b) invertebrate pest populations?	Scored against taxonomic groups. Response Range: + 10 major impact on biodiversity; + 5 moderate impact, 0 no change, -10 major benefit to biodiversity

Explanation

Pests are commonly described as species that are damaging to biodiversity, human concerns (such as livestock production) and/or social values. In Australia, herbivorous and invertebrate pest animals include both native and introduced species. For example, kangaroos and wallabies have become pests in disturbed pastoral, agricultural and forestry production areas. These pest herbivores may compete for pasture, leaves, flowers and fruits. Other examples include goats, deer and camels. The impacts of herbivorous pests are greater in areas of disturbance. Watering points increase grazing pressure. Some invertebrate species are favoured by disturbance and abundance and biomass is greater in exotic pastures (Bromham et al 1999). Elsewhere, invertebrate pests have been reported to transmit plant pathogens and/or predispose plants to pathogens (Dorrough et al 2004).

References

Bromham, L., Cardillo, M., Bennett, A.F. and Elgar, M.A. 1999. Effects of stock grazing on the ground invertebrate fauna of woodland remnants. Australian Journal of Ecology 24: 199-207.

Dorrough, J., Yen, A., Turner, V., Clarke, S. G., Crosthwaite, J. and Hirth, J.R. 2004. Livestock grazing management and biodiversity conservation in Australian temperate grassy landscapes. Australian Journal of Agricultural Research 55: 279-295.

Question 8. To what extent does the process (disturbance) increase the impacts of pathogens on the ecosystem?	Scored against taxonomic groups. Response Range: + 10 major impact to biodiversity, + 5 moderate impact, 0 no change, -10 major benefit to biodiversity.

Explanation

A pathogen is described as a microorganism such a as virus, bacterium, or fungus that causes disease in its host; the host may be an animal or a plant. While data is limited for animal and plant diseases, the threats to biodiversity are apparent in health and population viability, often leading to a reduction in reproduction and/or survival. Some examples include: *Phytopthora cinnamomi* soil born rootrot fungus in native vegetation; *Armillaria* spp. rootrot fungus in *Eucalyptus* spp.; the naturally occurring myrtle *Nothafagus cunninghamii* wilt fungus caused by the native pathogenic die-back fungus *Chalara australis*; the introduced myrtle rust *Uredo rangelii* on shrubs and trees in the Myrtaceae; Chytridiomycosis or Amphibian chytrid fungus disease *Batrachochytrium dendrobatidis*). For many diseases, only a few species are competent hosts, and it is argued that in a particular area where biological diversity is high, a dilution effect may occur, th at is, the area is generally associated with a greater proportion of incompetent hosts available for vectors to bite. The lifecycle of a pathogen is interrupted as pathogens are "diluted" in hosts poorly able, or unable, to pass them on to new vectors. This in turn reduces the chance of passing on infection. In a disturbed environment, the reality is that eradication is not possible for many of these pathogens.

References

Bromham, L., Cardillo, M., Bennett, A.F. and Elgar, M.A. 1999. Effects of stock grazing on the ground invertebrate fauna of woodland remnants. Australian Journal of Ecology 24: 199-207.

Dorrough, J., Yen, A., Turner, V., Clarke, S. G., Crosthwaite, J. and Hirth, J.R. 2004. Livestock grazing management and biodiversity conservation in Australian temperate grassy landscapes. Australian Journal of Agricultural Research 55: 279-295.

Question 9. To what extent does the process increase fragmentation of native vegetation coverage within the region?	Response Range: 10 = majority of vegetation cleared, only small and linear fragments remain in isolation producing strong edge effects (e.g. cities) 8 = 80 % of vegetation cleared, only small and linear fragments remain in isolation producing strong edge effects = 50 % of vegetation cleared, some larger fragments present with less isolation and reduced edge effects. 3= 30 % of vegetation cleared, many large fragments present with limited isolation and edge effects. 1= Vegetation not cleared, but internally fragmented by a network of roads, which results in some edge effects. 0 = No fragmentation or edge effects (benchmark communities of large size with little internal fragmentation by roads).

Explanation

Habitat fragmentation is a term used for the process that alters the structure and function of an ecosystem such that the ability of an organism to adapt and modify is reduced or there are discontinuities in an organism's favoured environment. Habitat fragmentation is a separate issue to habitat loss (Fahrig 2003). Habitat loss increases fragmentation. Fragmentation may cause low amounts of habitat loss e.g. roading in forested areas, however the associated fragmentation effect is large e.g. edge effects, isolation/separation (Didham 2010). Habitat fragmentation may occur through natural causes (e.g. fire, climate change) or through human activity. Where landscapes have been altered by human influence, the change usually occurs at a rate faster than natural events and involves the disintegration of continuous habitats, into smaller, disjunct and more isolated habitats. Fragmentation includes edge effects, changes in patch shape, reduced patch area, patch isolation, and alterations in the land-use types in the landscape.

References

Didham, R.K 2010. Ecological Consequences of Habitat Fragmentation. In: eLS. John Wiley & Sons Ltd, Chichester. http://www.els.net [doi: 10.1002/9780470015902.a0021904].

Fahrig, L. 2003. Effects of habitat fragmentation on biodiversity. Annual Review of Ecology, Evolution and Systematics 34: 487-515

Question 10. To what extent does the process affect connectivity of native vegetation across the region?	Response Range: 10 = majority of vegetation cleared, only isolated fragments remain and matrix is impermeable for dispersal of most species (e.g. cities); 8 = majority of vegetation cleared, only isolated fragments remain and matrix is slightly permeable for dispersal of most species ; 5 = 50 % of vegetation cleared, moderate connectivity present in the form of corridors or stepping stones and matrix has some permeability for dispersal of a sub-set of species.; 2. Vegetation not cleared but matrix is modified and fragmented by a network of roads, which may affect species with limited dispersal abilities; 0 = No fragmentation and no restrictions on species movements (benchmark communities of large size with little internal fragmentation by roads).

Explanation

The ability of a species to disperse and its mobility, both in time and through available space, will influence its capacity to survive and persist. The degree to which the landscape facilitates or impedes movement between suitable habitats is defined as landscape 'connectivity' or 'permeability'. Connectivity includes four types: landscape, habitat, ecological and evolutionary-process-connectivity (see Lindenmayer and Fischer 2006). Terms such as biolinks, landscape corridors, linear corridors, landscape linkages, ecological networks, stepping stones, are all used to describe connectivity areas. The matrix also strongly influences connectivity, for instance an urban matrix is a barrier to movement for many species as is a cleared and cropped paddock, but the presence of scattered paddock trees can facilitate movement for certain species, including bats. Different taxa have vastly different abilities to move through the landscape and respond in different ways to landscape barriers. So some highly mobile species that move over hundreds of kilometres are typically not strongly affected by the connectivity of vegetation (although they are likely to require stop-over habitat to facilitate their journey). Others move at much smaller scales and a forest road could potentially form a barrier to movement.

References

Lindenmayer, D.B. and Fischer, J. 2006. Habitat fragmentation and landscape change: an ecological and conservation synthesis. CSIRO Publishing, Collingwood, VIC.

Questions 11a and 11b

Question 11a. Compared to a benchmark state (e.g. pre-1750 vegetation) appropriate for the region in question[1], to what extent does the process (disturbance) *alter habitat structure and complexity*? **a.** [1]. **A benchmark state for Eden region might be undisturbed old growth forest; for pine plantation pre-existing forest or woodland/grassland; for cropping/pasture and/or rangeland grazing it might be remnant woodland vegetation. For an international audience, defer to 'naturalness'. Definitions for these terms are found in the question summary for Question 1.**).	Scored against taxonomic groups. Response Range: 10 = little to no structure remains; 8 = habitat scarce with little diversity in type and age; 5 = moderately diverse structure in complexity and age.; 2. Habitat not modified, diverse structures with multiple ages and good distribution; 0 = Habitat structure complex, no restriction on age and distribution (benchmark habitat structure and complexity).
Question 11b. Compared to the land-use *immediately prior* to the process in question[2], to what extent does the process *alter habitat structure and complexity*? [2] Land-use prior to the process is not considered to be of a benchmark state; for example in the forestry context it may be a mid-succession stage or second rotation crop, and for agriculture it may be annual cropping rotation or seasonal pasture grazing	Scored against taxonomic groups. Response Range: 10 = little to no structure remains; 8 = habitat scarce with little diversity in type and age; 5 = moderately diverse structure in complexity and age.; 2. Habitat not modified, diverse structures with multiple ages and good distribution; 0 = Habitat structure complex, no restriction on age and distribution (benchmark habitat structure and complexity).

Explanation

The pre-process state can be assumed to be similar to or the same as the ecosystem/s present in remnant patches of natural habitat or continuous habitat in the vicinity of the production estate. The physical structure of habitat has been highlighted as an important factor for many species. For many systems, species diversity is positively correlated with the complexity of a habitat. The increased complexity of habitat provides more environmental refuges and more foraging options, for example multiple vegetation layers, tree hollows, coarse woody debris, rock outcrops, etc. While this is the case for most taxa, there are exceptions (e.g. ants) (Lassau and Hochuli 2004). Grouping by functional groups in these cases may better explain relationships with habitat structure.

References

Lassau S. A. and Hochuli D. F. 2004. Effects of habitat complexity on ant assemblages. Ecography 27: 157-164.

Question 12. Will the process result in at risk species becoming eligible for IUCN listing or upgrading existing listings under IUCN?	Response range: 1 = YES, 0 + NO

Explanation

Biodiversity encompasses all species and ecological communities, however all species are not considered equally in a legislative framework. The IUCN (International Union for Conservation of Nature) Red List of Threatened Species provides a means of addressing those species recognised as threatened on a global scale. For a species to be considered as "at risk" (Table 1), it must either be placed:

i. under "Near Threatened" (NT) or in a higher category, or
ii. under "Least Concern" (LC) with a decreasing population trend

Table 1. A basis on which "at risk" species can be identified by considering the categories of the IUCN Red List of Threatened Species. The categories "Extinct" (EX) and "Extinct in the Wild" (EW) are excluded, as these do not apply to in-situ populations.

	IUCN Red List Category	Population Trend
Species to be considered as being "at risk"	Critically Endangered (CE)	Decreasing
	Endangered (EN)	Decreasing
	Vulnerable (VU)	Decreasing
	Near Threatened (NT)	Decreasing
	Least Concern (LC)	Decreasing
Species are not "at risk"	Least Concern (LC)	Increasing, Stable or Unknown
	Data Deficient (DD)	-
	Not Evaluated (NE)	-

The determination of whether a process would result in at risk species becoming eligible for IUCN listing or upgrading existing listings under IUCN can be a tentative task. We propose a two-stage approach to making this determination. The first stage is to identify any negative impact on a species as a direct result of the process; essentially the same assessment as Question 1. The second stage is to determine whether the process itself or any components of the process constitutes or encourages a Key Threatening Process. A viable example would be if a species is adversely impacted by native forestry as a result of the clearing of native vegetation. Table 2 outlines the 37 Key Threatening Processes recognised in NSW.

Table 2. Key Threatening Processes, as recognised by the Threatened Species Conservation (TSC) Act 1995.

Short name	Expanded explanation
Longwall Mining	Alteration of habitat following subsidence due to longwall mining
Hydrological Alterations	Alteration to the natural flow regimes of rivers and streams and their floodplains and wetlands
Climate Change	Anthropogenic climate change
Bushrock Removal	Bushrock removal
Clearing Native Vegetation	Clearing of native vegetation
European Rabbit	Competition and grazing by the feral European rabbit (*Oryctolagus cuniculus*)
Feral Goat	Competition and habitat degradation by feral goats (*Capra hircus*)

Honey Bee	Competition from feral honey bees (*Apis mellifera*)
Shark Control Program	Death or injury to marine species following capture in shark control programs on ocean beaches
Debris in Aquatic Systems	Entanglement in or ingestion of anthropogenic debris in marine and estuarine environments
Psyllids and/or Bell Miners	Forest Eucalypt dieback associated with over-abundant psyllids and bell miners
High Frequency Fire	High frequency fire resulting in the disruption of life cycle processes in plants and animals and loss of vegetation structure and composition
Feral Deer	Herbivory and environmental degradation caused by feral deer
Red Fire Ant	Importation of red imported fire ants (*Solenopsis invicta*)
Psittacine Circoviral Disease	Infection by psittacine circoviral (beak and feather) disease affecting endangered psittacine species and populations
Amphibian Chytrid	Infection of frogs by amphibian chytrid causing the disease chytridiomycosis
Phytophthora cinnamomi	Infection of native plants by *Phytophthora cinnamomi*
Myrtle Rust	Introduction and Establishment of Exotic Rust Fungi of the order Pucciniales pathogenic on plants of the family Myrtaceae
Earth Bumblebee	Introduction of the large earth bumblebee (*Bombus terrestris*)
Exotic Vine	Invasion and establishment of exotic vines and scramblers
Scotch Broom	Invasion and establishment of Scotch broom (*Cytisus scoparius*)
Cane Toad	Invasion and establishment of the cane toad (*Bufo marinus*)
African Olive	Invasion of native plant communities by African Olive *Olea europaea* L. subsp. *Cuspidata*
Lantana	Invasion, establishment and spread of *Lantana camara*
Bitou Bush	Invasion of native plant communities by *Chrysanthemoides monilifera* (bitou bush and boneseed)
Exotic Perennial Grasses	Invasion of native plant communities by exotic perennial grasses
Yellow Crazy Ant	Invasion of the yellow crazy ant (*Anoplolepis gracilipes* (Fr. Smith)) into NSW
Escaped Garden Plants	Loss and degradation of native plant and animal habitat by invasion of escaped garden plants, including aquatic plants
Loss of Hollow-Bearing Trees	Loss of hollow-bearing trees
Loss and/or Degradation of Hill-topping Sites	Loss or degradation (or both) of sites used for hill-topping by butterflies
Feral Dog	Predation and hybridisation of feral dogs (*Canis lupus familiaris*)
European Red Fox	Predation by the European red fox (*Vulpes vulpes*)
Feral Cat	Predation by the feral cat (*Felis catus*)
Plague Minnow	Predation by *Gambusia holbrooki* Girard, 1859 (plague minnow or mosquito fish)
Ship Rat	Predation by the ship rat (*Rattus rattus*) on Lord Howe Island
Feral Pig	Predation, habitat degradation, competition and disease transmission by feral pigs (*Sus scrofa*)
Removal of Dead Wood	Removal of dead wood and dead trees

Questions 13a, 13b, 13c and 13d

Question 13. Does the process affect threatened species or endangered ecological communities? a. – an individual threatened species?	Scored against taxonomic groups Response Range: +10 = strongly affecting many threatened species, 5 = moderately affecting some threatened species, 2 = minor effect on a few threatened species; 0 = no effect on threatened species;
Question 13. Does the process affect threatened species or endangered ecological communities? b. – an endangered ecological community?	Scored against taxonomic groups Response Range: +10 = strongly affecting many threatened species, 5 = moderately affecting some threatened species, 2 = small effect on a few threatened species; 0 = no effect on threatened species;
Question 13. Does the process affect threatened species or endangered ecological communities? c. – more than one threatened species?	Scored against taxonomic groups Response Range: +10 = strongly affecting many threatened species, 5 = moderately affecting some threatened species, 2 = small effect on a few threatened species; 0 = no effect on threatened species;
Question 13. Does the process affect threatened species or endangered ecological communities? d. – more than one endangered ecological community?	Scored against taxonomic groups Response Range: +10 = strongly affecting many threatened species, 5 = moderately affecting some threatened species, 2 = small effect on a few threatened species; 0 = no effect on a few threatened species; +10 strongly improvement on a few threatened species.

Explanation

This question asks, in parts a-d, if the process, through development, action or activity, directly threatens survival of a threatened species or reduces the diversity of an endangered ecological community.

Species or ecological communities that are considered threatened are listed under the relevant state or federal legislation in which the species occurs. In New South Wales, a species or ecological community is listed in the NSW Threatened Species Conservation Act 1995 if it is considered to be at an immediate or medium-term risk of extinction within the state by the NSW Scientific Committee, e.g. the pale-headed snake and Wollemi pine.

ADDITIONAL QUESTIONS TO BE ANSWERED USING A GIS	
A. What is the regional extent of the process? **Explanation** This question refers to the proportional coverage of the process over the total area of the bioregion for the 'time to recovery'. Bioregions are described as "relatively large land areas characterised by broad, landscape-scale natural features and environmental processes that influence the functions of entire ecosystems" (Thackway and Cresswell 1995). There are currently 89 bioregions recognised in Australia. Examples include the Sydney Basin, New England Tablelands, Cape York Peninsula and Tasmanian Southern Ranges. **References** **Thackway, R. and Cresswell, I.D. 1995.** An interim biogeographic regionalisation for Australia: a framework for setting priorities in the National Reserves System Cooperative Program, Version 4.0. Australian Nature Conservation Agency, Canberra.	

B. To what extent has the native vegetation in the region been cleared? **AND/OR** What is the proportion of land-clearing in the bioregion of interest?

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Researcher’s Disclaimer (if required)

Appendix 1. Species included in taxonomic groups

*Indicates introduced species; ^indicates endemic species; aquatic mammals (Monotremata, Ornithorhynchidae, Ornithorhynchus) and Fish are not included.

Taxonomic group	Phylum	Class	Order	Family	*Genus*	*Species*
Bryophytes (includes hornworts, liverworts and mosses)	Bryophyta					
	Marchantiophyta					
Vascular plants (includes horsetails and lycopods)	Charophyta					
Lichens	Ascomycota					
Fungi	Ascomycota (includes pathogens)					
	Basidiomycota					
Invertebrates	Arthropoda					
		Arachnida				
		Branchiopoda				
		Chilopoda				
		Diplopoda				
		Insecta				
		Malacostraca				
		Ostracoda				
	Annelida					
	Hirudinida					
		Oligochaeta				
	Mollusca					
		Bivalvia				
		Gastropoda				
	Nematoda					
		Chromodorea				
		Dorylaimea				
		Onchophora				
Frogs	Amphibia					
Reptiles	Reptilia					
Birds	Aves					
Large to medium mammals	Mammalia					
		Chordata				
Large to medium			Artiodactyla			

Taxonomic group	Phylum	Class	Order	Family	*Genus*	*Species*
mammals						
				Suidae		
					**Capra* (European Sheep) **Bos* (Goat)	
				Bovidae		
					**Cervus* (deer)	
				Cervidae *Sus (pig)		
			Perrisodactyla			
				Equidae		
			Carnivora		**Equus* (horse)	
				Canidae		
					**Canis* (dog, dingo), **Vulpes* (fox)	
				Felidae		
					**Felis* (cat)	
			Diprotodontia			
				Vombatidae		
					Vombatus	
				Macropodidae		
					Macropus	*Macropus rufus, M. giganteus, M. rufogriseus, M. robustus, M. fuliginosus*
					Wallabia	*Wallabia bicolor*
					Petrogale	*Petrogale pencillata (Brown tailed Rock Wallaby)*
					Thylogale	
						Thylogale thetis (Red necked Pademelon)
Ground mammals	Mammalia	Chordata				

Taxonomic group	Phylum	Class	Order	Family	*Genus*	*Species*
			Lagomorpha			
				Leporidae		
					**Oryctolagis* **Lepus*	(European Rabbit) (Hare)
			Dasyuromorphia			
				Dasyuridae		
					Planigale *Sminthopsis* *Antechinus* *Antechinomys* *Dasyurus*	
			Monotremata			
				Taschyglossidae		
					Tachyglossus	
			Permalelemorphia			
				Peremelidae		
					Perameles *Isodon*	
				Thylacomyidae		
					Macrotis	
			Rodentia			
				Muridae		
					Conilurus *Hydromys* *Mastacomys* **Mus* *Notomys* *Pseudomys* *Rattus*	
Bats	Mammalia					
		Chordata				
			Chiroptera			
				Vespertilionidae		
					Chalinolobus *Falsistrellus* *Kerivoula* *Myotis* *Nyctophilus* *Scoteanax* *Scotorepens* *Vespadelus*	
				Miniopteridae		

Taxonomic group	Phylum	Class	Order	Family	*Genus*	*Species*
					Miniopterus	
				Pteropodidae		
					Pteropus	
				Rhinolophidae		
					Rhinolophus	
				Emballonuridae		
					Saccolaimus	
				Molossidae		
					Tadarida Mormopterus	
Arboreal mammals (does not include bats)	Mammalia					
		Chordata				
			Dasyuromorphia			
				Dasyuridae		
					Phascogale	
			Diprotodontia			
				Acrobatidae		
					Acrobates	*(Feather Tail Glider)*
				Burramyidae		
					Cercarteus	*(Eastern Pygmy Possum)*
				Petauridae		
					Petaurus	*Petaurus australis (Yellow Bellied Glider), Petaurus norfolcensis (Squirrel Glider), Petaurus breviceps (Sugar Glider)*
				Phlangeridae		
					Trichosurus vulpecula	
				Pseudocheiridae		

Taxonomic group	Phylum	Class	Order	Family	*Genus*	*Species*
					Petauroides volans (Greater Glider), Pseudocheris peregrinus (Common Ringtail Possum)	
				Phascolarctidae		
					Phascolarctus	

Appendix 2. Survey and Literature Questions

1. What is the immediate loss of species diversity as a direct result of the process?

a. compared to a benchmark state (e.g. pre-1750 vegetation) appropriate for the region in question[1]

b. compared to the land-use immediately prior to the process in question[2]

[1] Compare this question to a benchmark state. For an international audience, defer to 'naturalness'. Definitions for these terms are found in the question summary above.

[2] Land-use prior to the process is not considered to be of a benchmark state; for example in the forestry context it may be a mid-succession stage or second rotation crop, and for agriculture it may be annual cropping rotation or seasonal pasture grazing.

Explanation

Species diversity is the effective number of different species that are represented in a community. The concept consists of two key components: species richness, and species evenness or the relative abundance of species. Species richness is a simple count of occurring species, and is used in biodiversity studies more often than species evenness (Ma 2005). Species evenness is more complex, looking at distribution of biomass among species. In the hypothetical example of a natural reserve that has 80 koalas and 80 sugar gliders and another reserve that has 80 koalas and 20 sugar gliders, the species richness is the same, but the species evenness is different. In the context of life cycle assessment in a production landscape, species evenness is considered in terms of changes to the abundance of species and any limitations to their distribution over land tenure. An example of the latter may be the response of greater gliders to the establishment of a pine plantation; the species does not colonise pine stands, but remains in the plantation estate by persisting in remnant patches of native forest (Pope et al 2004). Even if the abundance of the species does not change within remnant patches, its overall abundance across the estate has declined and its distribution within estate is reduced.

Changes in species diversity are usually determined in literature by using continuous habitat in the vicinity of the production estate as a control, e.g. a natural reserve adjacent to agricultural land. Less often, ecological surveys are carried out before and after the process occurs, e.g. surveying in periods before and after natural habitat is cleared and a plantation established and matured.

A benchmark is a reliable point against which a change can be quantified and studied. For Australian vegetation, a benchmark state would be vegetation with somewhat little modification and disturbance by humans. The introduction of modern technology i.e. the arrival of Europeans is taken as a 'starting point' for vegetation comparison and while it doesn't exclude the reality of aboriginal disturbance, it accepts aboriginal influence on ecosystems as being 'natural' (Mackey et al 1998, Machado 2004). It should be noted that the pre-1750 benchmark state is being used at a regional level, not site specific level. This distinction is important for biodiversity conservation because for example at a site level there will be vegetation communities that are no longer existent due to changes in conditions (changes in fire regime, salinity etc.) even though they may have been there previously or vegetation communities that are devalued in favour of pre-existing native vegetation, where the latter is no longer optimal for biodiversity conservation. LCA is focused on biodiversity in relation to a production process rather than its prevalence in remnants/specific sites of native vegetation. The concept of naturalness is one recognised at an international scale and is used to describe a state that has not been influenced and/or made by humans or technology (Machado 2004). In this respect, naturalness may be equated with pre-1750 vegetation.

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Response range

+10 = total loss, 0 = no change, -10 = total improvement

2. To what extent does species diversity recover?

a. between the primary disturbance events induced by the process or within 50 years since disturbance for processes that are non-cyclic disturbance events (e.g. mining) (When the process is not new, but is continuing the same existing process in that area)[1]

b. when the process has been newly established on existing, mature native vegetation[2]

[1] for example, in the forestry context, this means second rotation in regrowth, clearfall of an existing plantation and for agriculture, a second year of cropping.

[2] for example in the forestry context, logging of old growth, or where forest has been cleared for plantations establishment, and for agriculture clearance of remnant vegetation.

Explanation

Following disturbance, an ecosystem develops from a simple stage of organisation to something more akin to a complex community over generations (this process follows ecological succession). The time required for an ecosystem or population to return to a state where a stable structure, function and identity are achieved can be described as the 'time to recovery' or a measure of resilience. Threatened species management and conservation biology have an extensive history of species focused recovery plans, aimed at mitigating the decline of a species. The species-based approach has also been applied at the landscape scale in the emergent field of ecological restoration, which aims at accelerating the recovery of a system. Clearly different taxa will have different trajectories and time to recovery from a disturbance. For the present question we are focusing on the extent of species diversity recovery for a taxon or population between disturbance events induced by the process, within a region. For part (a) above, the disturbance event may alter the pre-disturbance/baseline level and establish a new level (Fig. 1). Subsequent impact may further alter that new level and influence the extent to recovery to pre-disturbance/baseline level. In a moderate system, natural succession trajectories facilitate recovery e.g. remnant components not destroyed by a disturbance.

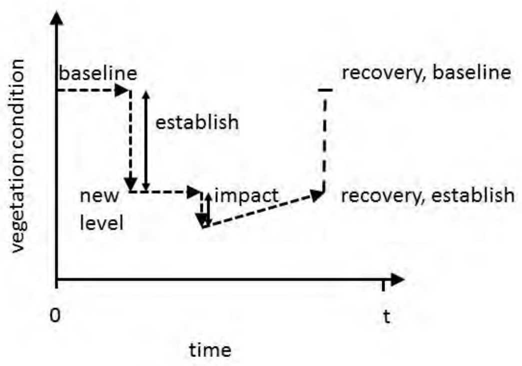

Fig. 1. Illustration of the extent of recovery of a system after disturbance.

Response range

+10 = total loss, 0 = no change, -10 = total improvement

3. To what extent does the process alter natural disturbance regimes?

Explanation

The concept 'natural disturbance regime' describes a pattern of disturbance events that shape an ecosystem over a long time. For many ecosystems (e.g. forests, grasslands), events such as changes in species diversity (e.g. feral predator impact), structure (e.g. land clearing) or function (e.g. alternate fire regime) are viewed as a shift from a natural disturbance regime. Humans have been at the heart of altering many natural systems: fire frequency; fire intensity; fire suppression; insect and pathogen outbreaks; flooding regimes; logging. Disruption of the natural disturbance regime may alter ecosystems resilience to environmental change and function. For example: Does the process increase the risk of fire or alter fire regimes?; Are flooding regimes altered (e.g. through damming of rivers and irrigation)?; Is the habitat altered in such a way to change levels of predation (e.g. by increasing the abundance and activity of ferals)? etc.

Response range

+ 10 = No recovery, 0 = Total recovery

4. To what extent does the disturbance increase the impacts of invasive predators?

Explanation

The term "invasive" is used to describe the ecological impact of a species or population: the effect(s) it may have on the environment it has migrated to and the process(es) it has interrupted/changed. An invasive predator is a carnivorous species that is described as occurring beyond an acknowledged historical distribution as a result of human activities. The damage caused by an invasive predator may threaten valued environmental, agricultural or other social resources. Native species may have responded to predator pressure through modifying behaviour or morphology to facilitate escape or avoid detection. Invasive predators can have a severe effect on the population size of native species, where native species have not developed defence mechanisms against the new invader/predator. They have been reported to be two times more harmful to prey populations than native predators (Salo et al 2007) and are implicated in the extinction of many species. Disturbances such as land clearing have created islands of habitat; small refuges for prey populations, while altered habitat extent and complexity can affect the movement and activity of introduced predators. These factors heighten the potential for stochastic loss at the patch scale, all in an environment where habitat loss and fragmentation are highly likely (Salo et al 2007, Fischer et al 2006).

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Response range

+10 = total loss, 0 = no change, -10 = total improvement

5. To what extent does the disturbance increase the impacts of invasive plants?

Explanation

As a result of human activities, many plant species have become invasive, that is, these species occur beyond their accepted normal distribution and cause significant damage, which in turn compromises resources such as agriculture and forestry. Invasive plant species (weeds) have been described as the second greatest threat to biodiversity, after habitat loss (humans). Invasive species modify the environment they invade. They displace native species and change burning patterns. In the agricultural region they assist in degrading habitat and arable land e.g. shallow rooted invasive annual grasses don't take up as much water as native perennial grasses, resulting in increased deep drainage, acidification and salinity (Hughes et al 2006). Activities by humans, domestic stock and invasive animals (e.g. rabbits) have contributed to creating conditions favourable to invasive plant growth, dispersal and persistence.

References

Hughes, J.D., Packer, I.J., Michalk, D.L., Dowling, P.M., King, W.M., Brisbane, S., Millar, G.D., Priest, S.M., Kemp, D.R. and Koen, T.B. 2006. Sustainable grazing systems for the Central Tablelands of New South Wales. 4. Soil water dynamics and runoff events for differently-managed pasture types. Australian Journal of Experimental Agriculture 46: 483-494.

Response range

+10 = total loss, 0 = no change, -10 = total improvement

6. To what extent does the disturbance increase the impacts of herbivorous and invertebrate pest populations?

Explanation

Pests are commonly described as species that are damaging to biodiversity, human concerns (such as livestock production) and/or social values. In Australia, herbivorous and invertebrate pest animals include both native and introduced species. For example, kangaroos and wallabies have become pests in disturbed pastoral, agricultural and forestry production areas. These pest herbivores may compete for pasture, leaves, flowers and fruits. Other examples include goats, deer and camels. The impacts of herbivorous pests are greater in areas of disturbance. Some invertebrate species are favoured by disturbance and abundance and biomass is greater in exotic pastures (Bromham et al 1999). Elsewhere, invertebrate pests have been reported to transmit plant pathogens and/or predispose plants to pathogens (Dorrough et al 2004).

References

Bromham, L., Cardillo, M., Bennett, A.F. and Elgar, M.A. 1999. Effects of stock grazing on the ground invertebrate fauna of woodland remnants. Australian Journal of Ecology 24: 199-207.

Dorrough, J., Yen, A., Turner, V., Clarke, S. G., Crosthwaite, J. and Hirth, J.R. 2004. Livestock grazing management and biodiversity conservation in Australian temperate grassy landscapes. Australian Journal of Agricultural Research 55: 279-295.

Response range

+10 = total loss, 0 = no change, -10 = total improvement

7. To what extent does the disturbance increase the impacts of pathogens?

Explanation

A pathogen is described as a microorganism such a as virus, bacterium, or fungus that causes disease in its host; the host may be an animal or a plant. While data is limited for animal and plant diseases, the threats to biodiversity are apparent in health and population viability, often leading to a reduction in reproduction and/or survival. Some examples include: *Phytopthora cinnamomi* soil born rootrot fungus in native vegetation; *Armillaria* spp. rootrot fungus in *Eucalyptus* spp.; the naturally occurring myrtle *Nothafagus cunninghamii* wilt fungus caused by the native pathogenic die-back fungus *Chalara australis*; the introduced myrtle rust *Uredo rangelii* on shrubs and trees in the Myrtaceae; Chytridiomycosis or Amphibian chytrid fungus disease *Batrachochytrium dendrobatidis*). For many diseases, only a few species are competent hosts, and it is argued that in a particular area where biological diversity is high, a dilution effect may occur, that is, the area is generally associated with a greater proportion of incompetent hosts available for vectors to bite. The lifecycle of a pathogen is interrupted as pathogens are "diluted" in hosts poorly able, or unable, to pass them on to new vectors. This in turn reduces the chance of passing on infection. In a disturbed environment, the reality is that eradication is not possible for many of these pathogens.

References

Bromham, L., Cardillo, M., Bennett, A.F. and Elgar, M.A. 1999. Effects of stock grazing on the ground invertebrate fauna of woodland remnants. Australian Journal of Ecology 24: 199-207.

Dorrough, J., Yen, A., Turner, V., Clarke, S. G., Crosthwaite, J. and Hirth, J.R. 2004. Livestock grazing management and biodiversity conservation in Australian temperate grassy landscapes. Australian Journal of Agricultural Research 55: 279-295.

Response range

+10 = total loss, 0 = no change, -10 = total improvement

8. To what extent does the process affect connectivity of native vegetation across the region?

Explanation

The ability of a species to disperse and its mobility, both in time and through available space, will influence its capacity to survive and persist. The degree to which the landscape facilitates or impedes movement between suitable habitats is defined as landscape 'connectivity'. Connectivity includes four types: landscape, habitat, ecological and evolutionary-process-connectivity (see Lindenmayer and Fischer 2006). Where the aim is to retain biodiversity through inter-connectedness in areas that include semi-natural, natural and altered habitats, all four types of connectivity would be involved (Worboys and Pulsford 2011; Worboys and Mackey 2013). Terms such as biolinks, landscape corridors, linear corridors, landscape linkages, ecological networks, stepping stones, are all used to describe connectivity areas. Different taxa have vastly different abilities to move through the landscape and respond in different ways to landscape barriers. So some highly mobile species that move over hundreds of kilometres are typically not strongly affected by the connectivity of vegetation (although they are likely to require stop-over habitat to facilitate their journey). Others move at much smaller scales and a forest road could potentially form a barrier to movement.

References

Lindenmayer, D.B. and Fischer, J. 2006. Habitat fragmentation and landscape change: an ecological and conservation synthesis. CSIRO Publishing, Collingwood, VIC.

Worboys G. and Pulsford, I. 2011. Connectivity conservation in Australian landscapes. Report prepared for the Australian Government Department of Sustainability, Environment, Water, Population and Communities. State of the Environment 2011 Committee, Canberra.

Worboys , G.L. and Mackey, B. 2013. Connectivity Conservation initiatives: a national and international perspective. Pp 7-21 in Fitzsimons, J., Pulsford, I. and Wescott, G. (eds.). Linking Australia's Landscapes: Lessons and Opportunities from Large-scale Conservation Networks. CSIRO Publishing, Collingwood.

Response range

+10 = total loss, 0 = no change, -10 = total improvement

9. To what extent does the process alter habitat structure?

a. compared to a benchmark state (e.g. pre-1750 vegetation) appropriate for the region in question[1]

b. compared to the land-use immediately prior to the process in question[2]

[1] Compare this question to a benchmark state. See summaries for definition of pre-1750 benchmark state. For an international audience defer to 'naturalness' under this summary (references included).

[2] Land-use prior to the process is not considered to be of a benchmark state; for example in the forestry context it may be a mid-succession stage or second rotation crop, and for agriculture it may be annual cropping rotation or seasonal pasture grazing

Explanation

The pre-process state can be assumed to be similar to or the same as the ecosystem/s present in remnant patches of natural habitat or continuous habitat in the vicinity of the production estate. The physical structure of habitat has been highlighted as an important factor for many species. For many systems, species diversity is positively correlated with the complexity of a habitat. The increased complexity of habitat provides more environmental refuges and more foraging options. While this is the case for most taxa, there are exceptions (e.g. ants) (Lassau and Hochuli 2004). Grouping by functional groups in these cases may better explain relationships with habitat structure.

References

Lassau S. A. and Hochuli D. F. 2004. Effects of habitat complexity on ant assemblages. Ecography 27: 157-164.

Response range

+10 = total loss, 0 = no change, -10 = total improvement

10. To what extent does the process reduce the resilience of the system – capacity to absorb stochastic disturbance – flood, fire, drought?

Explanation

Disturbance of significant magnitude or disturbance that continues for an extended period can place pressure on an ecosystem that pushes it beyond a threshold, resulting in a regime shift. This capacity of an ecosystem to counter or to absorb the disturbance and recover to an extent that function and structure are maintained is termed resilience. Disturbance may include stochastic events such as fire, flood and drought. Biodiversity has been found to increase resilience of ecosystems from stochastic disturbance or damaging human interference. The resilience of an ecosystem is considered in environmental policy and management e.g. development must consider the impact upon threatened ecosystems and/or species (NSW Threatened Species Conservation Act 1995)

Response range

+10 = total loss, 0 = no change, -10 = total improvement

11. To what extent does the disturbance have a negative impact on keystone species?

Explanation

Keystone species have been described as species that have a disproportionately positive effect on ecosystems relative to either their low abundance or limited spatial occupancy. They may provide a wide range of important ecological functions. It has been argued that conservation priority should be given to species that fulfil unique functional roles rather than functionally redundant species. Keystone species fulfil these criteria because their loss from an ecosystem could potentially lead to cascading changes and loss of overall biodiversity. Examples in the published literature have included scattered trees in agricultural landscapes (Manning et al

2006), fig trees in tropical rainforest (Yang et al 1999; Lambert and Marshall 1991), flying foxes on South Pacific islands (Cox et al 1991) and top order predators (Kitchell et al 1999). Often there is limited evidence available in the literature to identify keystone species in different ecosystems. Alternatively, it is possible that certain ecosystems may not have stand-out or obvious keystone species that exert disproportionate influence.

References

Cox, P.A., Elmqvist, T., Pierson, E.D. and Rainey, W.E. 1991. Flying foxes as strong interactors in South Pacific island ecosystems: a conservation hypothesis. Conservation Biology 5(4): 448-454.

Kitchell, J.F., Boggs, C.H., He, X. and Walters, C.J. 1999. Keystone predators in the Central Pacific. Ecosystem approaches for fisheries management, pp. 665-683.

Lambert, F.R. and Marshall, A.G. 1991. Keystone characteristics of bird-dispersed *Ficus* in a Malaysian lowland rain forest. Journal of Ecology 79: 793-809.

Manning, A.D., Fischer, J. and Lindenmayer, D.B. 2006. Scattered trees are keystone structures – implications for conservation. Biological Conservation 132: 311-321.

Yang, D.R., Li, C.D., Han, D.B. and Yao, R.Y. 1999. The effects of fragmenting of tropical rainforest on the species structure of fig wasps and fig trees, China. Zoological Research 20(2): 126-130.

Response range

+10 = total loss, 0 = no change, -10 = total improvement

12. Will the process result in at risk species becoming eligible for IUCN listing or upgrading existing listings under IUCN?

Explanation

Biodiversity encompasses all species and ecological communities, however all species are not considered equally in a legislative framework. The IUCN (International Union for Conservation of Nature) Red List of Threatened Species provides a means of addressing those species recognised as threatened on a global scale. For a species to be considered as "at risk" (Table 1), it must either be placed:

iii. under "Near Threatened" (NT) or in a higher category, or
iv. under "Least Concern" (LC) with a decreasing population trend

Table 1. A basis on which "at risk" species can be identified by considering the categories of the IUCN Red List of Threatened Species. The categories "Extinct" (EX) and "Extinct in the Wild" (EW) are excluded, as these do not apply to in-situ populations.

	IUCN Red List Category	Population Trend
Species to be considered as being "at risk"	Critically Endangered (CE)	Decreasing
	Endangered (EN)	Decreasing
	Vulnerable (VU)	Decreasing
	Near Threatened (NT)	Decreasing
	Least Concern (LC)	Decreasing
Species are not "at risk"	Least Concern (LC)	Increasing, Stable or Unknown
	Data Deficient (DD)	-
	Not Evaluated (NE)	-

The determination of whether a process would result in at risk species becoming eligible for IUCN listing or upgrading existing listings under IUCN can be a tentative task. We propose a two-stage approach to making this determination. The first stage is to identify any negative impact on a species as a direct result of the process; essentially the same assessment as Question

1. The second stage is to determine whether the process itself or any components of the process constitutes or encourages a Key Threatening Process. A viable example would be if a species is adversely impacted by native forestry as a result of the clearing of native vegetation. Table 2 outlines the 37 Key Threatening Processes recognised in NSW.

Table 2. Key Threatening Processes, as recognised by the Threatened Species Conservation (TSC) Act 1995.

Short name	**Expanded explanation**
Longwall Mining	Alteration of habitat following subsidence due to longwall mining
Hydrological Alterations	Alteration to the natural flow regimes of rivers and streams and their floodplains and wetlands
Climate Change	Anthropogenic climate change
Bushrock Removal	Bushrock removal
Clearing Native Vegetation	Clearing of native vegetation
European Rabbit	Competition and grazing by the feral European rabbit (*Oryctolagus cuniculus*)
Feral Goat	Competition and habitat degradation by feral goats (*Capra hircus*)
Honey Bee	Competition from feral honey bees (*Apis mellifera*)
Shark Control Program	Death or injury to marine species following capture in shark control programs on ocean beaches
Debris in Aquatic Systems	Entanglement in or ingestion of anthropogenic debris in marine and estuarine environments
Psyllids and/or Bell Miners	Forest Eucalypt dieback associated with over-abundant psyllids and bell miners
High Frequency Fire	High frequency fire resulting in the disruption of life cycle processes in plants and animals and loss of vegetation structure and composition
Feral Deer	Herbivory and environmental degradation caused by feral deer
Red Fire Ant	Importation of red imported fire ants (*Solenopsis invicta*)
Psittacine Circoviral Disease	Infection by psittacine circoviral (beak and feather) disease affecting endangered psittacine species and populations
Amphibian Chytrid	Infection of frogs by amphibian chytrid causing the disease chytridiomycosis
Phytophthora cinnamomi	Infection of native plants by *Phytophthora cinnamomi*
Myrtle Rust	Introduction and Establishment of Exotic Rust Fungi of the order Pucciniales pathogenic on plants of the family Myrtaceae
Earth Bumblebee	Introduction of the large earth bumblebee (*Bombus terrestris*)
Exotic Vine	Invasion and establishment of exotic vines and scramblers
Scotch Broom	Invasion and establishment of Scotch broom (*Cytisus scoparius*)
Cane Toad	Invasion and establishment of the cane toad (*Bufo marinus*)
African Olive	Invasion of native plant communities by African Olive *Olea europaea* L. subsp. *Cuspidata*
Lantana	Invasion, establishment and spread of *Lantana camara*
Bitou Bush	Invasion of native plant communities by *Chrysanthemoides monilifera* (bitou bush and boneseed)
Exotic Perennial Grasses	Invasion of native plant communities by exotic perennial grasses
Yellow Crazy Ant	Invasion of the yellow crazy ant (*Anoplolepis gracilipes* (Fr. Smith)) into NSW
Escaped Garden Plants	Loss and degradation of native plant and animal habitat by invasion of escaped garden plants, including aquatic plants

Loss of Hollow-Bearing Trees	Loss of hollow-bearing trees
Loss and/or Degradation of Hill-topping Sites	Loss or degradation (or both) of sites used for hill-topping by butterflies
Feral Dog	Predation and hybridisation of feral dogs (*Canis lupus familiaris*)
European Red Fox	Predation by the European red fox (*Vulpes vulpes*)
Feral Cat	Predation by the feral cat (*Felis catus*)
Plague Minnow	Predation by *Gambusia holbrooki* Girard, 1859 (plague minnow or mosquito fish)
Ship Rat	Predation by the ship rat (*Rattus rattus*) on Lord Howe Island
Feral Pig	Predation, habitat degradation, competition and disease transmission by feral pigs (*Sus scrofa*)
Removal of Dead Wood	Removal of dead wood and dead trees

Response range: 1 = YES, 0 + NO

13. Does the process affect threatened species or endangered ecological communities?

a. – an individual threatened species?

b. – an endangered ecological community?

c. – more than one threatened species?

d. – more than one endangered ecological community?

Explanation

This question asks, in parts a-d, if the process, through development, action or activity, directly threatens survival of a threatened species or reduces the diversity of an endangered ecological community.

Species or ecological communities that are considered threatened are listed under the relevant state or federal legislation in which the species occurs. In New South Wales, a species or ecological community is listed in the NSW Threatened Species Conservation Act 1995 if it is considered to be at an immediate or medium-term risk of extinction within the state by the NSW Scientific Committee, e.g. the pale-headed snake and Wollemi pine.

Response range

+10 = total loss, 0 = no change, -10 = total improvement

THE FOLLOWING QUESTIONS WILL BE ANSWERED USING A GIS

A. What is the regional extent of the process?

Explanation

This question refers to the proportional coverage of the process over the total area of the bioregion for the 'time to recovery'. Bioregions are described as "relatively large land areas characterised by broad, landscape-scale natural features and environmental processes that influence the functions of entire ecosystems" (Thackway and Cresswell 1995). There are currently 89 bioregions recognised in Australia. Examples include the Sydney Basin, New England Tablelands, Cape York Peninsula and Tasmanian Southern Ranges.

References

Thackway, R. and Cresswell, I.D. 1995. An interim biogeographic regionalisation for Australia: a framework for setting priorities in the National Reserves System Cooperative Program, Version 4.0. Australian Nature Conservation Agency, Canberra.

B. To what extent does the process increase fragmentation of native vegetation coverage within the region?

Explanation

Habitat fragmentation is a term used for the process that alters the structure and function of an ecosystem such that the ability of an organism to adapt and modify is reduced or there are discontinuities in an organism's favoured environment. Habitat fragmentation is a separate issue to habitat loss (Fahrig 2003). Habitat loss increases fragmentation. Fragmentation may cause low amounts of habitat loss e.g. roading in forested areas, however the associated fragmentation effect is large e.g. edge effects, isolation/separation (Didham 2010). Habitat fragmentation may occur through natural causes (e.g. fire, climate change) or through human activity. Where landscapes have been altered by human influence, the change usually occurs at a rate faster than natural events and involves the disintegration of continuous habitats, into smaller, disjunct and more isolated habitats. Fragmentation includes edge effects, changes in patch shape, reduced patch area, patch isolation, and alterations in the land-use types in the landscape.

References

Didham, R.K 2010. Ecological Consequences of Habitat Fragmentation. In: eLS. John Wiley & Sons Ltd, Chichester. http://www.els.net [doi: 10.1002/9780470015902.a0021904].

Fahrig, L. 2003. Effects of habitat fragmentation on biodiversity. Annual Review of Ecology, Evolution and Systematics 34: 487-515.

C. To what extent has the native vegetation in the region been cleared?

AND/OR

What is the proportion of land-clearing in the bioregion of interest?

Appendix 3 Expertise by Region and Taxonomic Group

Figure 1. Central West Cropping Expertise by taxonomic groups

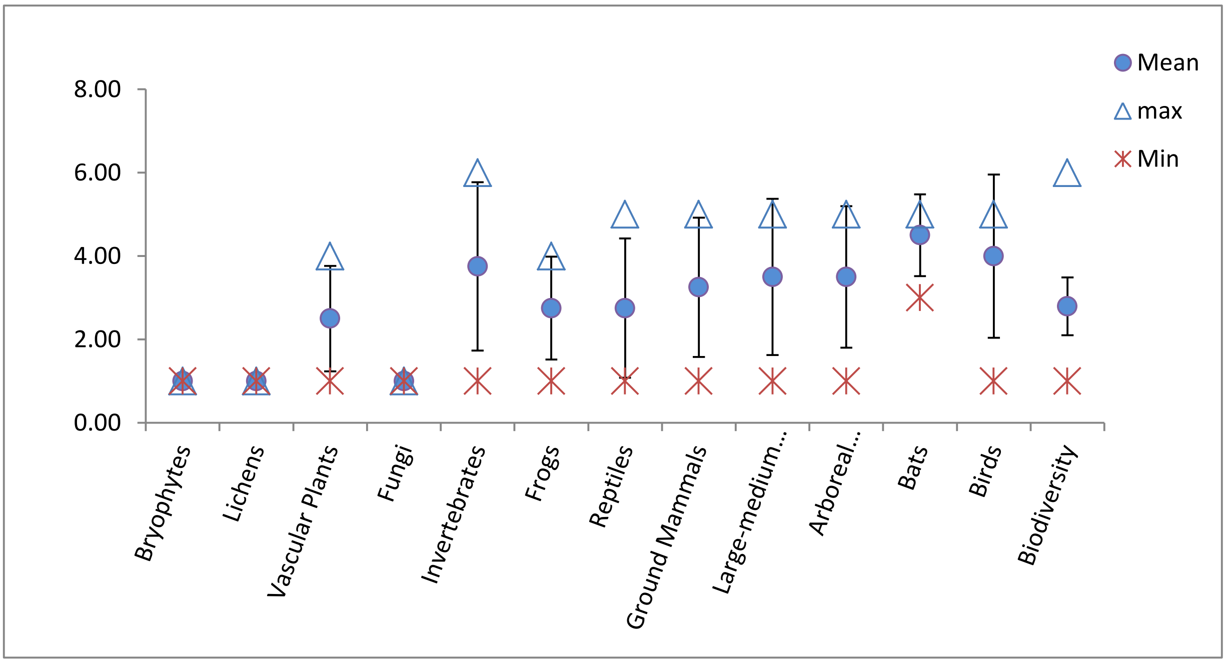


Figure 2. Central West rangeland grazing by taxonomic expertise

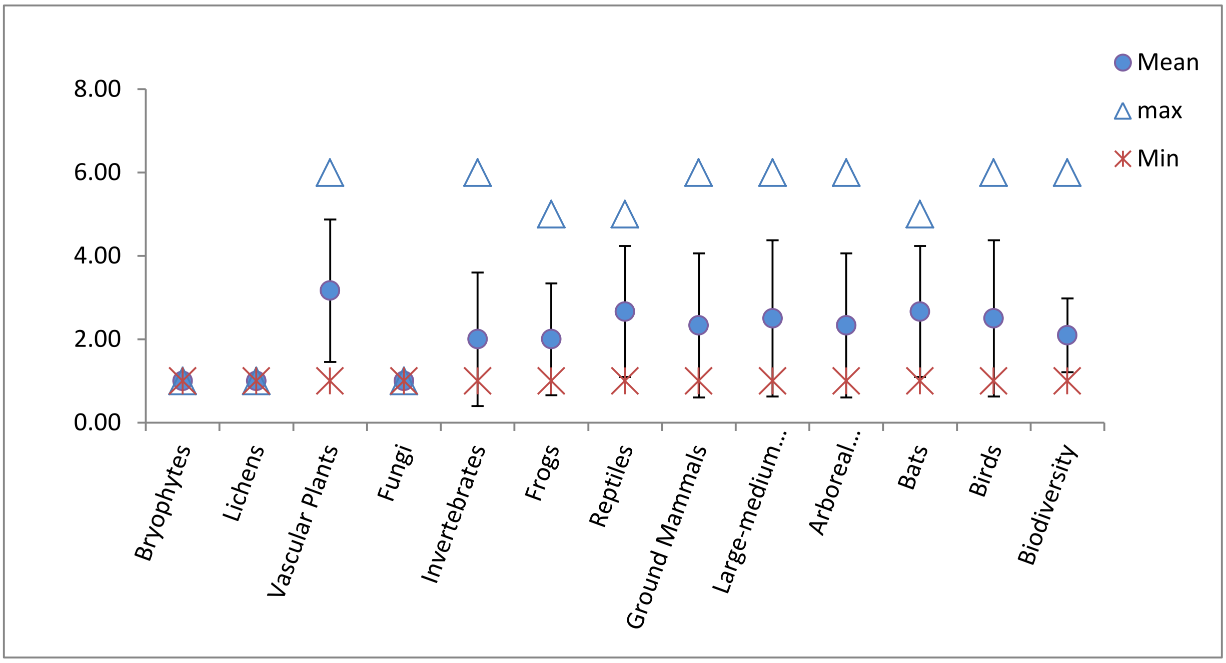


Figure 3. Eden by taxonomic expertise

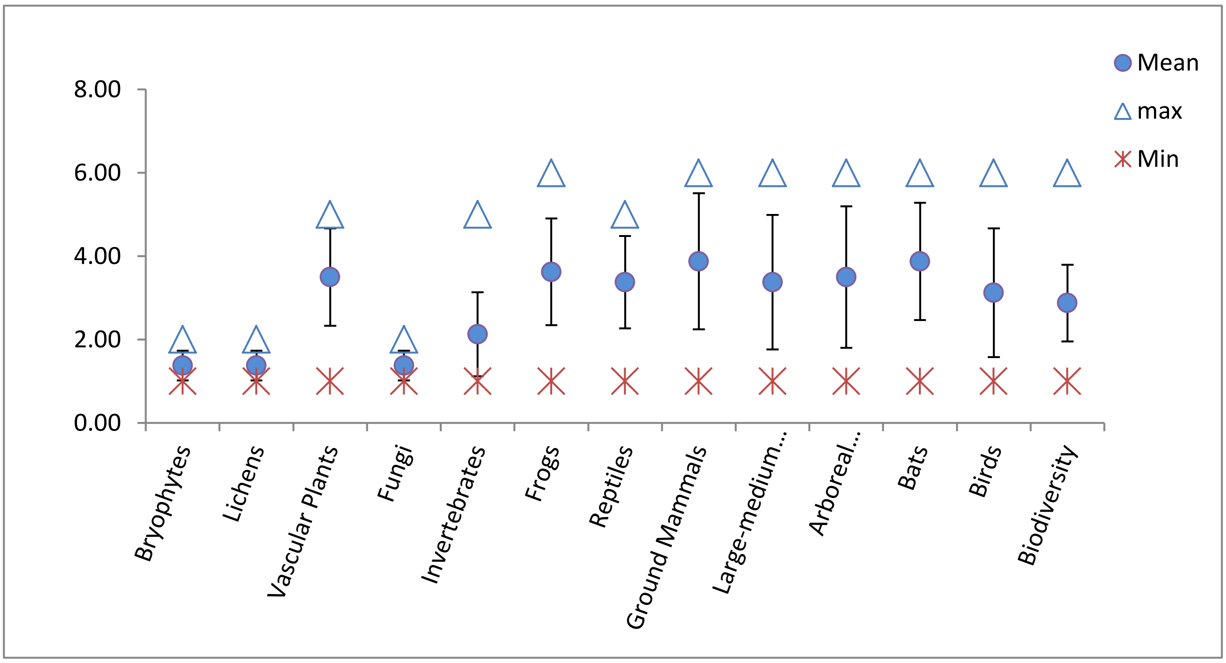
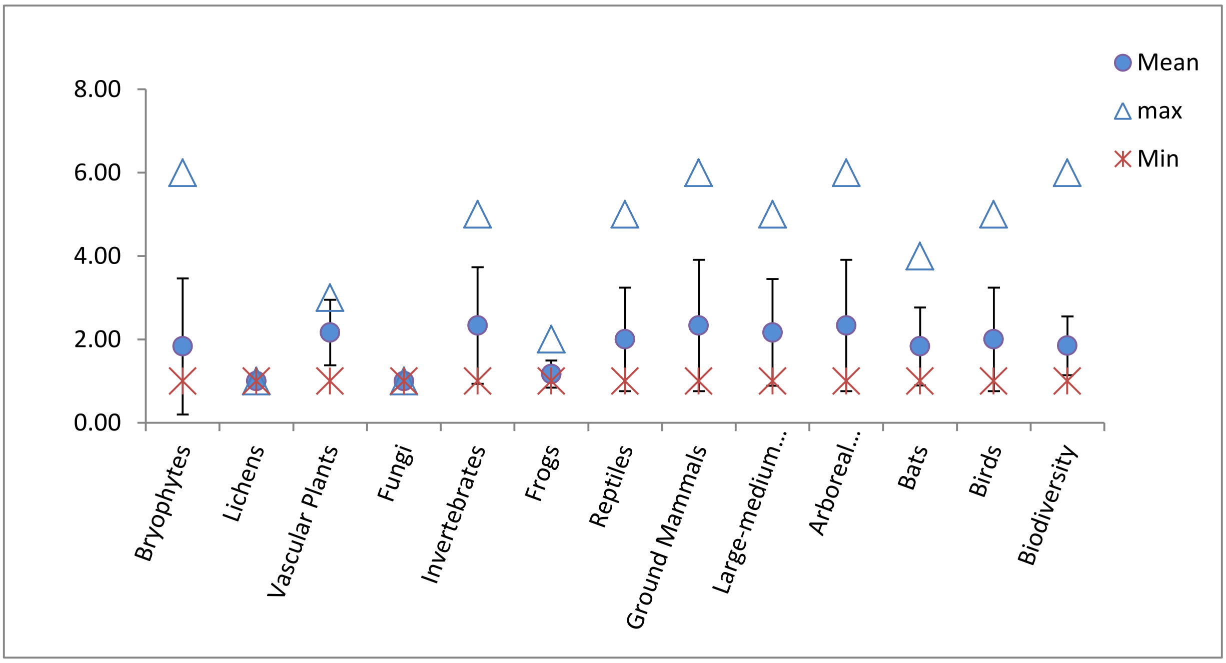


Figure 4. Hume by taxonomic expertise



Appendix 4 Key Concept survey questions.

Table 1. Questions ordered in terms of the proportion of responses that indicated the question was of 'major importance'.

Question number	Question	Proportion of "major"	Number of responses
1	Does the disturbance result in increased fragmentation of the landscape	88%	211
2	To what extent does the disturbance impact upon ecosystem function	88%	194
3	How long does the population take to recover to pre disturbance levels	86%	211
4	To what extent does the disturbance alter habitat structure	85%	195
5	Are populations of keystone species likely to be altered by the disturbance	85%	194
6	Does the disturbance isolate populations	84%	213
7	What proportion of a region is affected by the disturbance	80%	214
8	To what extent does the disturbance increase the potential for invasive or pest animal populations	80%	212
9	What is the frequency at which the disturbance is likely to occur	79%	211
10	To what extent does the disturbance increase the potential for alien flora species	78%	215
11	What proportion of species in the community are affected by the disturbance	78%	209
12	Does the disturbance affect Endangered Ecological Communities listed under legislation	76%	194
13	Does the disturbance affect regionally threatened species	76%	194
14	Over what time period will the disturbance be present For example cropping as a disturbance is relatively permanent compared to timber harvesting which may take a period of weeks to occur followed by x years of recovery	76%	211
15	Is the disturbance considered a key threatening process	74%	193
16	Does the process affect threatened species listed under legislation	73%	193
17	Does the disturbance reduce or prevent gene flow within the landscape	68%	214
18	To what extent does this disturbance alter natural disturbance regimes	67%	194
19	Will intervention be required to return the system to the pre disturbance state	65%	193
20	What is the current conservation status of the bioregion in which the disturbance occurs	63%	213
21	Does the disturbance result in genetic bottlenecks	62%	194
22	To what extent does the disturbance increase the potential for diseases or pathogens	62%	215
23	Prior to the disturbance to what extent has the landscape been altered from its perceived natural state	58%	194
24	Will long term evolutionary processes be affected by this disturbance	57%	194
25	Will the disturbance result in species being eligible for listing as a threatened species	52%	195
26	Are ameliorative conservation measures important for considering the impact of a disturbance	48%	193

Appendix 5. Survey Comments

Number	Comment
1	The value of the ecosystem service provided by the vegetation that may be disturbed. Compare this to the value of the material to be harvested. What is the long term stewardship model of the affected landscape. How will policy and procedures be effectively policed. How much of the profit will be returned to conservation and environmental restoration programs. What will be the consultation process prior to project start up. Can sustainable plantations with novel products and processes replace the need to harvest from intact and untouched ecological communities?
2	Does the activity result in multiple impacts that have a large cumulative effect? Does the activity combine with other threatening processes (such as climate change) to further impact on biodiversity?
3	Will the ecosystem recover at all following the disturbance?
4	All concepts raised are of importance so it is the relative interaction that defines the magnitude/consequence. Have you thought about choice modelling to assess biodiversity values?
5	The list looks very comprehensive.
6	Is the community affected well conserved in other parts of its range, ie how significant to the conservation of the community is the area to be disturbed? Will the disturbance interrupt important behavioural processes of species within the community? Or place prey species at greater risk of predation?
7	Species lifespan and demographic rates. Life history traits may predispose some species to being more sensitive or particularly vulnerable to synergistic impacts of climate + anthropogenic disturbance.
8	Above all prevention is better and cheaper than the cure. That is to say saving wild habitats in their natural states is ever so must easier,wildlife friendly,safer,and more productive than trying to restoring wildlife and their habitats once they have been destroyed or made locally extinct or extinct altogether ,in which case a species is lost forever.
9	Disturbances should not be considered in isolation, as is the case in current impact assessment protocols. There should be tools available to consider the cumulative impact of the many disturbances which are going on/being proposed simultaneously
10	Effects on soil Effects on apex predators
11	None come to mind
12	many of the criteria are linked to legislation or statutory listings, which are often flawed or less 'site-relevant', accordingly, what is happening in terms of ecosystem function on the site affected is of more importance than legislative requirements.

Number	Comment
13	1/ The scale of disturbance in relation to the whole area and potential area of effect (outside the defined area). 2/ Minimum population levels of an organism required to sustain a population. 3/A populations ability to escape or survive from minor disasters eg fire/ flood / pollution
14	Whether impacts on the vegetation / ecosystems will be rigorously assessed, and whether mitigation measures are implemented effectively.
15	There are many things that were mentioned that could be asked in a different way, e.g. how long might it take to return to pre-disturbance condition, does the disturbance result in changes that may never recover naturally, what does the disturbed state provide (habitat, structure, function) while returning to its original state, could recovery be cheaply and simply accelerated through management? Not sure if the questions on the previous pages cover all of these alternatives.
16	What is the level of biodiversity present in the area planned for disturbance?
17	answers to thesse questions are on a species by species and site basis- not necessarily generic
18	connectivity of habitats
19	Negative impacts of disturbance on human population (e.g. water contamination, reduced green area, aesthetic questions, etc) Role/involvement of local citizens/local government in conservation of disturbed area
20	Cultural significance to indigenous peoples rights
21	Does the disturbance affect susceptibility to abiotic stresses? Does disturbance affect susceptibility to natural disturbances?
22	How well is the biodiversity of the affected area known? Will the disturbance change the physical environment (eg strip mining, topsoil removal, pollution of water or soil)?
23	Amount of knowledge of the impacted biome: i.e. many terrestrial ecologies are understood considerably more than marine, or high alpine environments, for example.
24	I work in The Bahamas (which I didn't see on the country list)
25	Can the impacts of the disturbance be fully compensated for by ecological restoration elswhere? Can the carbon emissions that result from the disturbance be fully offset?
26	That was a long list of incredibly important considerations!!

Number	Comment
27	These days "biodiversity" is generally taken to mean "species richness", especially by industry & governments. There is an immediate educational task to be undertaken here, to explain to the community (and most scientists) that mature ecosystems tend to support species equilibria, the values of which may be used to measure community stability. Mathematical measurement of equilibria & hence stability seems little advanced since the work of the pioneers in this field, well summarized in the Brookhaven Symposium in Biology No.22 edited by Woodwell & Smith. Another issue not clearly addressed by you is the progressive degradation of communities over long time periods following disturbance (incl. climate changes). Published examples of this include Onley's basic studies of the decline in forest bird diversity in NZ over decadal intervals following logging (Notornis 30:187-197); and the change in phytoplankton species composition in the South Atlantic from the 1920s to today. However, I believe issues of genetic bottlenecks to be exaggerated and can recall few papers where this has been actually demonstrated, except where species numbers have fallen to 10s of individuals.
28	The questions are all inter-related to the major themes of genetics, conservation status, quantitative habitat loss, qualitative ecosystem functioning at different scales e.g. within species (genetics), between species (populations), rate of change. Some questions relate to absolute measures and others to relative measures (e.g. proportion) and policy (which is highly subjective). I think you need to re-think WHAT you are asking and HOW the information could be used.
29	Effects of new disturbances on the relative balance (e.g., age structure) of different succession stages in an area, association of endangered species with one or more of these stages.
30	You can do more damage if you're willing to pay more on repairs. So the statement about intervention is very important to me; if industry commits resources to dealing with a necessary problem, I'd be more comfortable with it.
31	Size of disturbance relative to the overall size of a given habitat.
32	related topics: 1) what is the importance of the biodiversity in the culture and micro-economics of hunter/gatherers and shifting agriculturalists with a high dependence on resources from forests or other habitats. 2) how far will any hidden costs of disturbance or mitigation be borne by indigenous people, local communities
33	How can this be related to a product and functional unit in LCA easily. What is the best way of communicating the results.
34	Extent of remaining ecosystem should be a factor
35	There needs to be a clear difference between the two concepts: as an exogenous ecological disruption and as a natural pattern of mortality (disturbance regimes).
36	Reconciling natural disturbance with human induced disturbance when humans are conceived as part of nature rather than being conceived as being separate from nature

Number	Comment
37	Many of the questions listed are inter-related i.e. if a system is fragmented there are other things that occur. Any system should be simple and easy to use and minimise duplication.
38	The duration of disturbance posed to an area, means and ways of anthropogenic activities that cause disturbance, should also be taken into account.
39	connecitivy
40	support of human societies/political decision makers for changing land use behaviours and damaging disturbance patterns
41	Change in landscape processes, such as hydrology.
42	Overall size of the disturbance in the context of the local area and region. E.g. effect on vegatation patch size. Whether or not 1ha of veg disturbance is important may depend on overall patch size and disturbance to the region - is it the last ha or 0.001%?
43	Is it possible to create a system of coexistence, as in the concept of Traditional Ecological Knowledge TEK.
44	the nature of the disturbing agent; intervals between exposure to disturbing agent; timing of the disturbance in relation to the organisms' life cycle, annual cycle etc; intensity of the disturbance. The other relevant factors frequency of disturbance, duration of exposure to disturbing agent were already considered.
45	potentially a few things: - will the disturbance decrease the species / community's resilience to climate change? - what other threatening processes are currently impacting on the species / community (i.e. will this disturbance add to already existing pressures?) - location of the disturbance site - is it currently acting as a corridor / buffer zone? - quality of the disturbance site - is it of such high quality / condition that it should not be disturbed? - protection status of the disturbance site (is it under some form of legal protection such as a covenant?) - degree of uncertainty about the site for any of the above - how much do we know, and can we really make a decision?
46	Effects on subsequent changes in invasibility
47	Resilience - ie. frequency of the disturbances over time, cumulative impacts of frequent disturbances, effectiveness of responses ....
48	I found the concepts/factors poorly worded and therefore am not happy with my answers. On what scale is biodiversity being assessed? If it is on a local scale then regional status is not relevant. The concepts/factors meander from population to community and back again. I do not think a popular vote is a useful way of creating what should be a conceptual model structured according to ecological principles.
49	no

Number	Comment
50	Type of disturbance is going to be instrumental in assessing impacts upon biodiversity and it is therefore difficult rating importance without knowing what the disturbance type is.
51	resilience of landscapes to recover, capacity to implement and monitori amelioration measures
52	Scope for suitable offsets (however defined)
53	Considering LCA without paying head to the ectoxicological effects of the threat and not just the ecological is miopic and inefficient.
54	Disturbance is essential for ecosystem functioning. So questions like how close does the disturbance mimic natural disturbance regimes.
55	the impacts that are overlooked by conventional impact evaluations, and that threaten landscape intactness
56	Considering that very few resources (financial and human capital) are available for the conservation management of bio-diverse landscapes under threat from anthropogenic and other disturbances, the most appropriate response must surely be holistic (i.e. conserving the integrity of a landscape - e.g. ecosystem processes, species' dispersal, habitat connectivity etc.) rather than focused on particular target species (i.e. those listed as 'threatened') that are perceived to be at relatively high risk of extinction (which is our current narrow approach). Indeed, the continued allocation of limited resources to 'threatened' species is probably a leading cause of landscape-scale degradation of Australia's natural ecosystems. We must see the forest, not the trees, so to speak.
57	How to reduce human influences on the environment
58	Is the disturbance associated with incremental biodiversity impacts and thus needs to be considered strategically and not in isolation. What is the resilience of the ecosystem to recover after the disturbance (to be considered in association with the proportion of the ecosystem being disturbed).
59	For a life cycle assessment, the 'disturbances' should include those associated with packaging, disposal, transport, energy generation for manufacturing or processing, etc. This survey doesn't indicate which disturbances are under consideration or how they are weighted.
60	I don't think it is possible to obtain 1 overall 'score' with all of the variables. I don't think factors can easily be weighted either. Very problematic this whole concept.
61	Essentially, the inter-connectivity of landscapes requires for all of the concepts listed to be considered when determining perturbations, either anthropogenic or "natural". To not do so implies a lack of understanding of ecological processes. As a practitioner in the EIA process, I also have to be concerned with the legislative implications. Unsure as to what you are really trying to get at with this survey.

Number	Comment
62	Social and economic factors need to be included in an assessment.
63	multiple interactions between disturbance and invasive species and fire etc. It is important to the impact of these factors in synergy with others.
64	Cumulative impacts of all projects in a given area/region and by far the most important thing to consider.
65	Yes. The concept of thresholds and intesnity of distubrance and the ability to intervene and ability to reverse the state of the system to pre-disturbance state.
66	I was willing to undertake this Q, and the questions are detailed, but i find it impossible to address any of them without some information on 'the disturbance'. Ecologically, disturbance come in a great many forms, they occur at many spatial and temporal scales and patterns. I cant answer any of these questions in relation to a notional 'disturbance'. If you were specific about it, i probably could. sorry
67	Has biodiversity already experienced a significant decline in the disturbance area (prior to the new disturbance, i.e. is it worth saving or doomed anyway?)

Appendix 6. Literature Review References

Central West Cropping/Pasture

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Appendix 7. Individual biodiversity scores for each taxonomic group, for each of the questions and production systems.

In the section below we present the figures related to the individual biodiversity scores for each taxonomic group, for each of the questions and production systems. For some questions, the answers relate to all taxa combined, and for others, responses are for individual taxa. The figures below include scores derived from the relevant literature and expert advice. "CWCP" relates to "cropping", "CWRG" relates to "rangelands grazing", "Eden" relates to native forestry and "Hume" relates to softwood production.

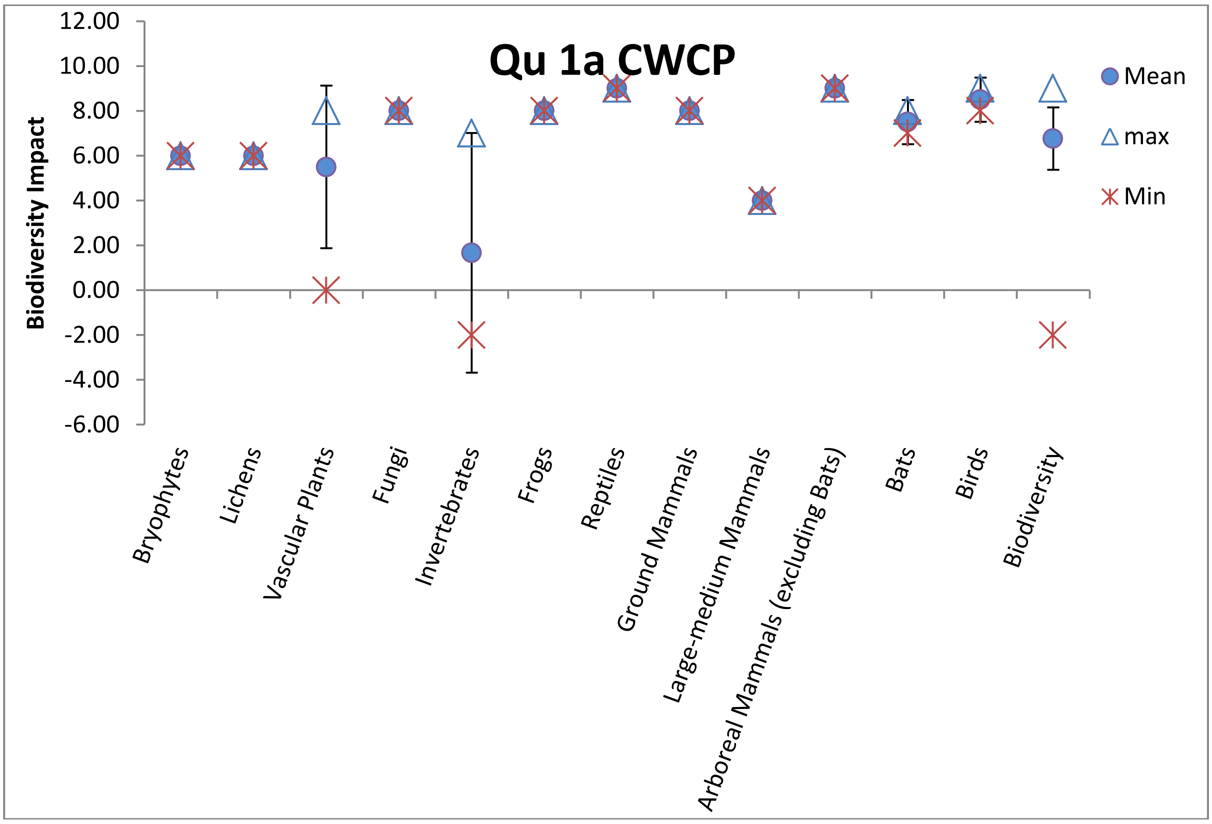
QUESTION 1

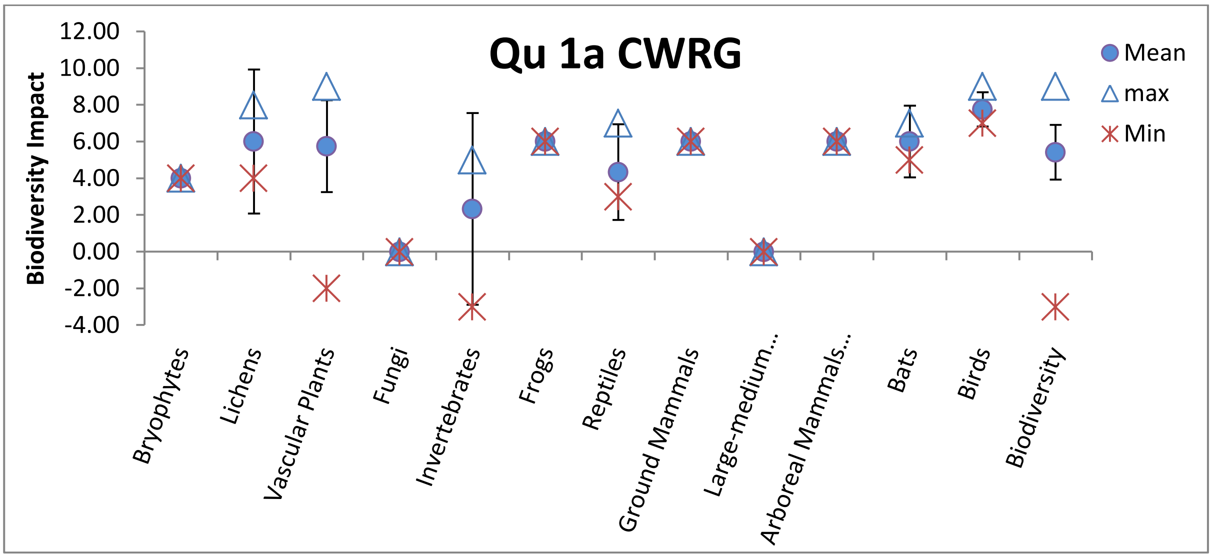
Question 1A: What is the immediate loss of species diversity as a direct result of the process?

a. compared to a benchmark state (e.g. pre-1750 vegetation) appropriate for the region in question

b. compared to the land-use immediately prior to the process in question

Literature scores

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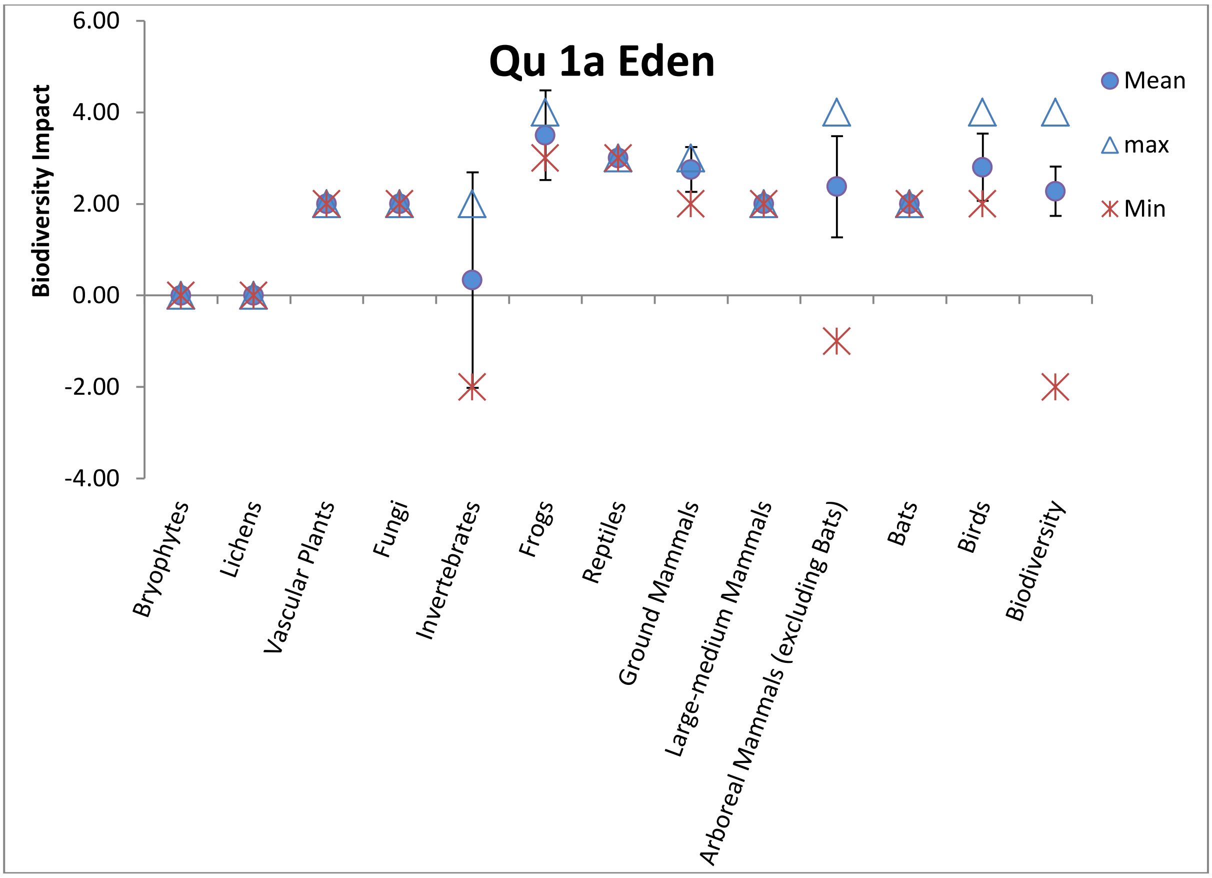
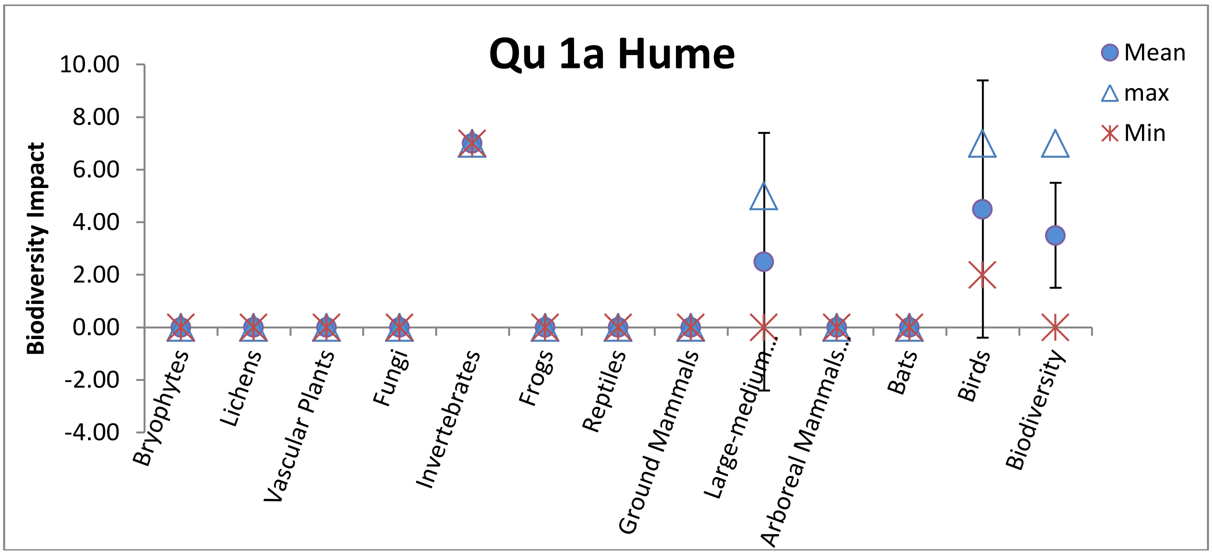
Biodiversity Impact
12.00
10.00
8.00
6.00
4.00
2.00
0.00
-2.00
-4.00
Mean
max
Min
Bryophytes
Lichens
Vascular Plants
Fungi
Invertebrates
Frogs
Reptiles
Ground Mammals
Large-medium...
Arboreal Mammals...
Bats
Birds
Biodiversity


Qu 1a Eden
Biodiversity Impact
6.00
4.00
2.00
0.00
-2.00
-4.00
Mean
max
Min
Bryophytes
Lichens
Vascular Plants
Fungi
Invertebrates
Frogs
Reptiles
Ground Mammals
Large-medium Mammals
Arboreal Mammals (excluding Bats)
Bats
Birds
Biodiversity


Qu 1a Hume
Mean
max
Min
Biodiversity Impact
10.00
8.00
6.00
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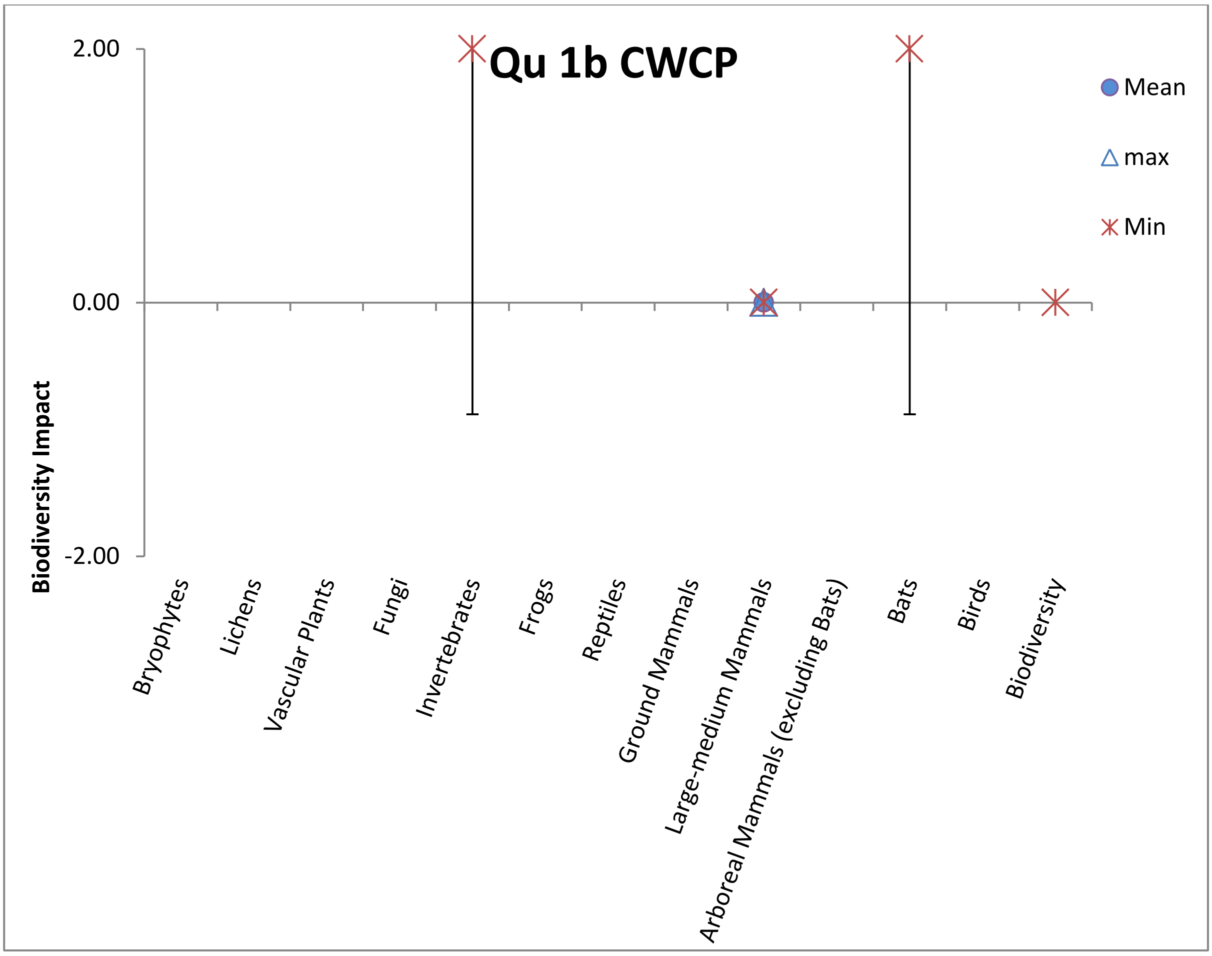
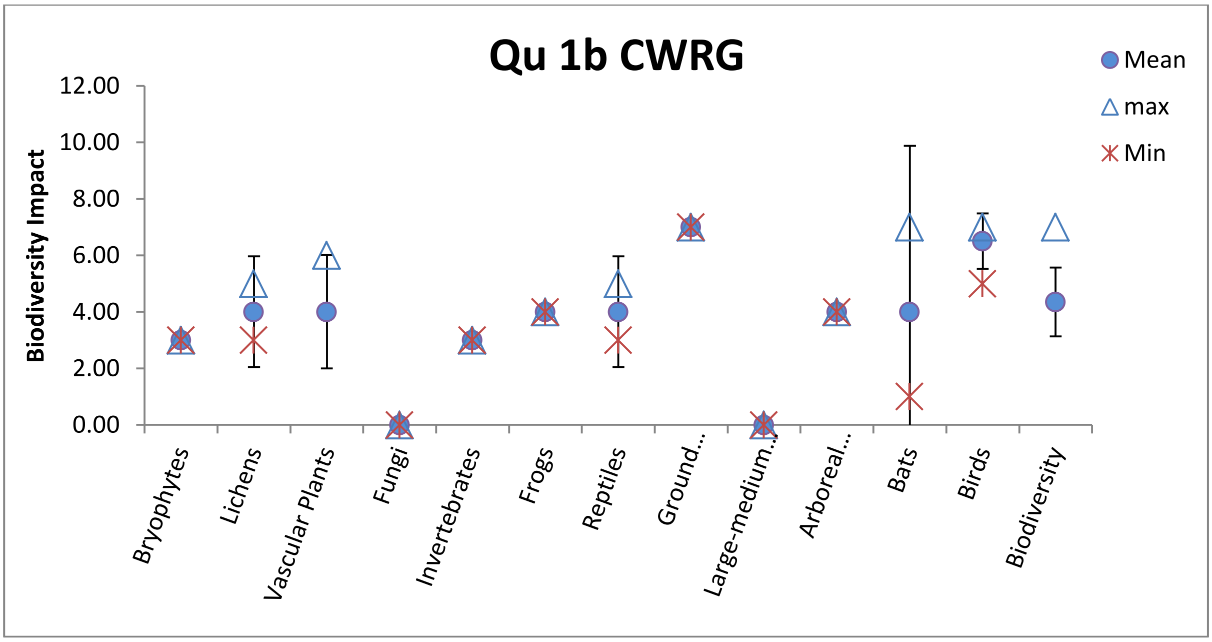
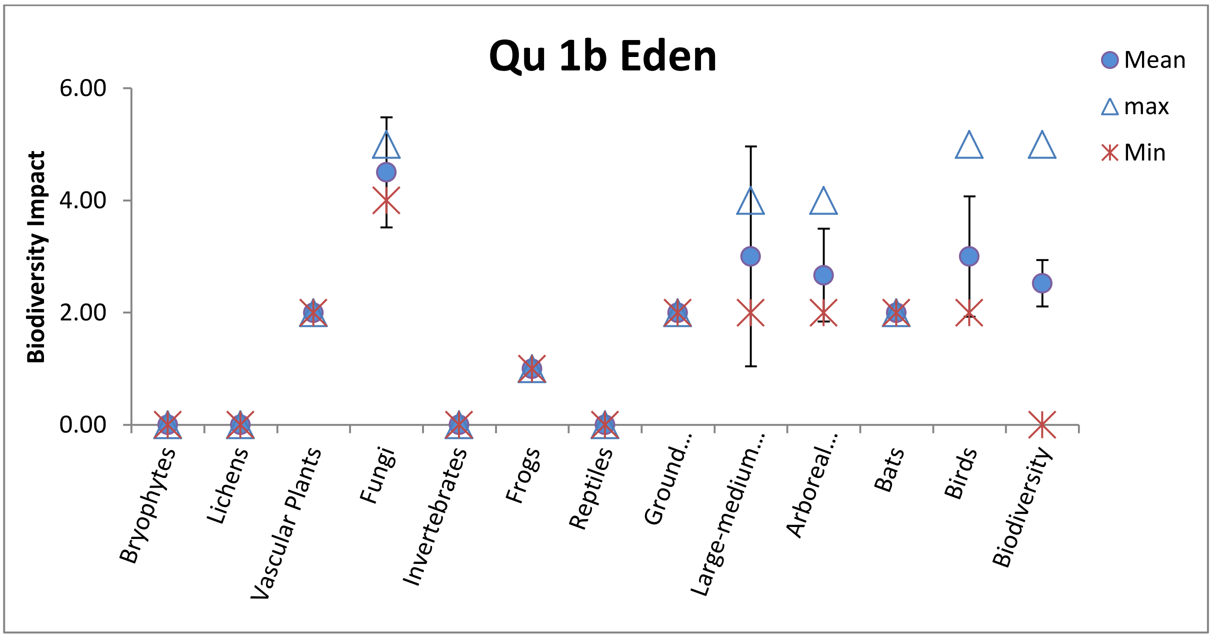
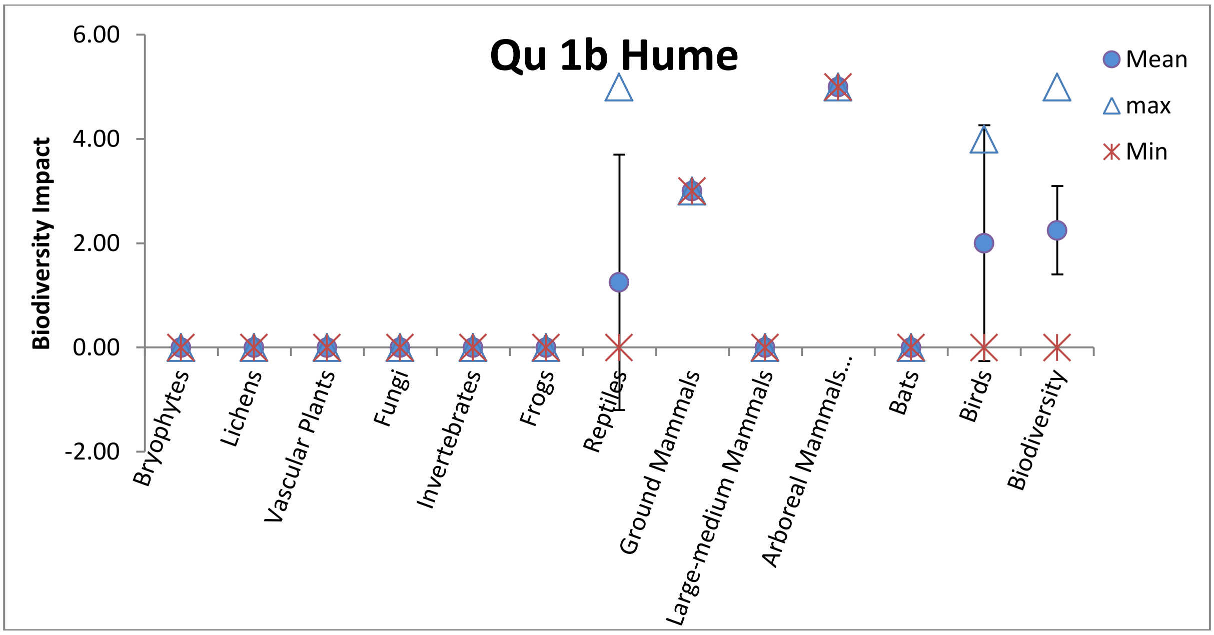
0.00
-2.00
-4.00
Bryophytes
Lichens
Vascular Plants
Fungi
Invertebrates
Frogs
Reptiles
Ground Mammals
Large-medium...
Arboreal Mammals...
Bats
Birds
Biodiversity


Qu 1b CWCP
Mean
max
Min
Biodiversity Impact
2.00
0.00
-2.00
Bryophytes
Lichens
Vascular Plants
Fungi
Invertebrates
Frogs
Reptiles
Ground Mammals
Large-medium Mammals
Arboreal Mammals (excluding Bats)
Bats
Birds
Biodiversity

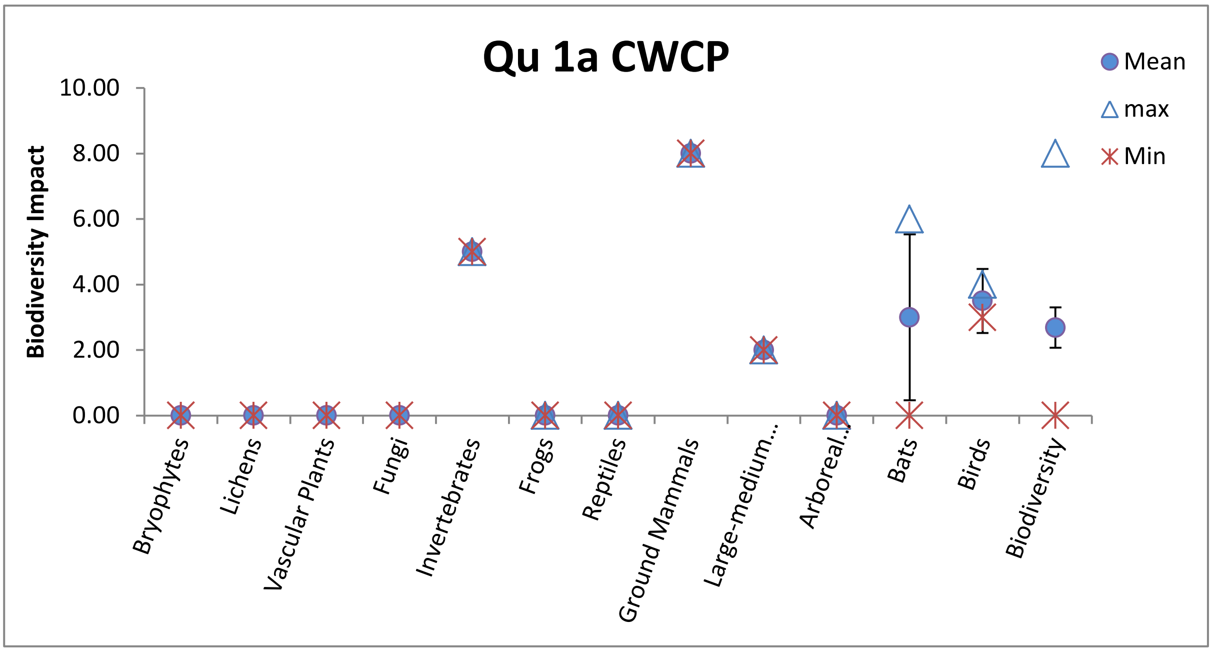

Qu 1b CWRG
Mean
max
Min
Biodiversity Impact
12.00
10.00
8.00
6.00
4.00
2.00
0.00
Bryophytes
Lichens
Vascular Plants
Fungi
Invertebrates
Frogs
Reptiles
Ground...
Large-medium...
Arboreal...
Bats
Birds
Biodiversity

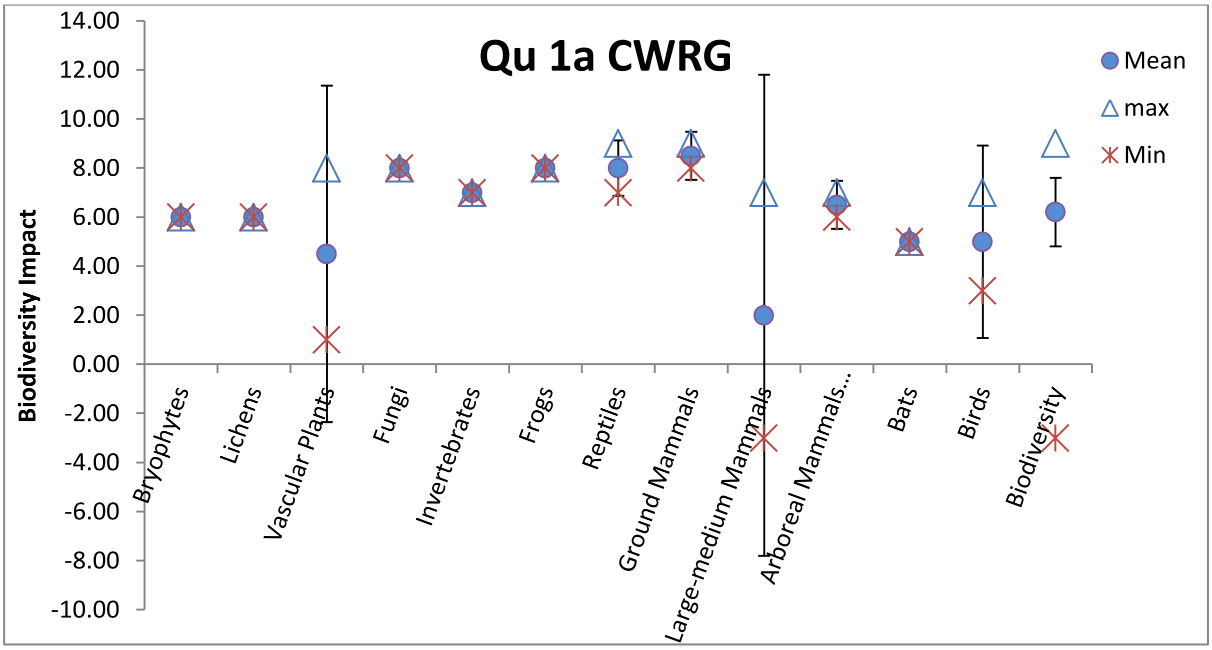

Qu 1b Eden
Mean
max
Min
Biodiversity Impact
6.00
4.00
2.00
0.00
Bryophytes
Lichens
Vascular Plants
Fungi
Invertebrates
Frogs
Reptiles
Ground...
Large-medium...
Arboreal...
Bats
Birds
Biodiversity

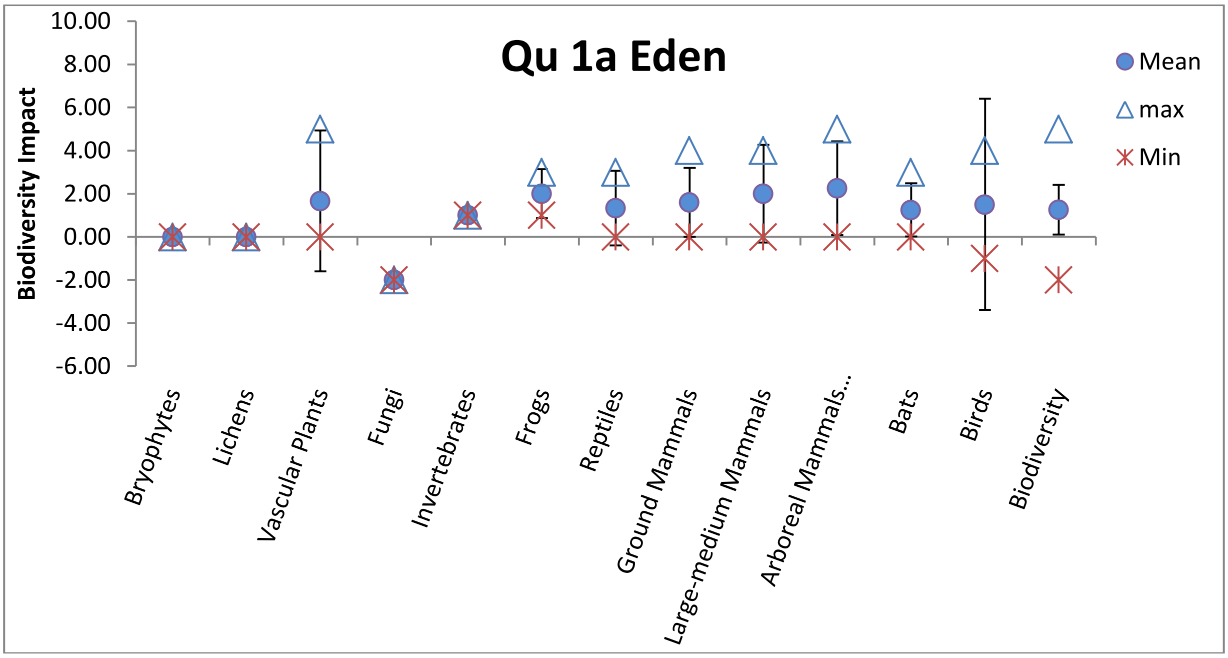


Qu 1b Hume
Biodiversity Impact
6.00
4.00
2.00
0.00
-2.00
Mean
max
Min
Bryophytes
Lichens
Vascular Plants
Fungi
Invertebrates
Frogs
Reptiles
Ground Mammals
Large-medium Mammals
Arboreal Mammals...
Bats
Birds
Biodiversity

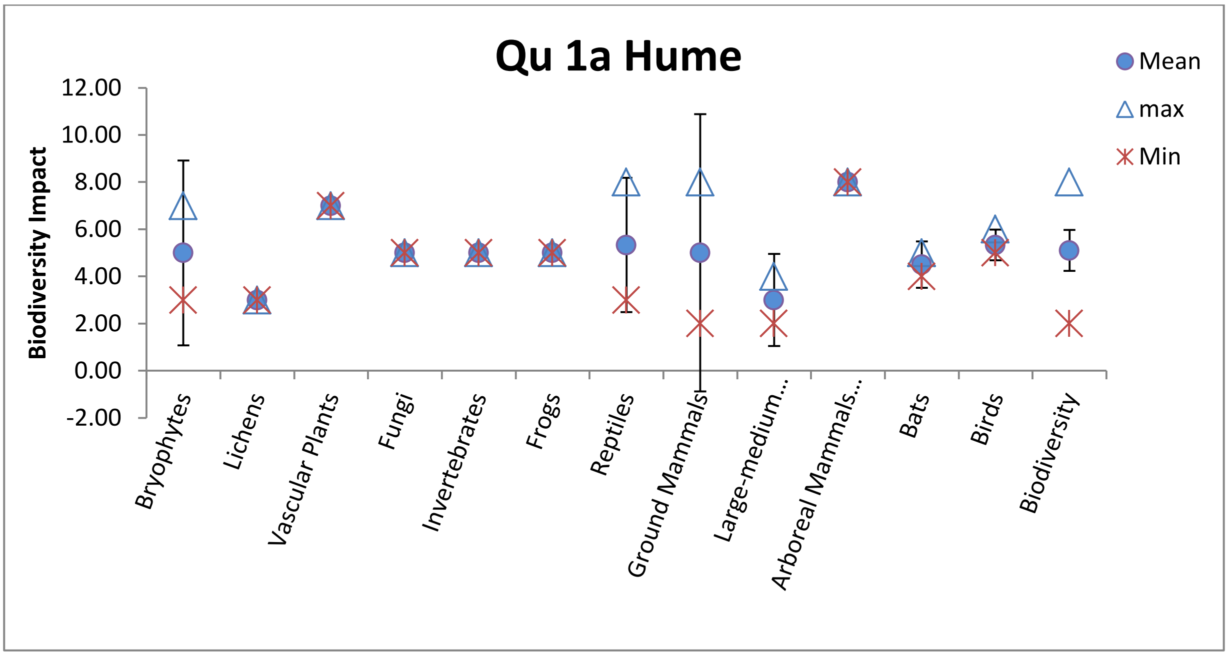
Survey scores



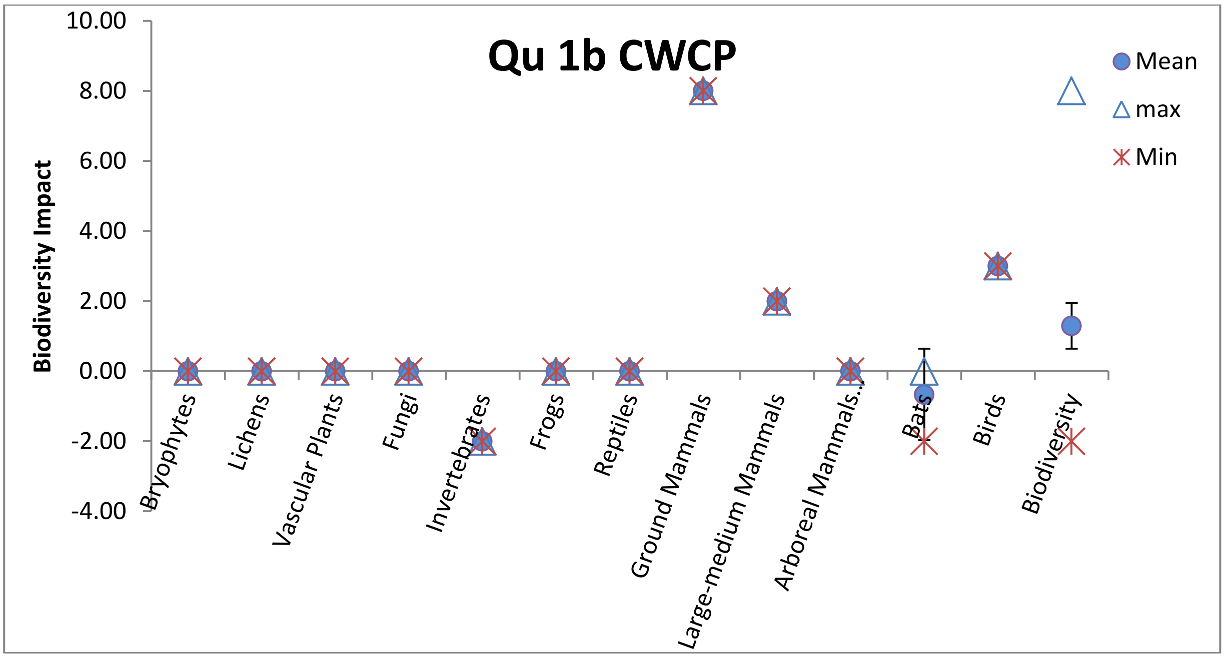




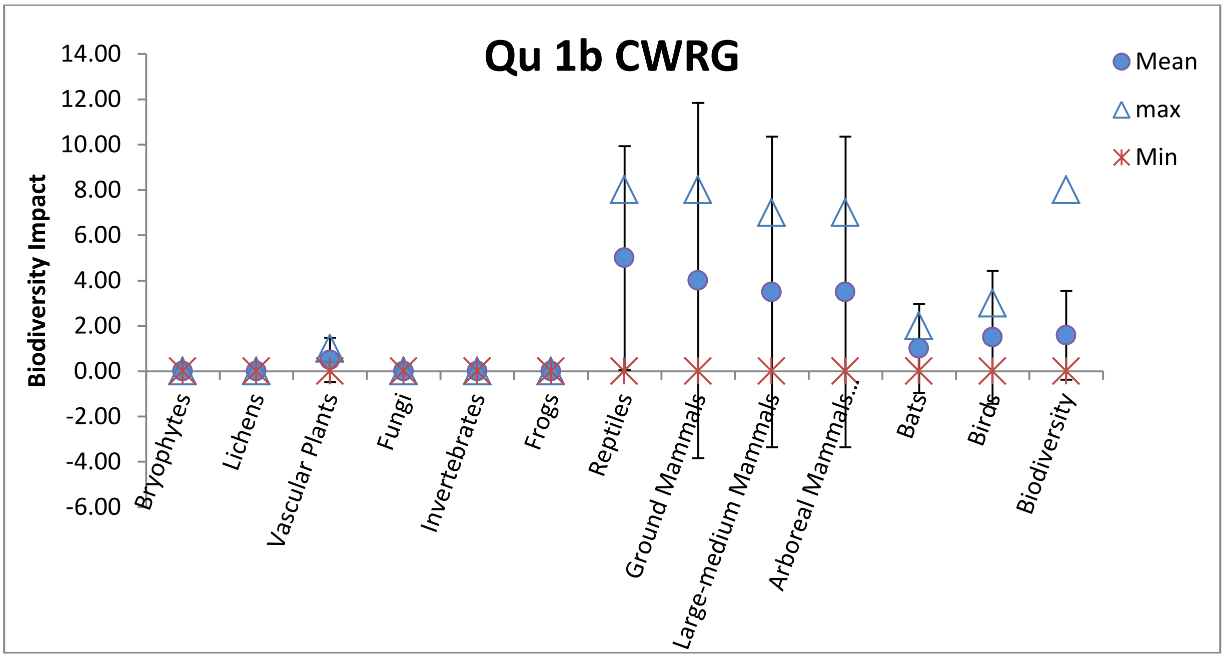
Qu 1a Eden
Mean
max
Min
Biodiversity Impact
10.00
8.00
6.00
4.00
2.00
0.00
-2.00
-4.00
-6.00
Bryophytes
Lichens
Vascular Plants
Fungi
Invertebrates
Frogs
Reptiles
Ground Mammals
Large-medium Mammals
Arboreal Mammals...
Bats
Birds
Biodiversity



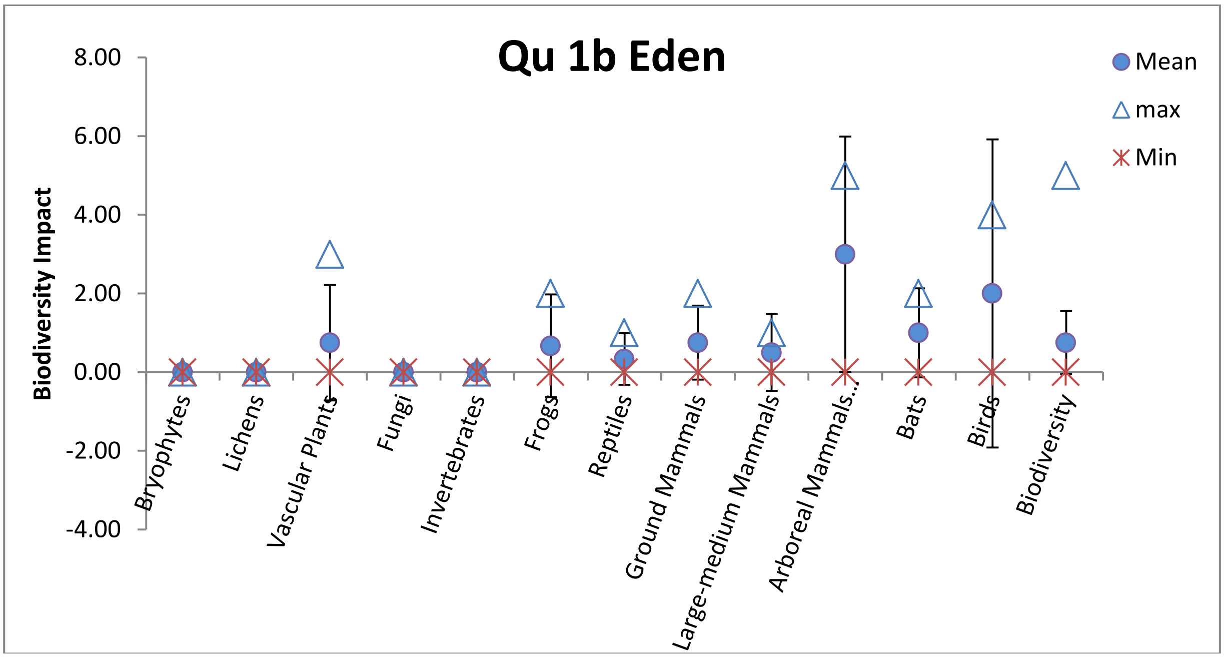
Qu 1a Hume
Mean
max
Min
Biodiversity Impact
12.00
10.00
8.00
6.00
4.00
2.00
0.00
-2.00
Bryophytes
Lichens
Vascular Plants
Fungi
Invertebrates
Frogs
Reptiles
Ground Mammals
Large-medium...
Arboreal Mammals...
Bats
Birds
Biodiversity



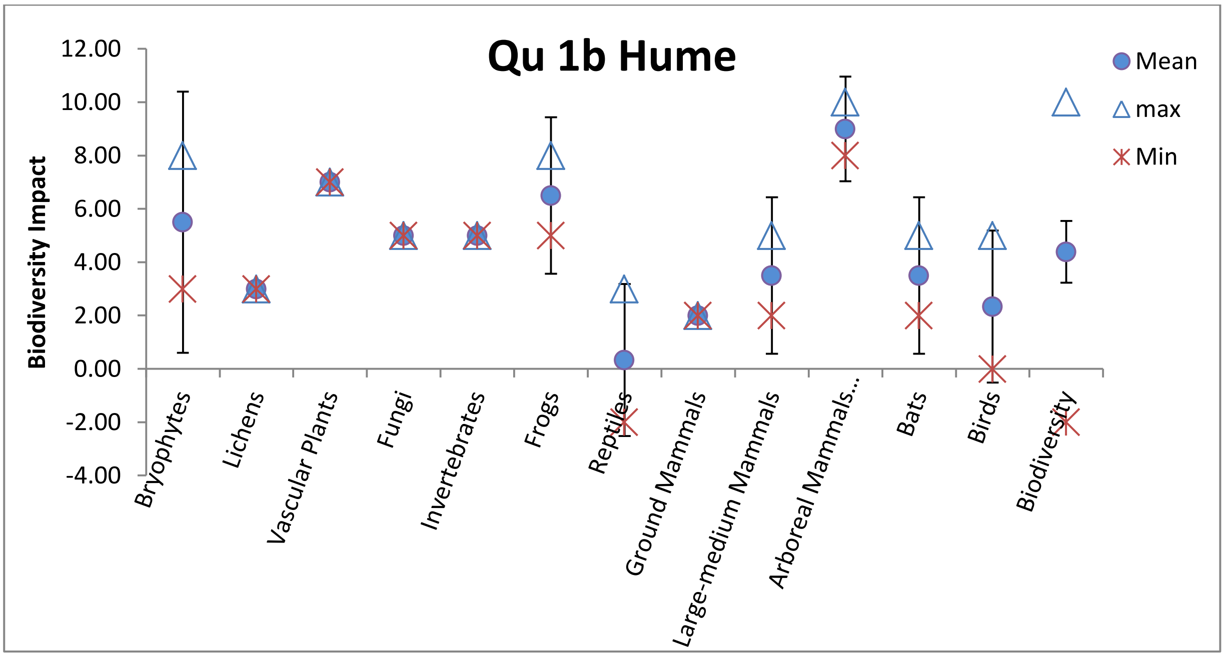
Qu 1b CWCP
Biodiversity Impact
10.00
8.00
6.00
4.00
2.00
0.00
-2.00
-4.00
Bryophytes
Lichens
Vascular Plants
Fungi
Invertebrates
Frogs
Reptiles
Ground Mammals
Large-medium Mammals
Arboreal Mammals...
Bats
Birds
Biodiversity
Mean
max
Min



Qu 1b CWRG
Biodiversity Impact
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
-2.00
-4.00
-6.00
Bryophytes
Lichens
Vascular Plants
Fungi
Invertebrates
Frogs
Reptiles
Ground Mammals
Large-medium Mammals
Arboreal Mammals...
Bats
Birds
Biodiversity
Mean
max
Min



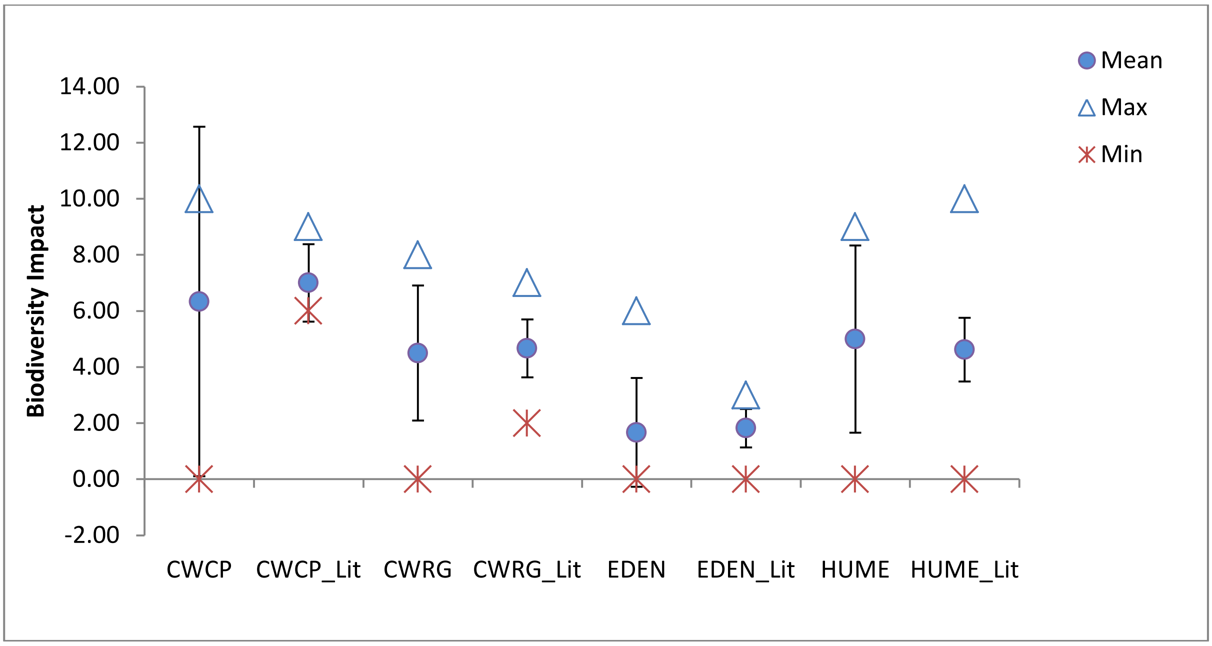
Qu 1b Eden
Biodiversity Impact
8.00
6.00
4.00
2.00
0.00
-2.00
-4.00
Bryophytes
Lichens
Vascular Plants
Fungi
Invertebrates
Frogs
Reptiles
Ground Mammals
Large-medium Mammals
Arboreal Mammals...
Bats
Birds
Biodiversity
Mean
max
Min

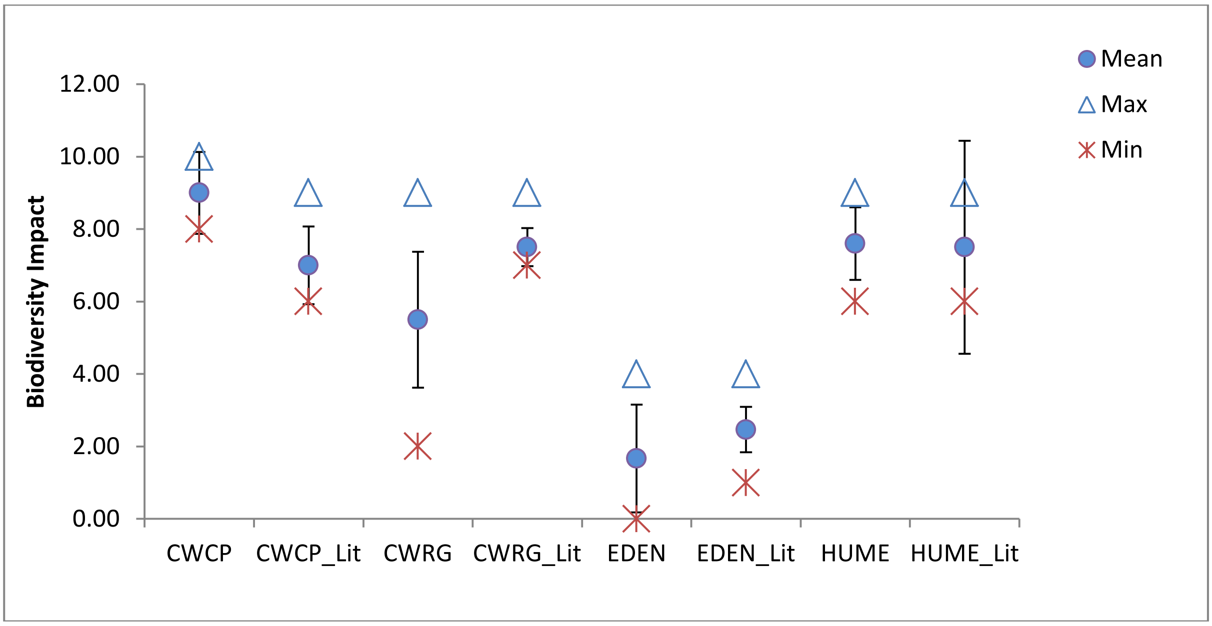


Qu 1b Hume
Biodiversity Impact
12.00
10.00
8.00
6.00
4.00
2.00
0.00
-2.00
-4.00
Bryophytes
Lichens
Vascular Plants
Fungi
Invertebrates
Frogs
Reptiles
Ground Mammals
Large-medium Mammals
Arboreal Mammals...
Bats
Birds
Biodiversity
Mean
max
Min

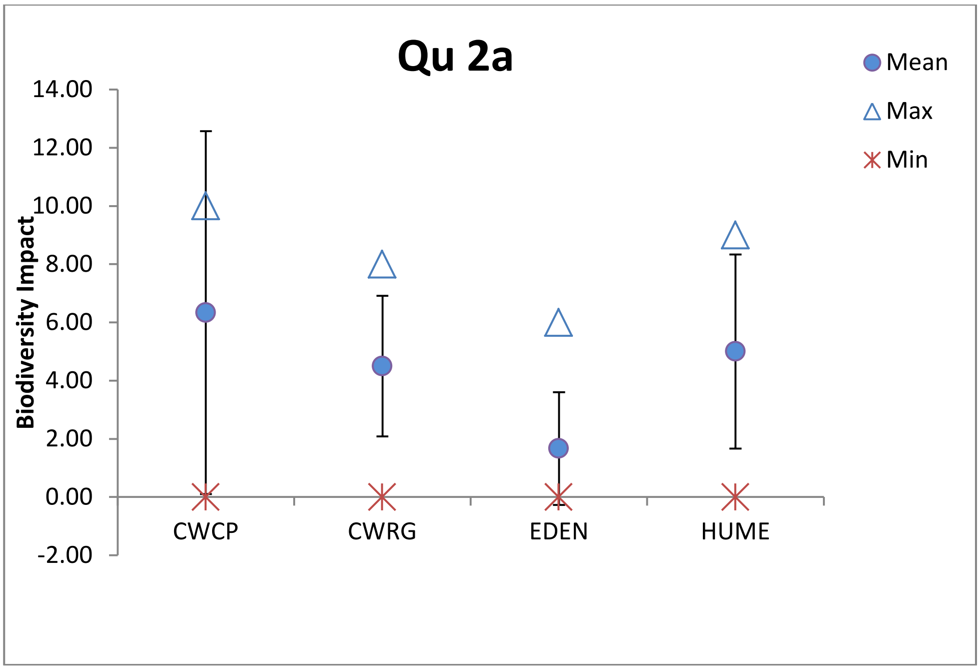
Question 2
2. To what extent does species diversity recover?
a. between the primary disturbance events induced by the process or within 50 years since disturbance for processes that are non-cyclic disturbance events (e.g. mining) (When the process is not new, but is continuing the same existing process in that area)
b. when the process has been newly established on existing, mature native vegetation

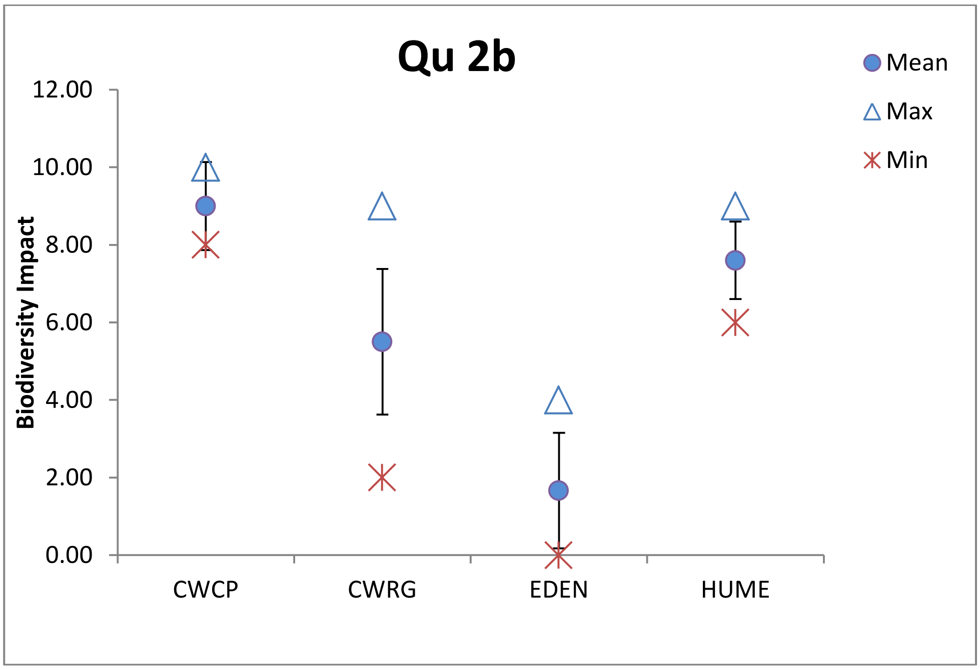
Literature and survey scores





Survey scores

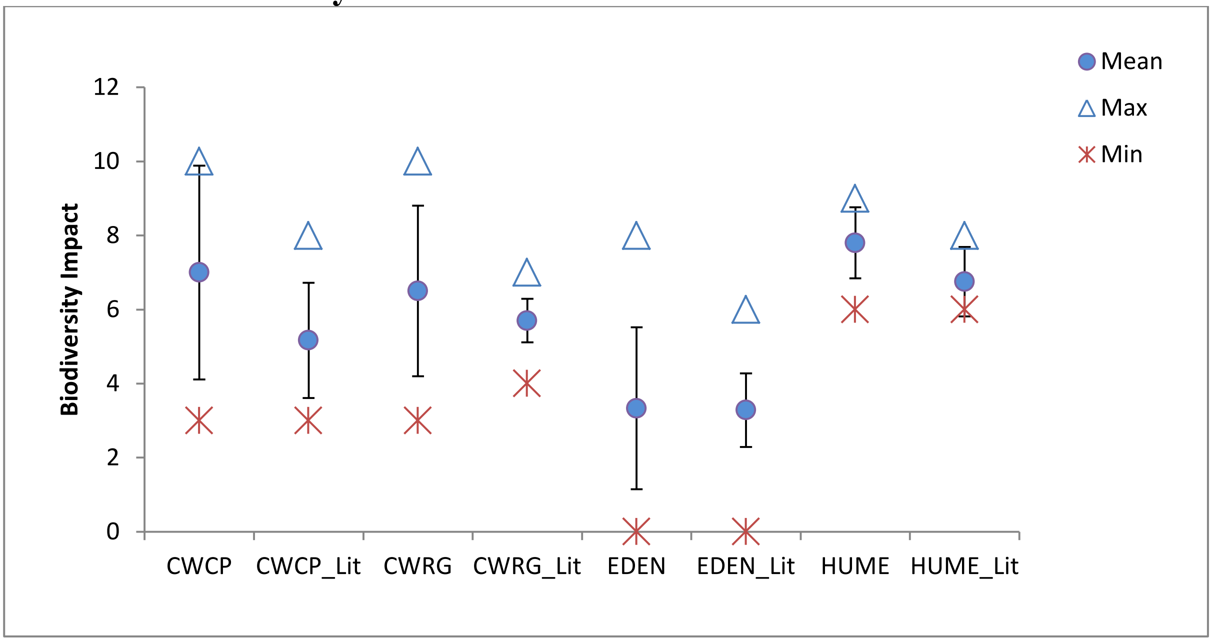




Question 3

To what extent does the process alter natural disturbance regimes?

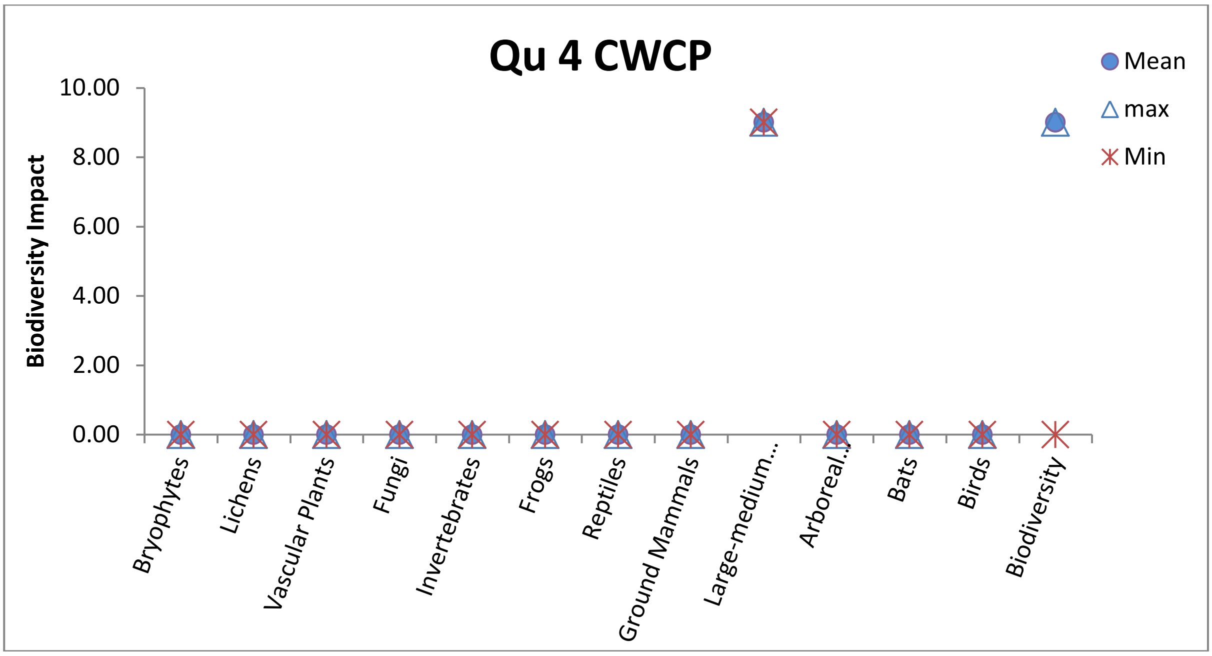
Literature and survey scores

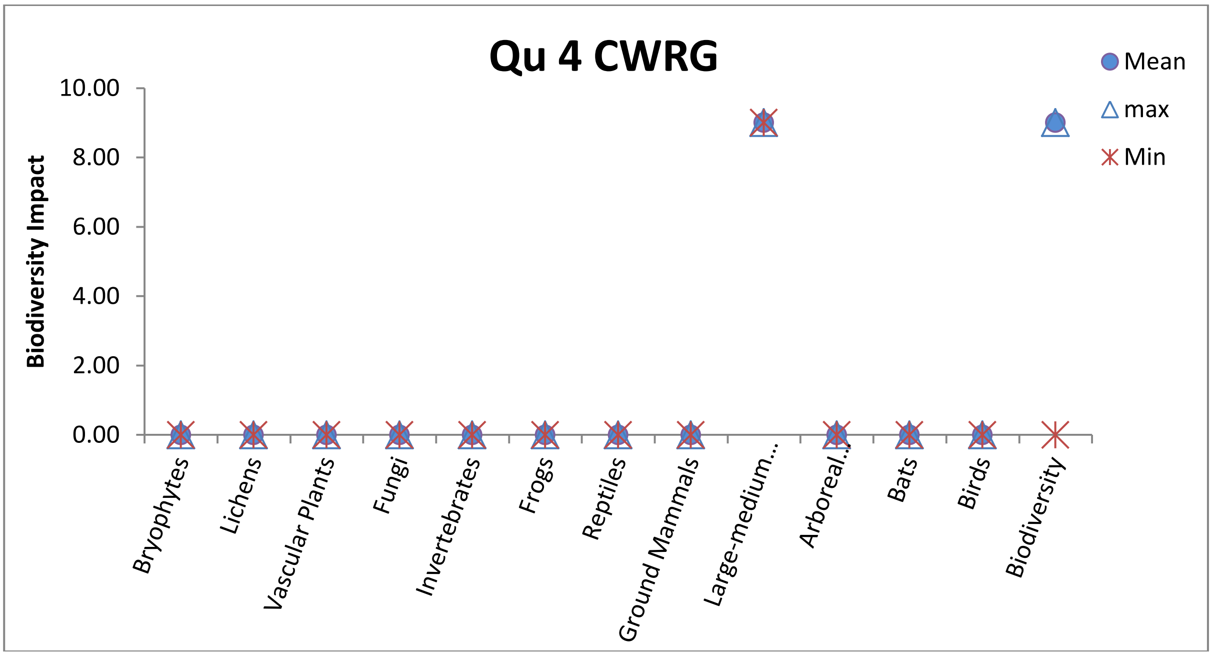


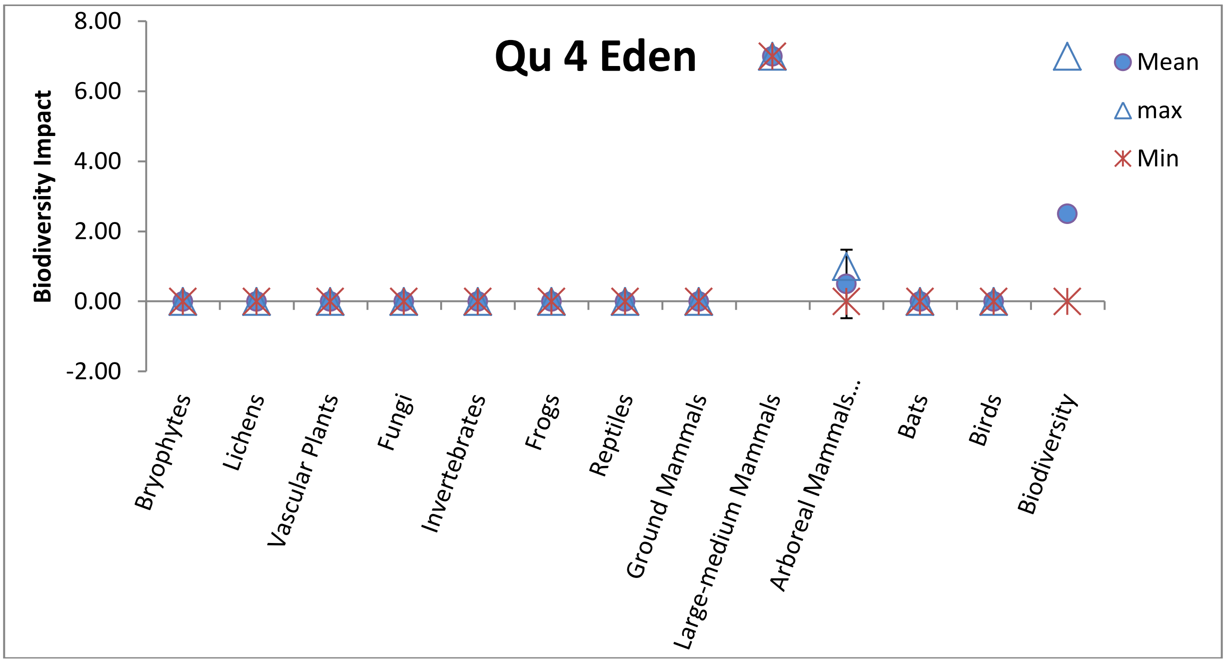
Question 4

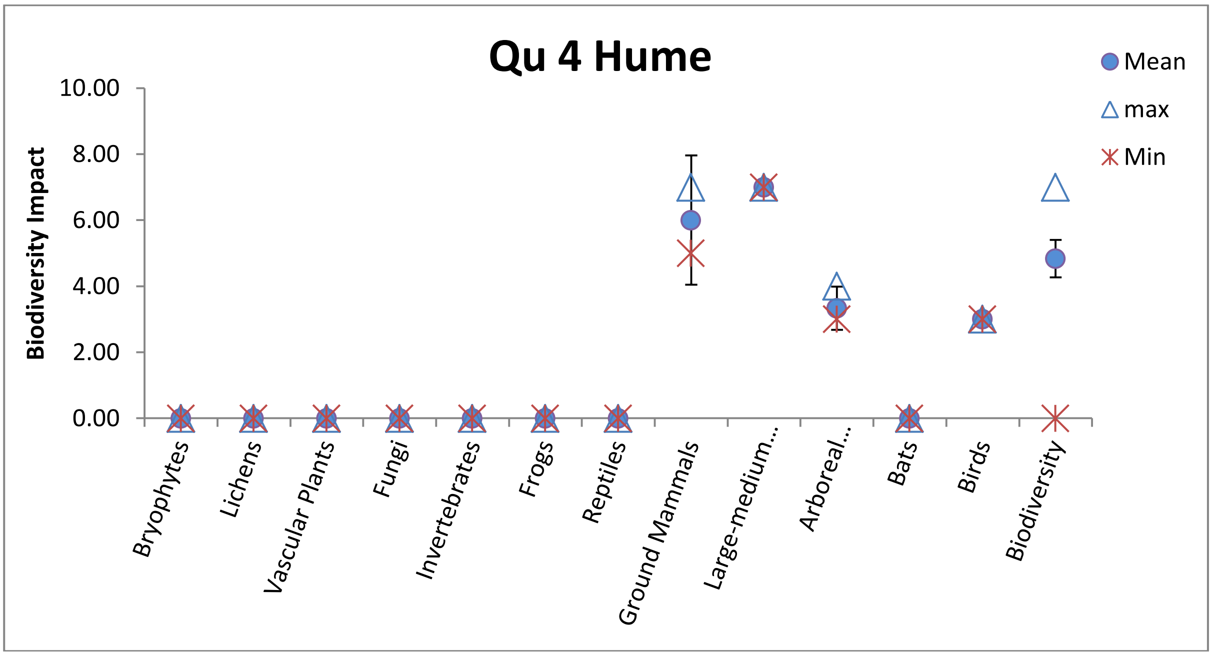
To what extent does the disturbance increase the impacts of invasive predators?

Literature scores

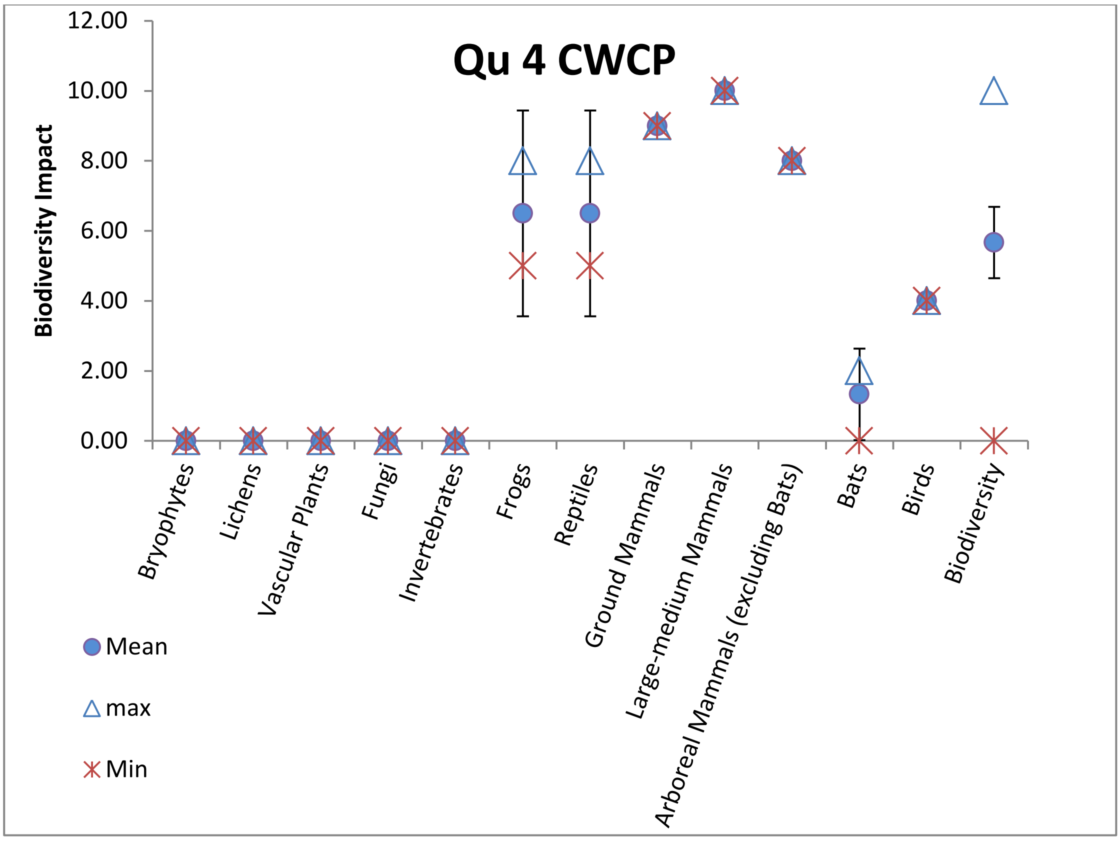


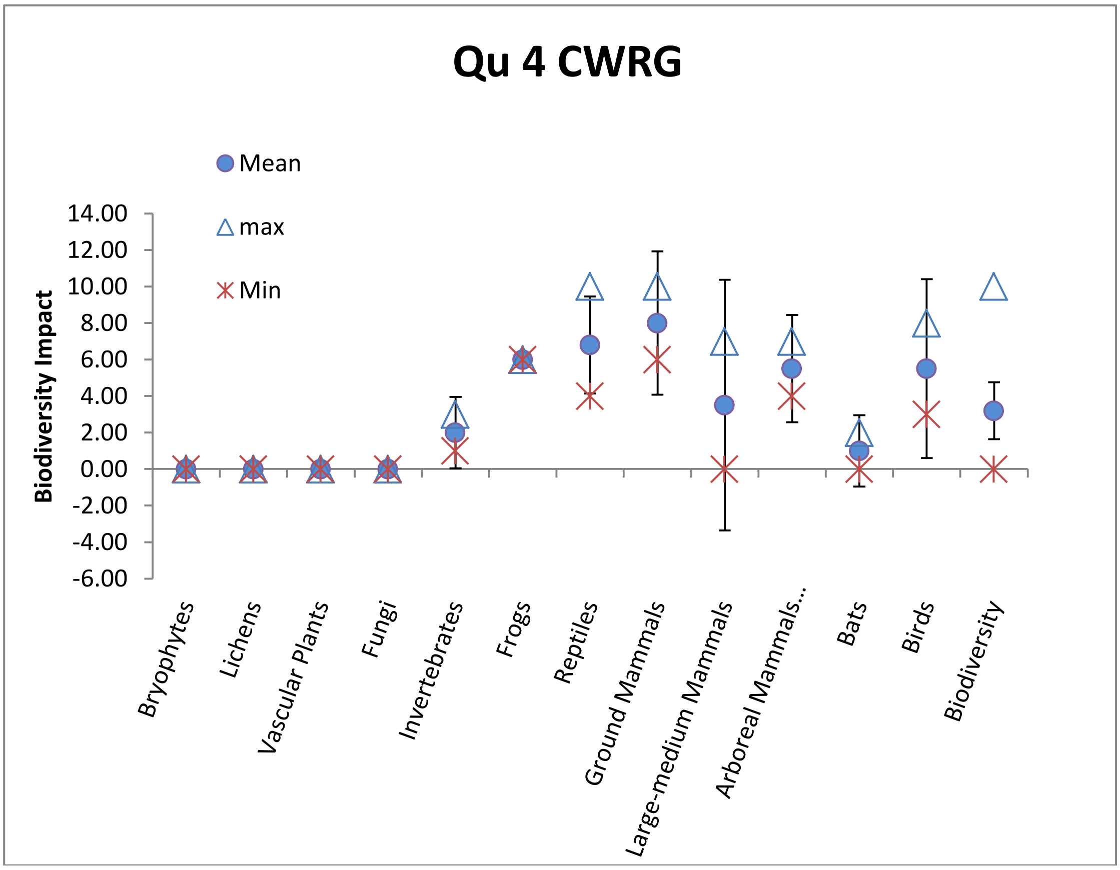


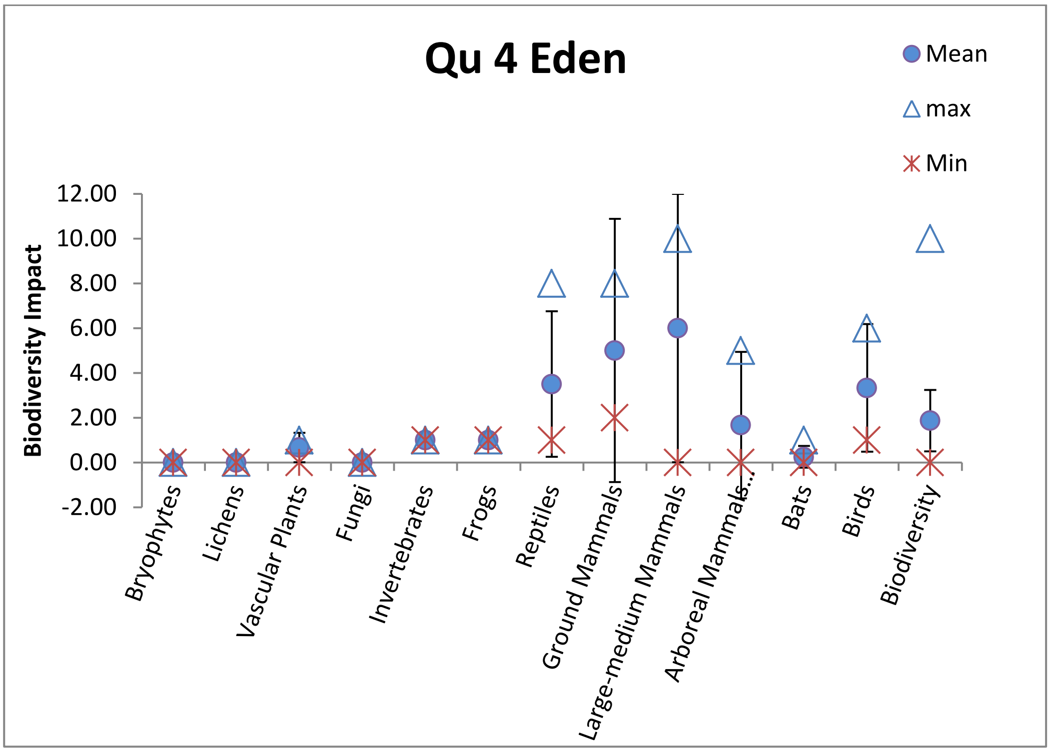

Qu 4 Eden
Biodiversity Impact
8.00
6.00
4.00
2.00
0.00
-2.00
Mean
max
Min
Bryophytes
Lichens
Vascular Plants
Fungi
Invertebrates
Frogs
Reptiles
Ground Mammals
Large-medium Mammals
Arboreal Mammals...
Bats
Birds
Biodiversity

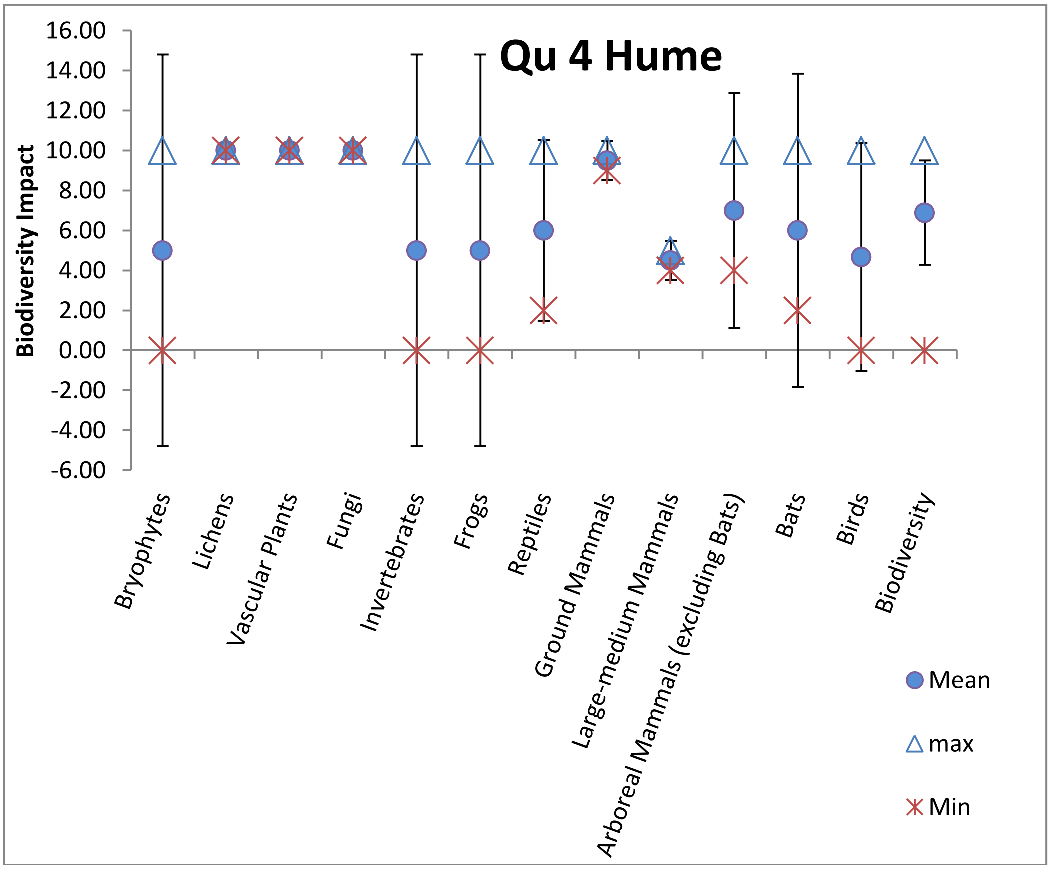

Qu 4 Hume
Biodiversity Impact
10.00
8.00
6.00
4.00
2.00
0.00
Mean
max
Min
Bryophytes
Lichens
Vascular Plants
Fungi
Invertebrates
Frogs
Reptiles
Ground Mammals
Large-medium...
Arboreal...
Bats
Birds
Biodiversity

Survey scores





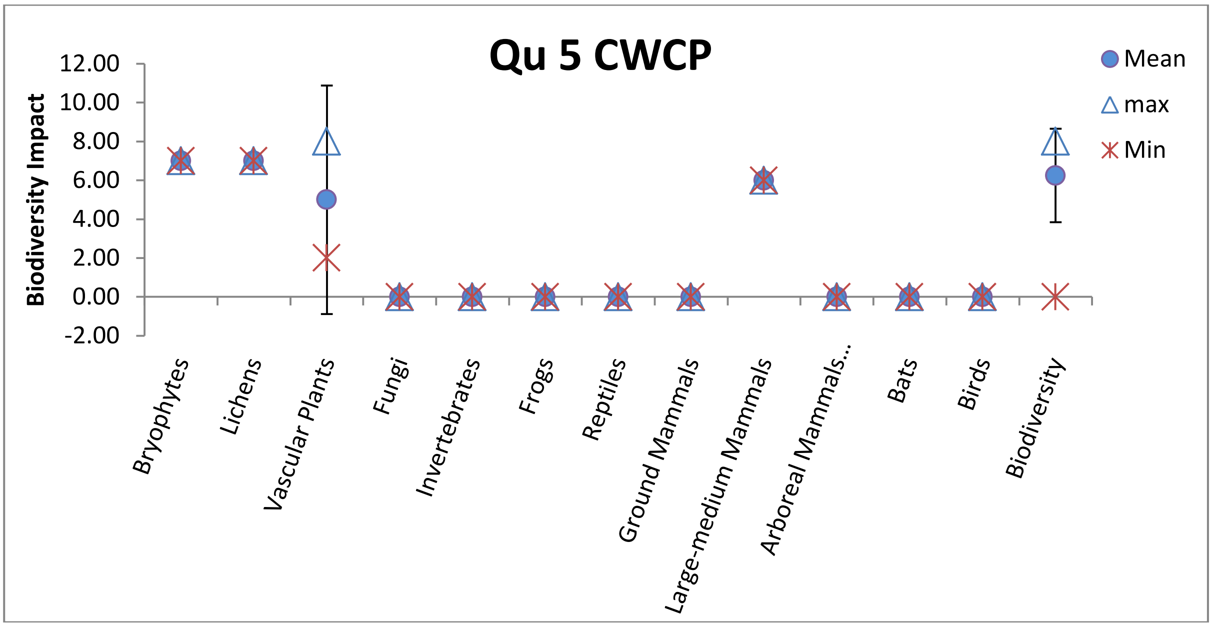

Qu 4 Eden
Mean
max
Min
Biodiversity Impact
12.00
10.00
8.00
6.00
4.00
2.00
0.00
-2.00
Bryophytes
Lichens
Vascular Plants
Fungi
Invertebrates
Frogs
Reptiles
Ground Mammals
Large-medium Mammals
Arboreal Mammals...
Bats
Birds
Biodiversity

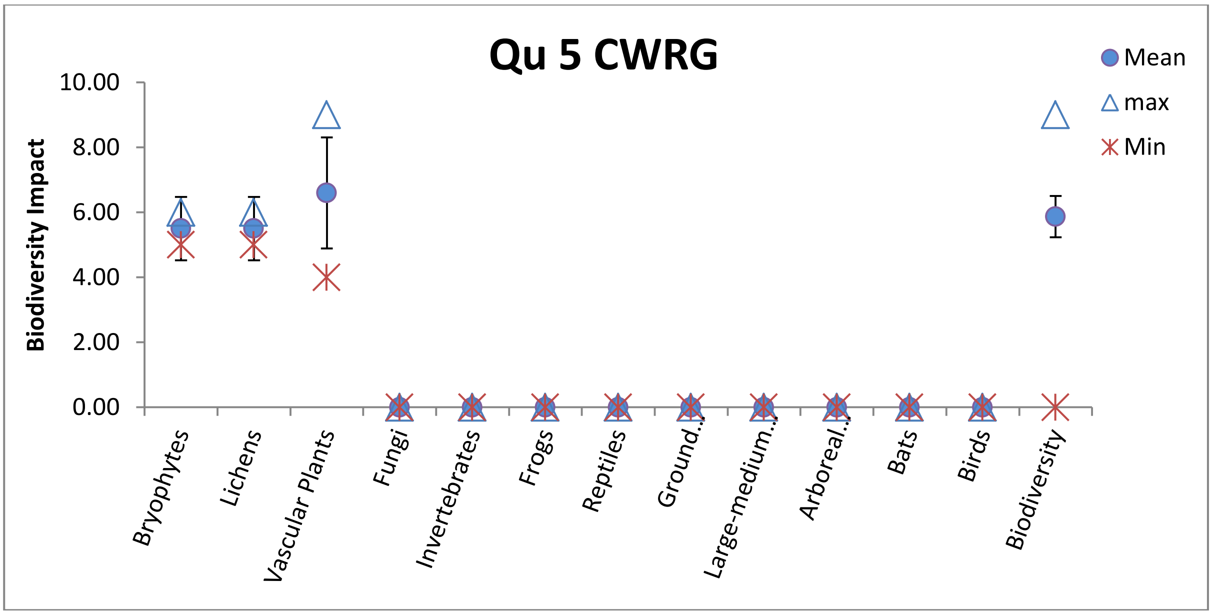

Qu 4 Hume
Biodiversity Impact
16.00
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
-2.00
-4.00
-6.00
Bryophytes
Lichens
Vascular Plants
Fungi
Invertebrates
Frogs
Reptiles
Ground Mammals
Large-medium Mammals
Arboreal Mammals (excluding Bats)
Bats
Birds
Biodiversity
Mean
max
Min

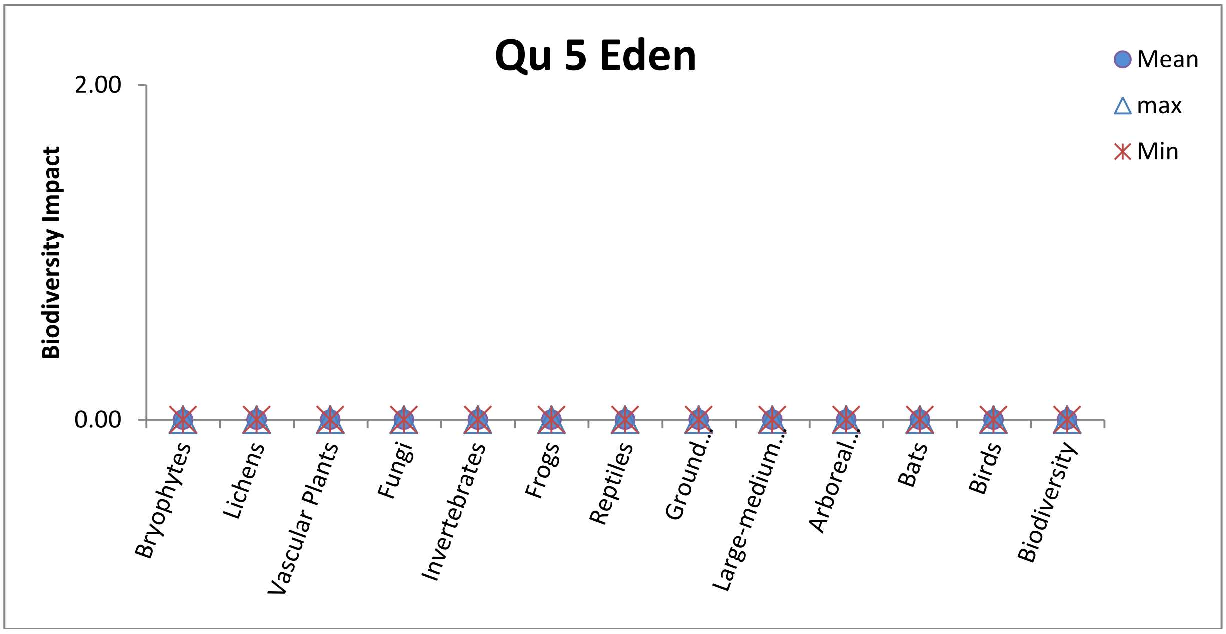
Question 5

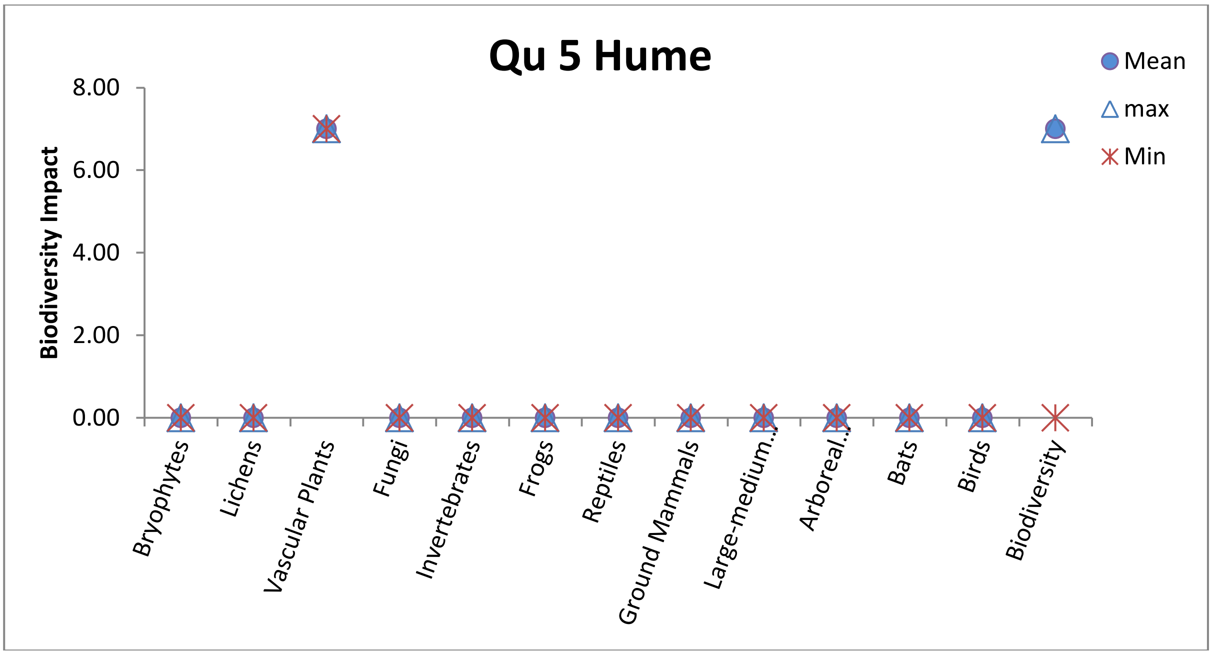
To what extent does the disturbance increase the impacts of invasive plants?

Literature scores

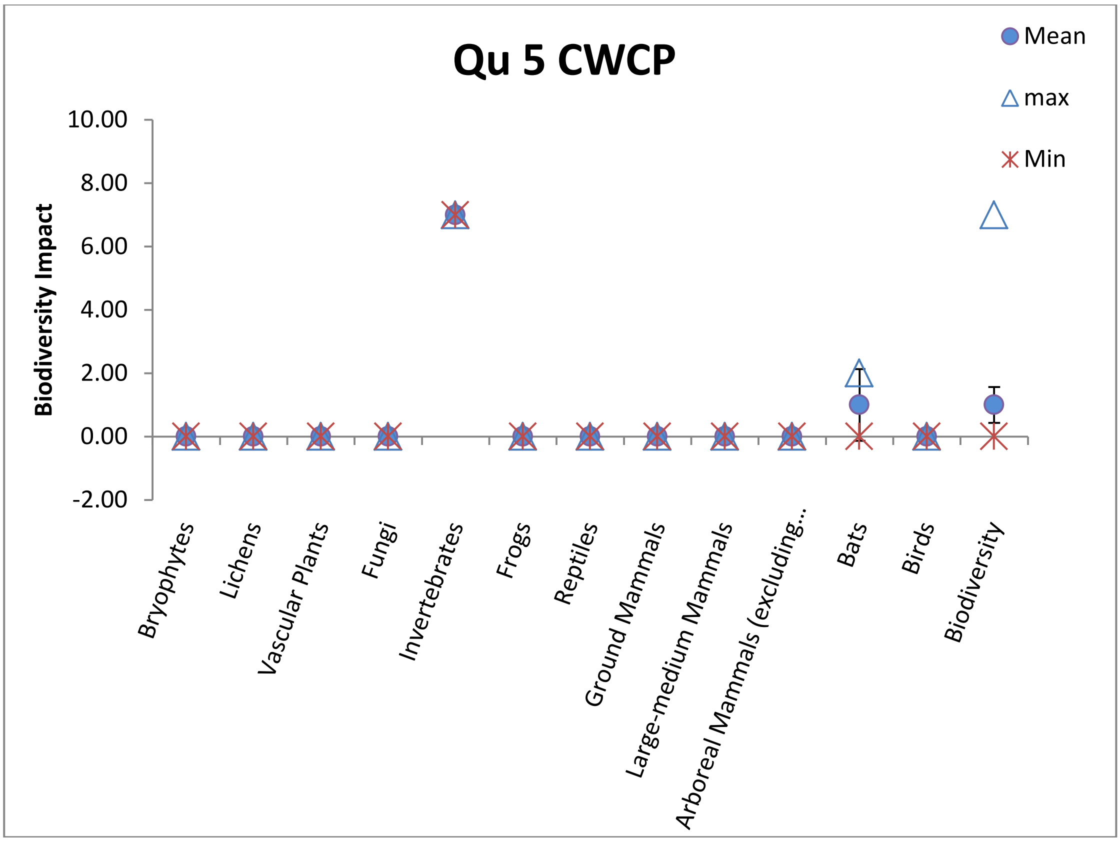


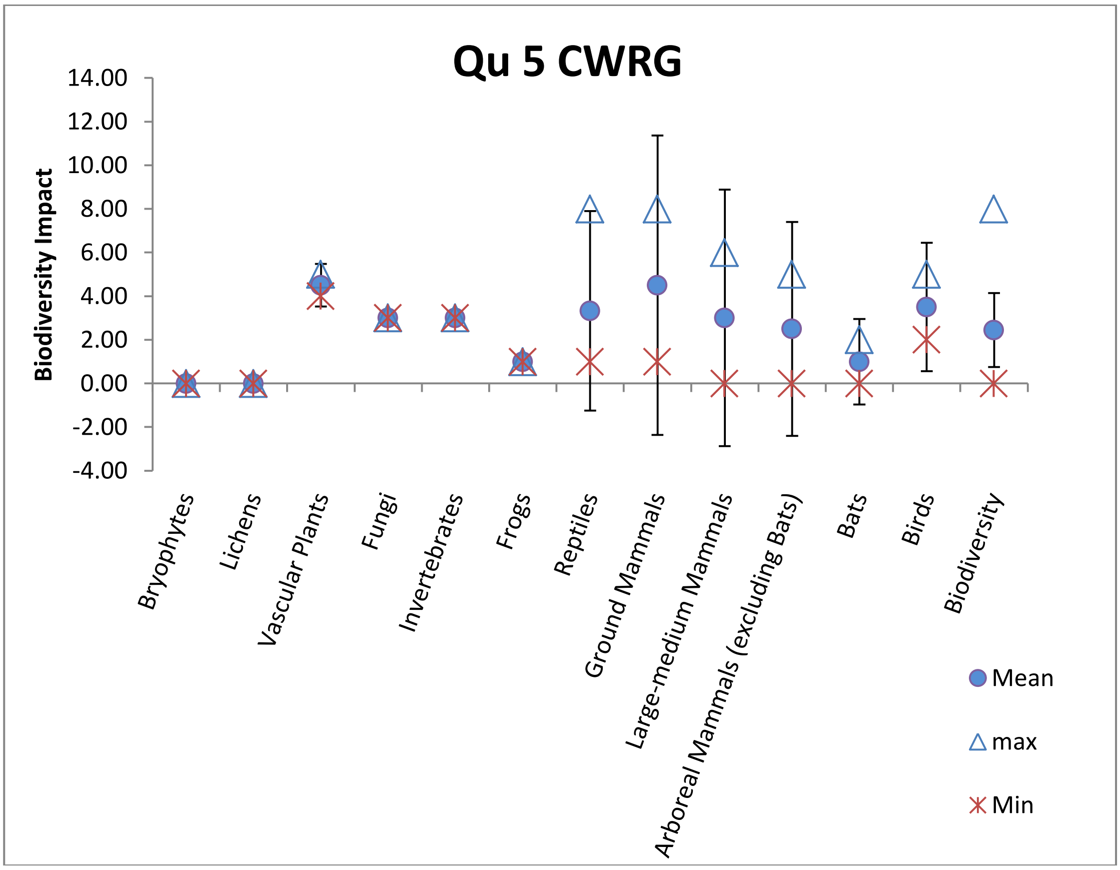


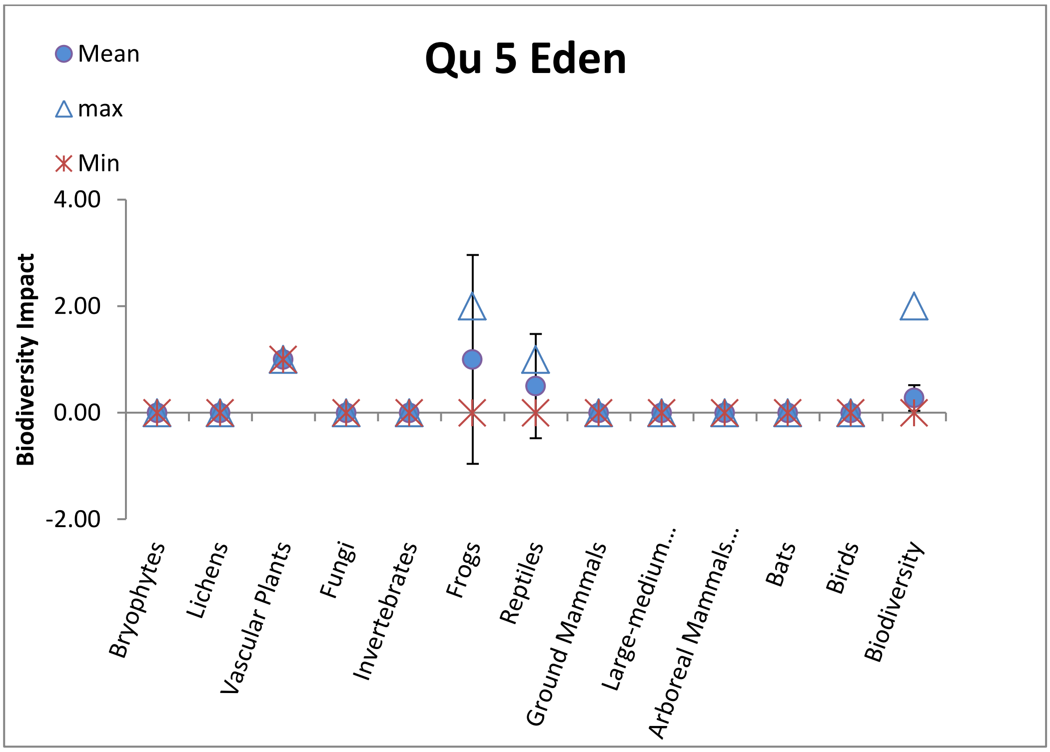

Qu 5 Eden
Mean
max
Min
Biodiversity Impact
2.00
0.00
Bryophytes
Lichens
Vascular Plants
Fungi
Invertebrates
Frogs
Reptiles
Ground...
Large-medium...
Arboreal...
Bats
Birds
Biodiversity

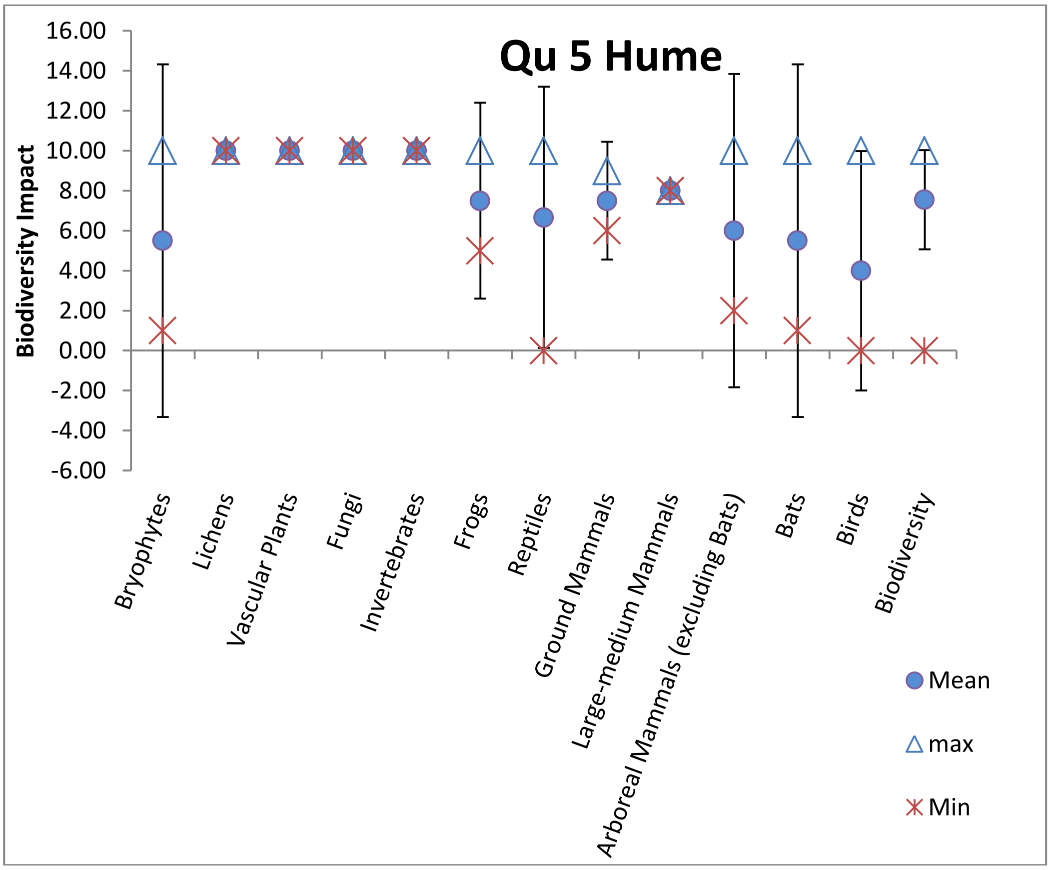

Qu 5 Hume
Mean
max
Min
Biodiversity Impact
8.00
6.00
4.00
2.00
0.00
Bryophytes
Lichens
Vascular Plants
Fungi
Invertebrates
Frogs
Reptiles
Ground Mammals
Large-medium...
Arboreal...
Bats
Birds
Biodiversity

Survey scores





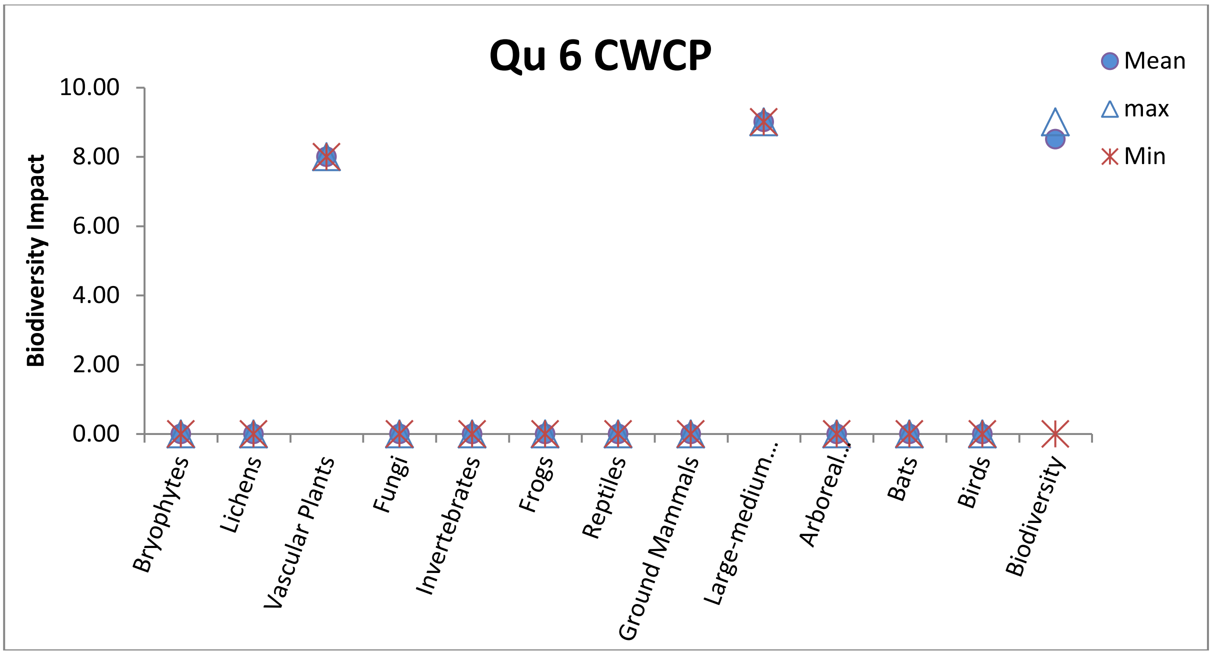

Qu 5 Eden
Mean
max
Min
Biodiversity Impact
4.00
2.00
0.00
-2.00
Bryophytes
Lichens
Vascular Plants
Fungi
Invertebrates
Frogs
Reptiles
Ground Mammals
Large-medium...
Arboreal Mammals...
Bats
Birds
Biodiversity

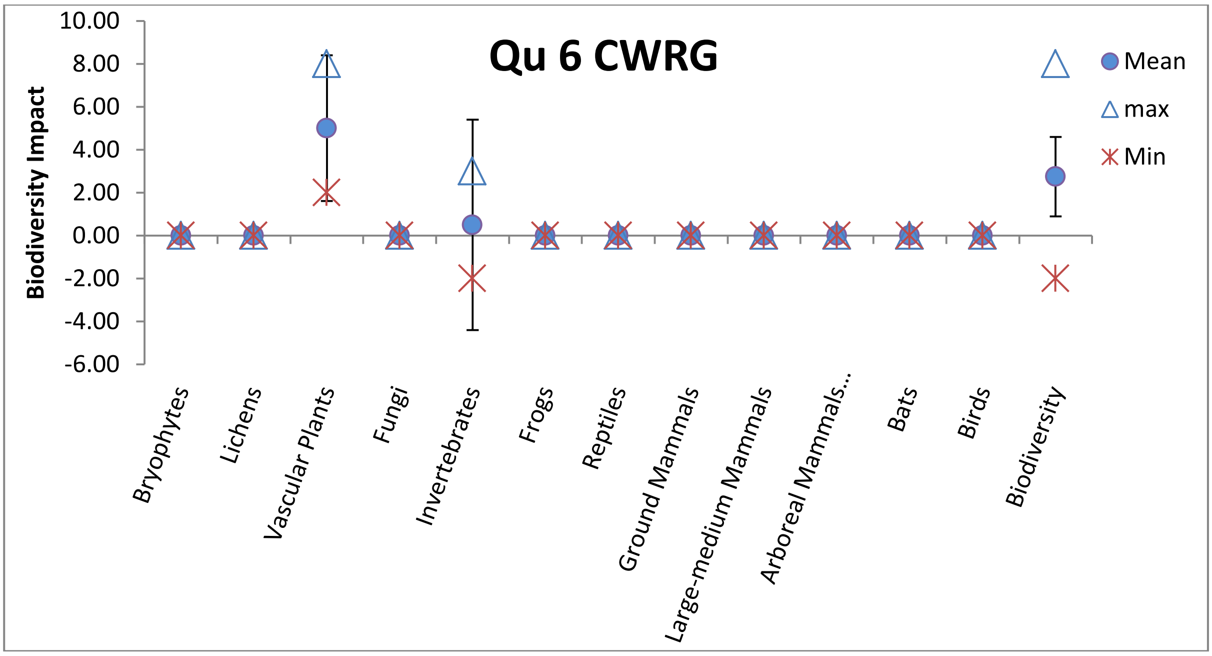

Qu 5 Hume
Biodiversity Impact
16.00
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
-2.00
-4.00
-6.00
Bryophytes
Lichens
Vascular Plants
Fungi
Invertebrates
Frogs
Reptiles
Ground Mammals
Large-medium Mammals
Arboreal Mammals (excluding Bats)
Bats
Birds
Biodiversity
Mean
max
Min

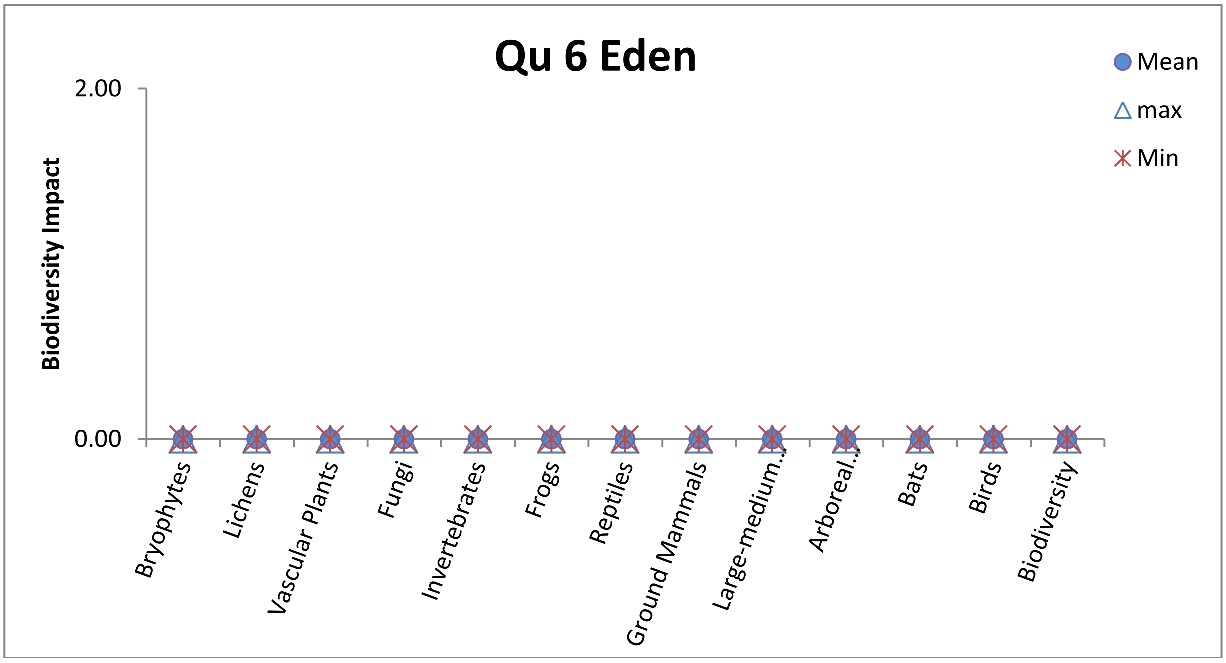
Question 6

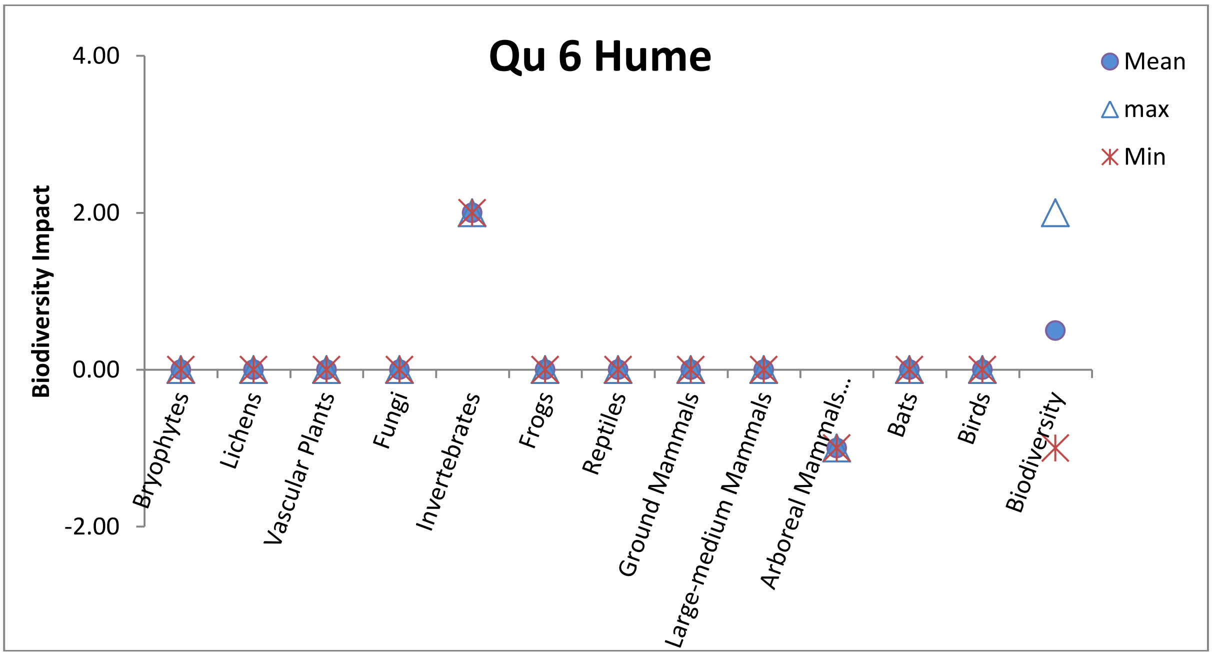
To what extent does the disturbance increase the impacts of herbivorous and invertebrate pest populations?

Literature scores

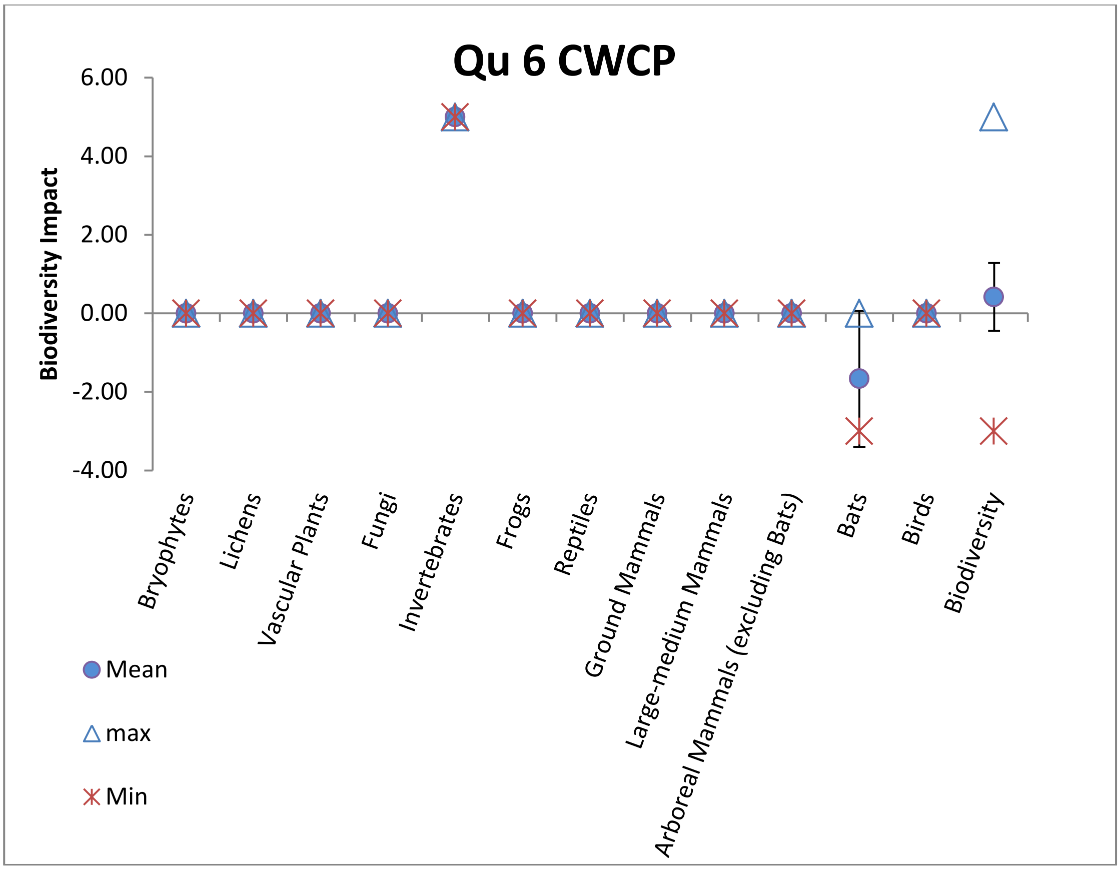


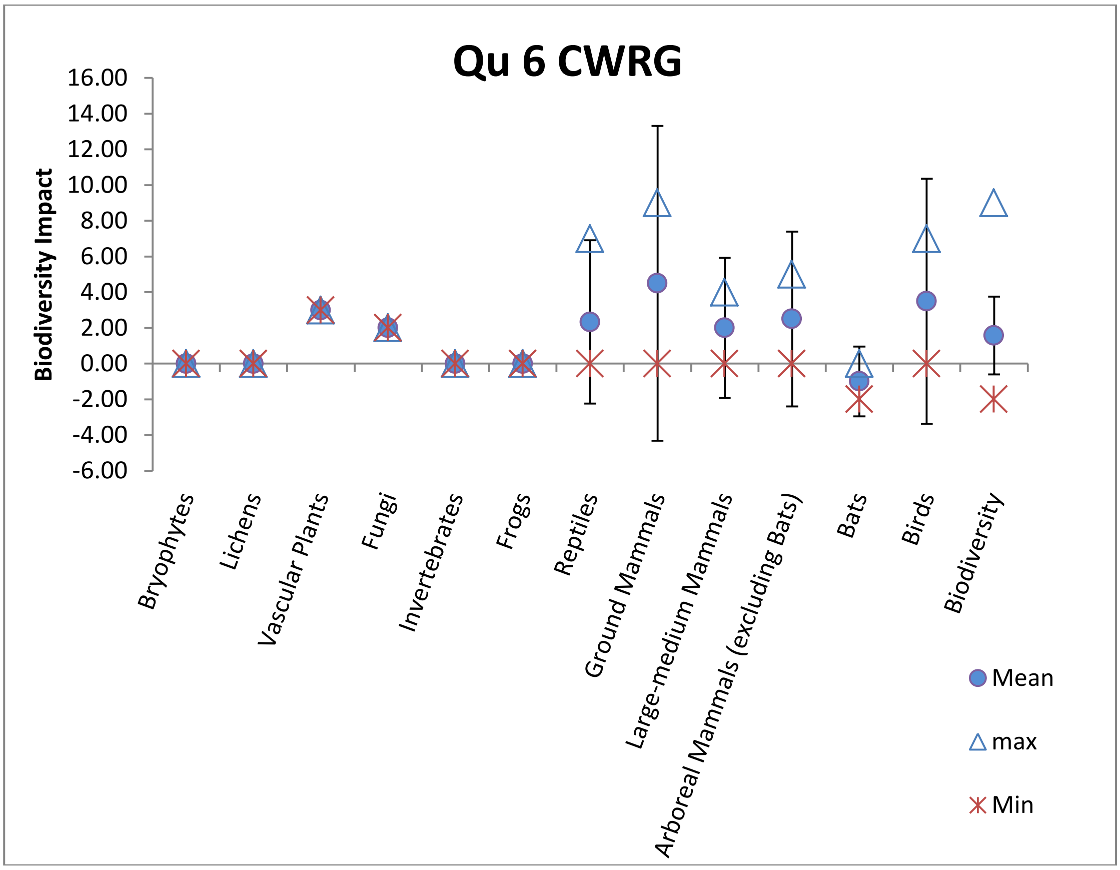


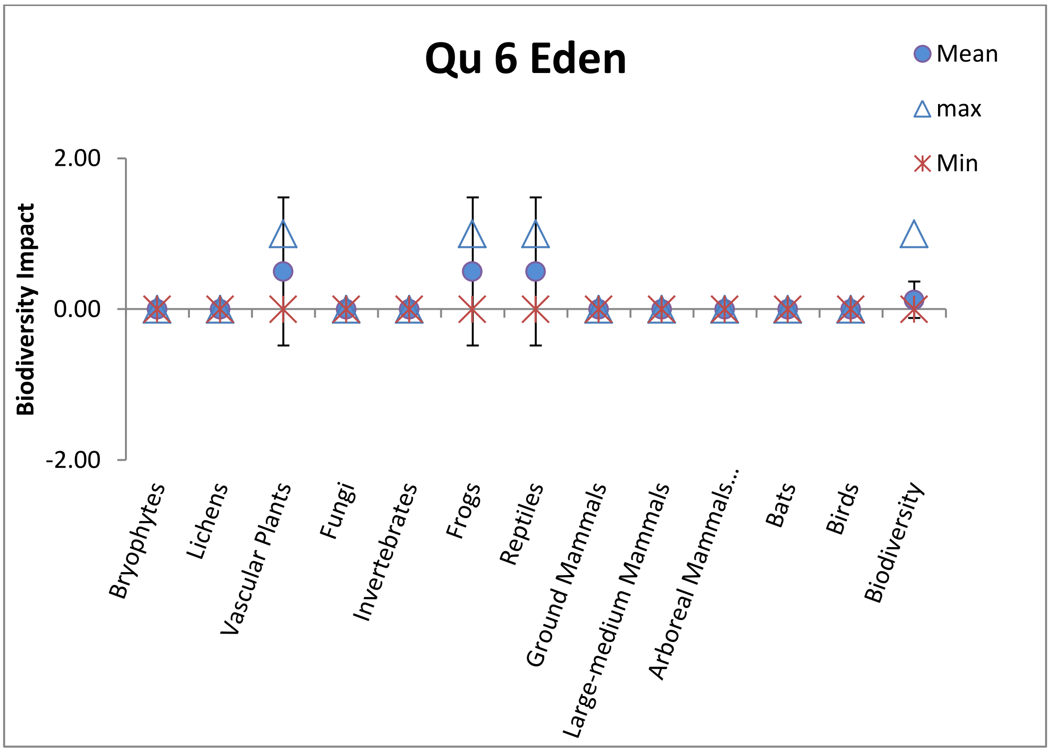

Qu 6 Eden
Mean
max
Min
2.00
0.00
Biodiversity Impact
Bryophytes
Lichens
Vascular Plants
Fungi
Invertebrates
Frogs
Reptiles
Ground Mammals
Large-medium...
Arboreal...
Bats
Birds
Biodiversity

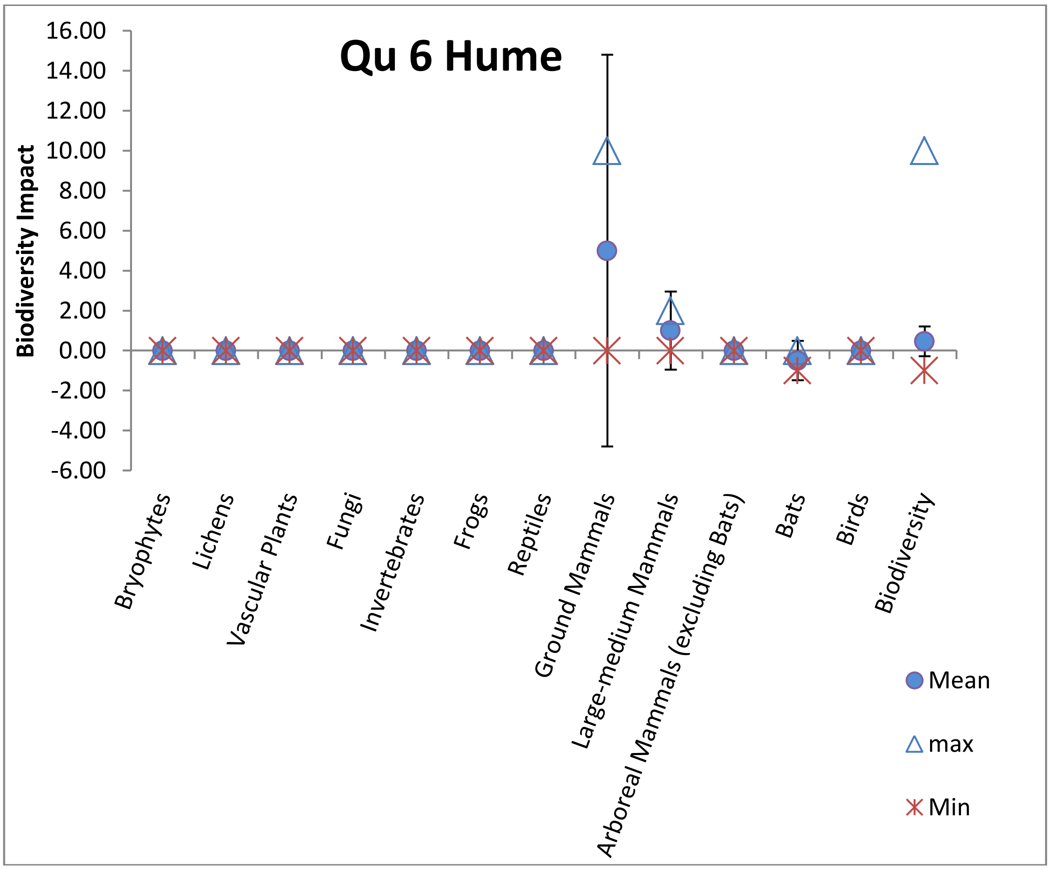

Qu 6 Hume
Mean
max
Min
4.00
2.00
0.00
-2.00
Biodiversity Impact
Bryophytes
Lichens
Vascular Plants
Fungi
Invertebrates
Frogs
Reptiles
Ground Mammals
Large-medium Mammals
Arboreal Mammals...
Bats
Birds
Biodiversity

Survey scores





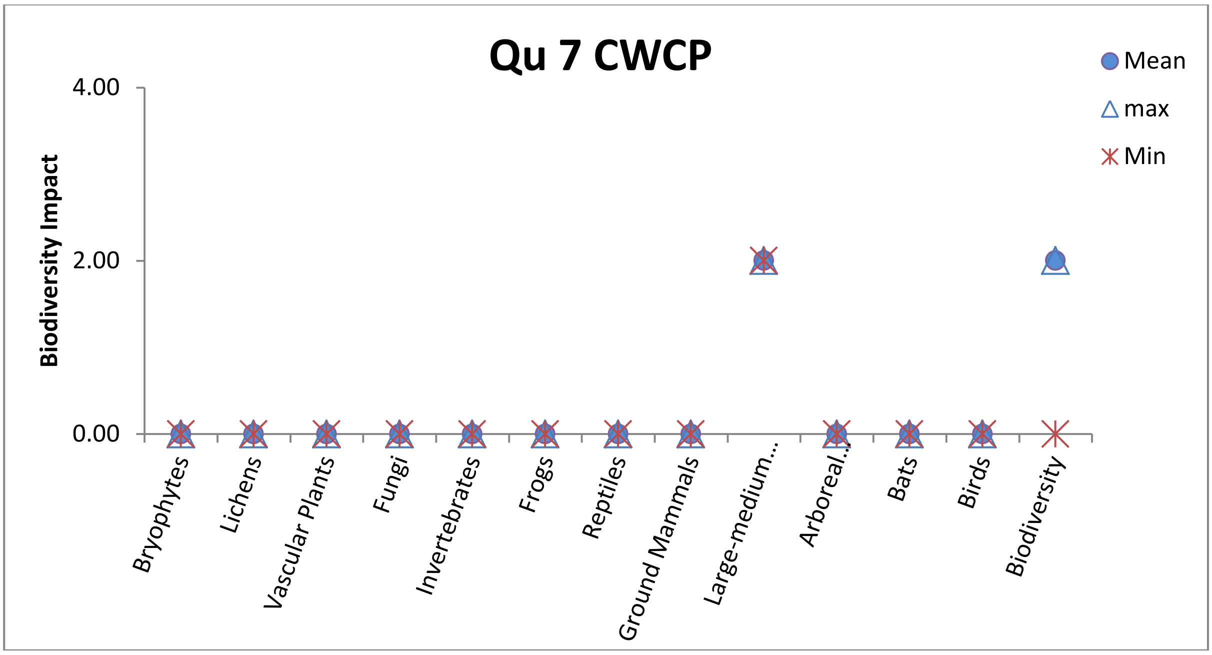

Qu 6 Eden
Mean
max
Min
Biodiversity Impact
2.00
0.00
-2.00
Bryophytes
Lichens
Vascular Plants
Fungi
Invertebrates
Frogs
Reptiles
Ground Mammals
Large-medium Mammals
Arboreal Mammals...
Bats
Birds
Biodiversity

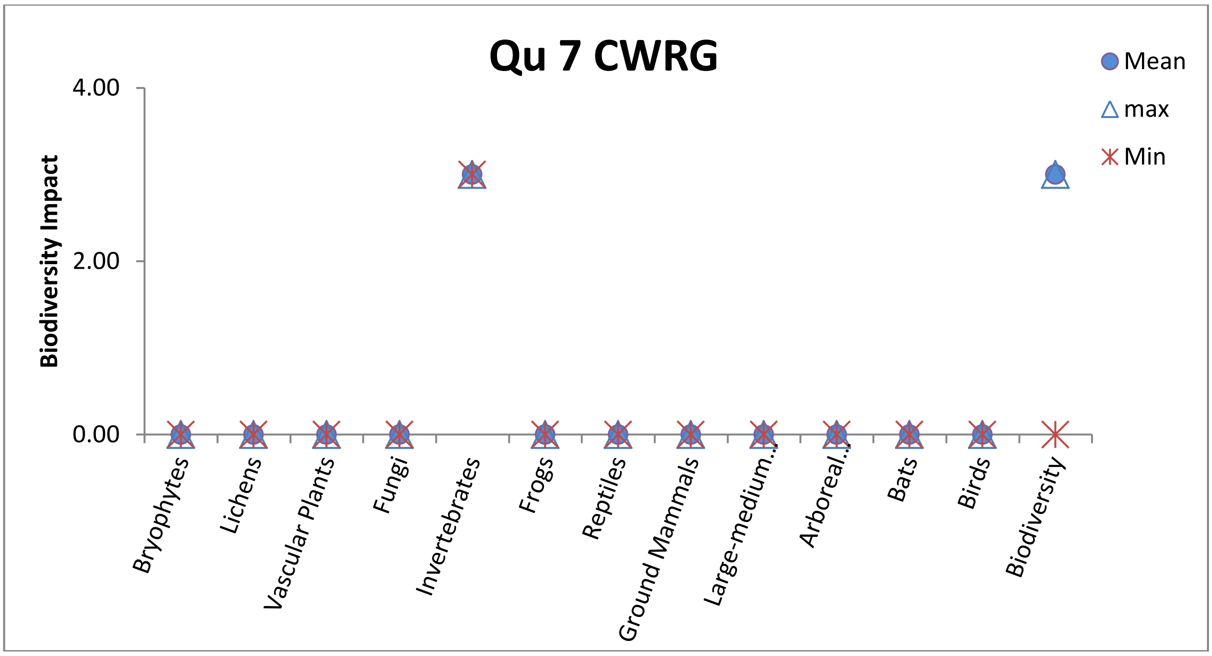

Qu 6 Hume
Biodiversity Impact
16.00
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
-2.00
-4.00
-6.00
Bryophytes
Lichens
Vascular Plants
Fungi
Invertebrates
Frogs
Reptiles
Ground Mammals
Large-medium Mammals
Arboreal Mammals (excluding Bats)
Bats
Birds
Biodiversity
Mean
max
Min

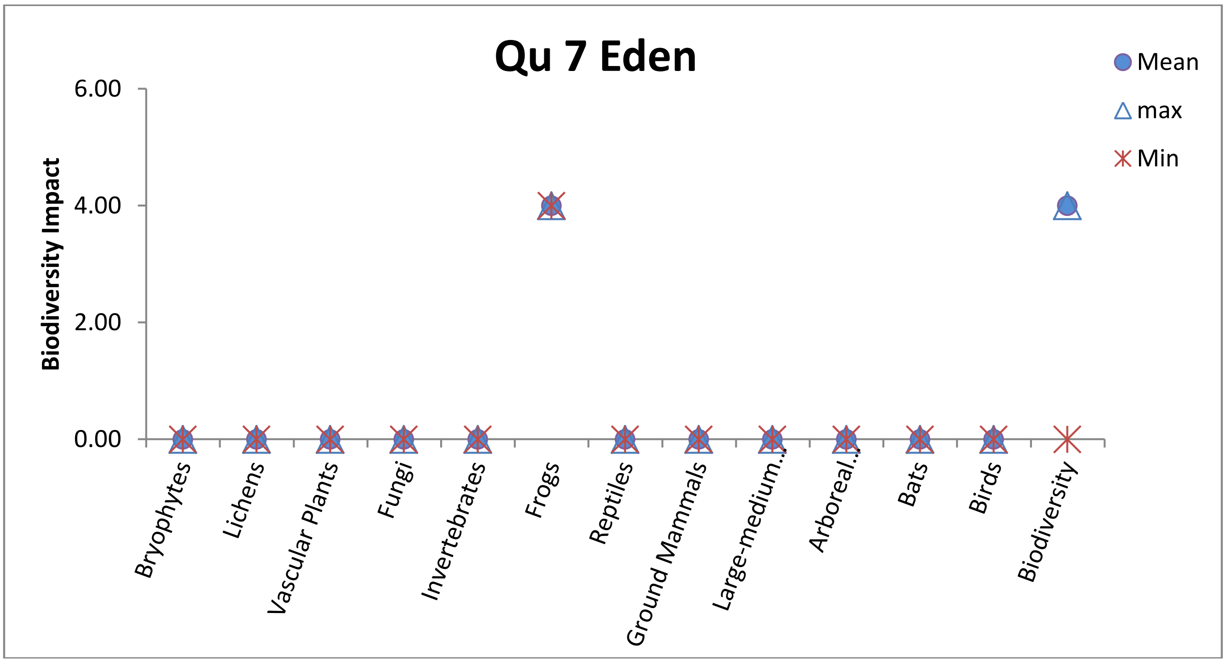
Question 7

To what extent does the disturbance increase the impacts of pathogens?

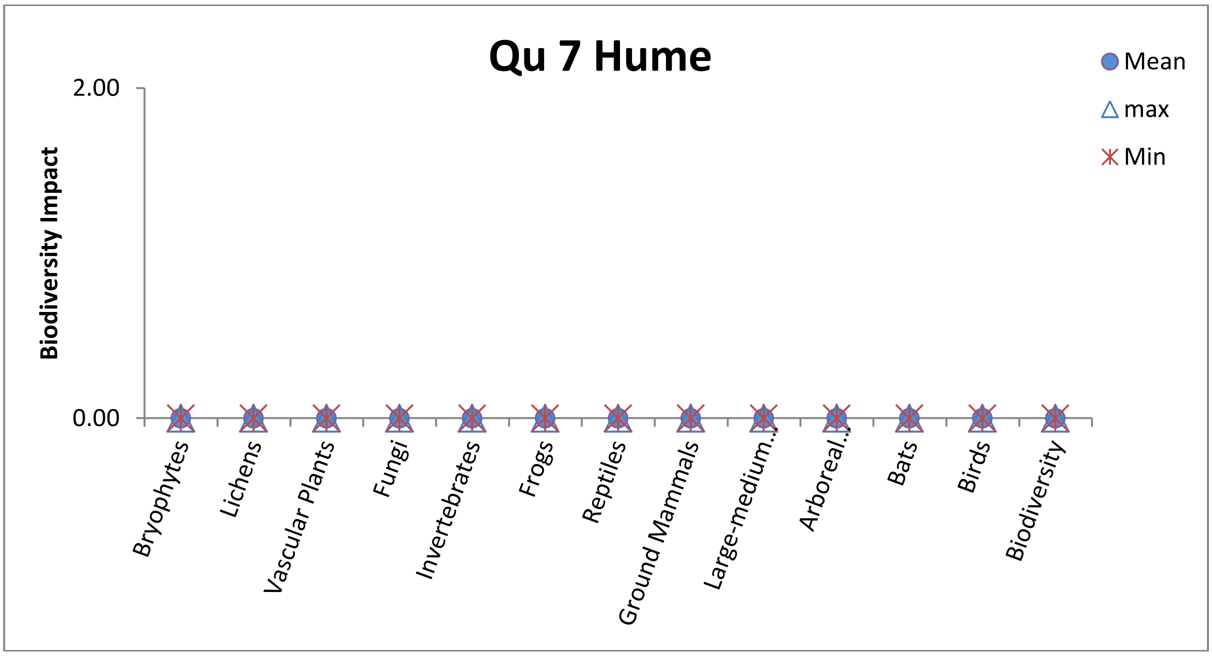
Literature scores





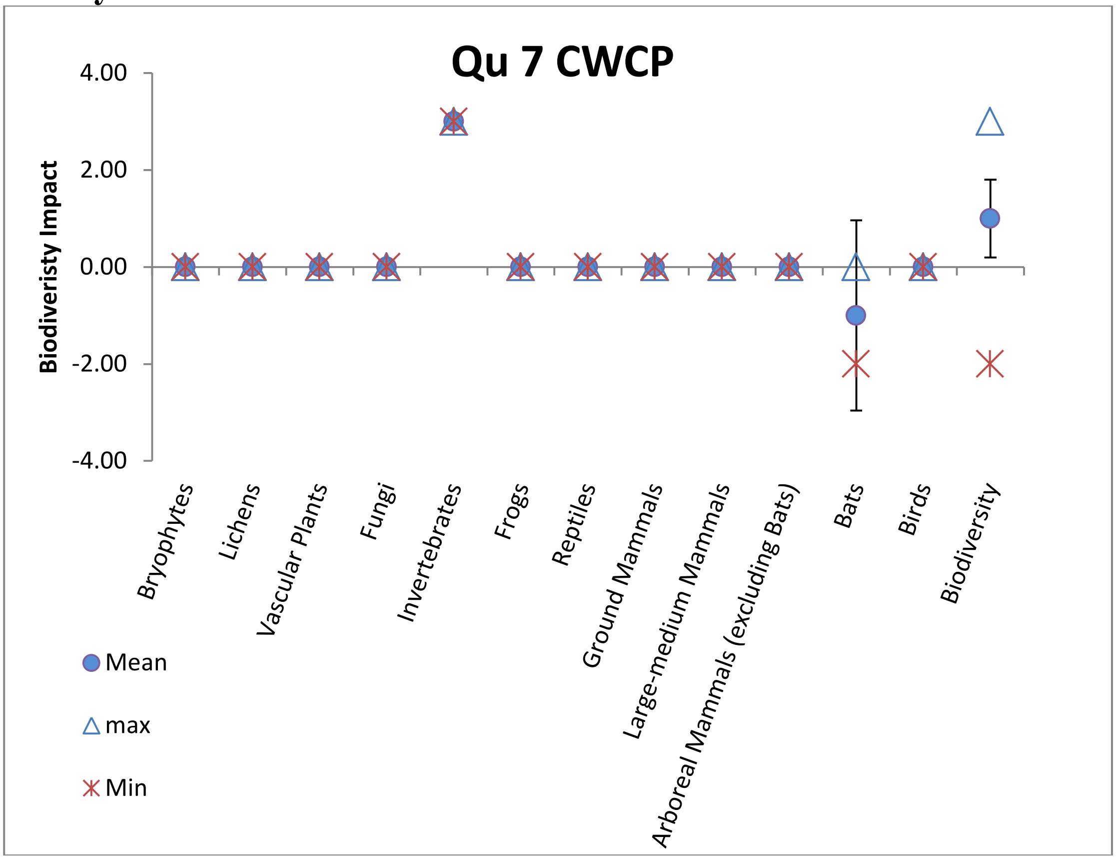


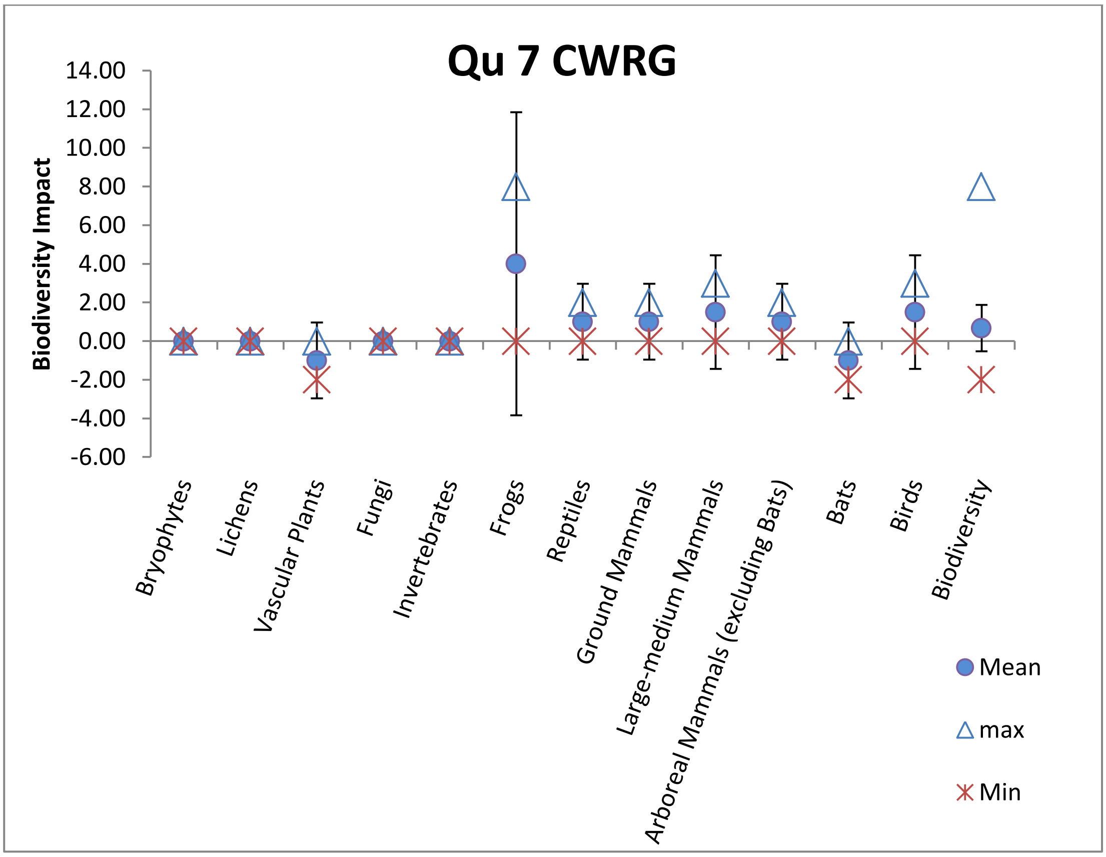
Qu 7 Eden
Mean
max
Min
6.00
4.00
2.00
0.00
Biodiversity Impact
Bryophytes
Lichens
Vascular Plants
Fungi
Invertebrates
Frogs
Reptiles
Ground Mammals
Large-medium...
Arboreal...
Bats
Birds
Biodiversity

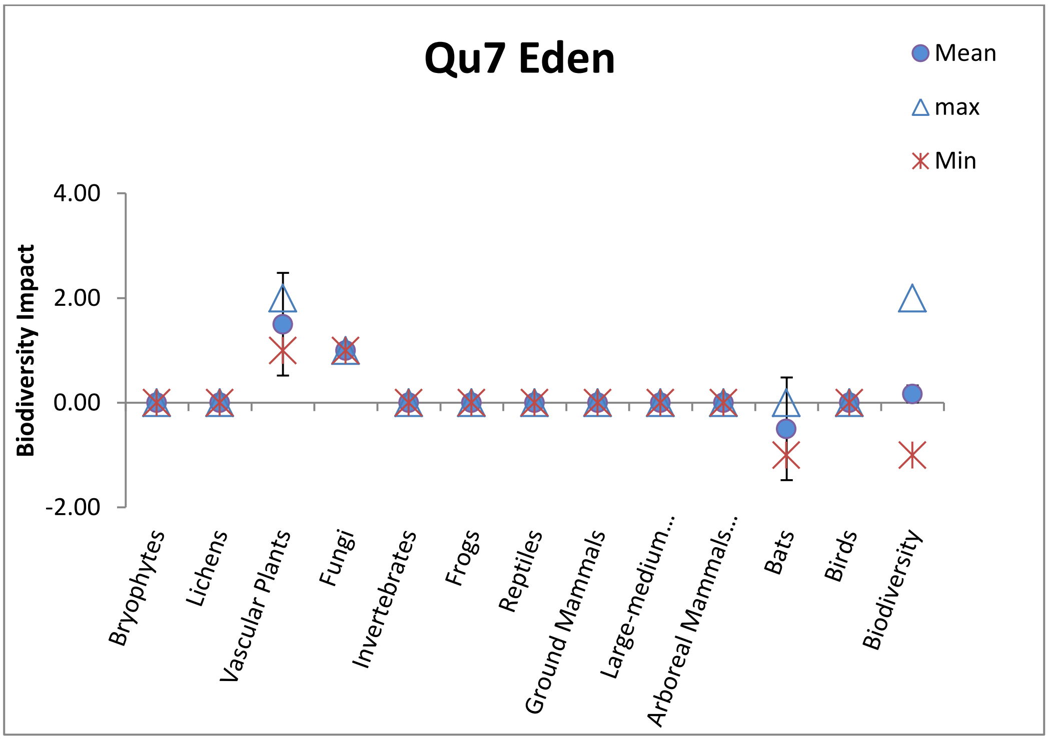


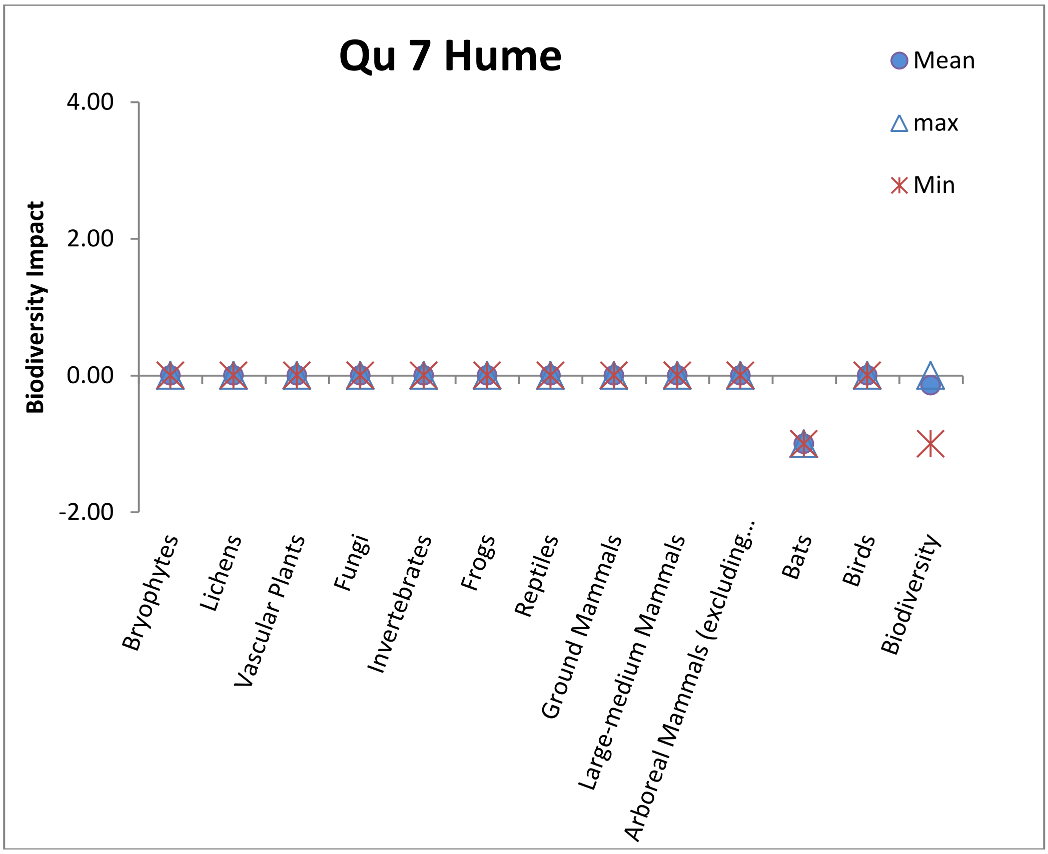
Qu 7 Hume
Mean
max
Min
2.00
0.00
Biodiversity Impact
Bryophytes
Lichens
Vascular Plants
Fungi
Invertebrates
Frogs
Reptiles
Ground Mammals
Large-medium...
Arboreal...
Bats
Birds
Biodiversity

Survey scores





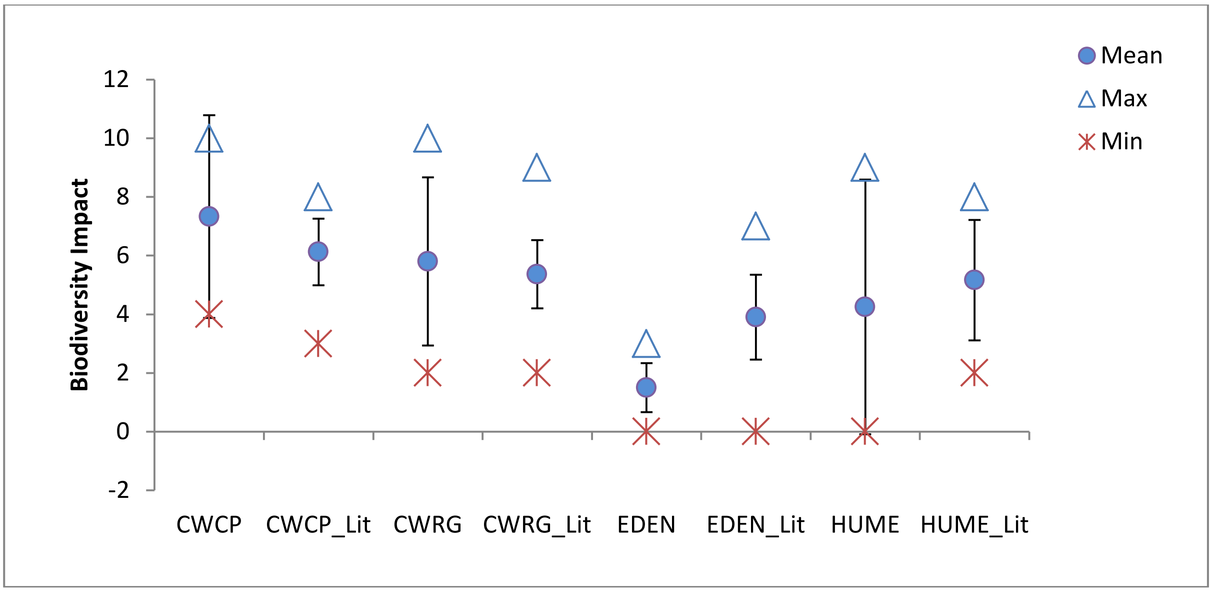

Qu7 Eden
Mean
max
Min
4.00
2.00
0.00
-2.00
Biodiversity Impact
Bryophytes
Lichens
Vascular Plants
Fungi
Invertebrates
Frogs
Reptiles
Ground Mammals
Large-medium...
Arboreal Mammals...
Bats
Birds
Biodiversity


Qu 7 Hume
Mean
max
Min
4.00
2.00
0.00
-2.00
Biodiversity Impact
Bryophytes
Lichens
Vascular Plants
Fungi
Invertebrates
Frogs
Reptiles
Ground Mammals
Large-medium Mammals
Arboreal Mammals (excluding...
Bats
Birds
Biodiversity

Question 8

To what extent does the process affect connectivity of native vegetation across the region?

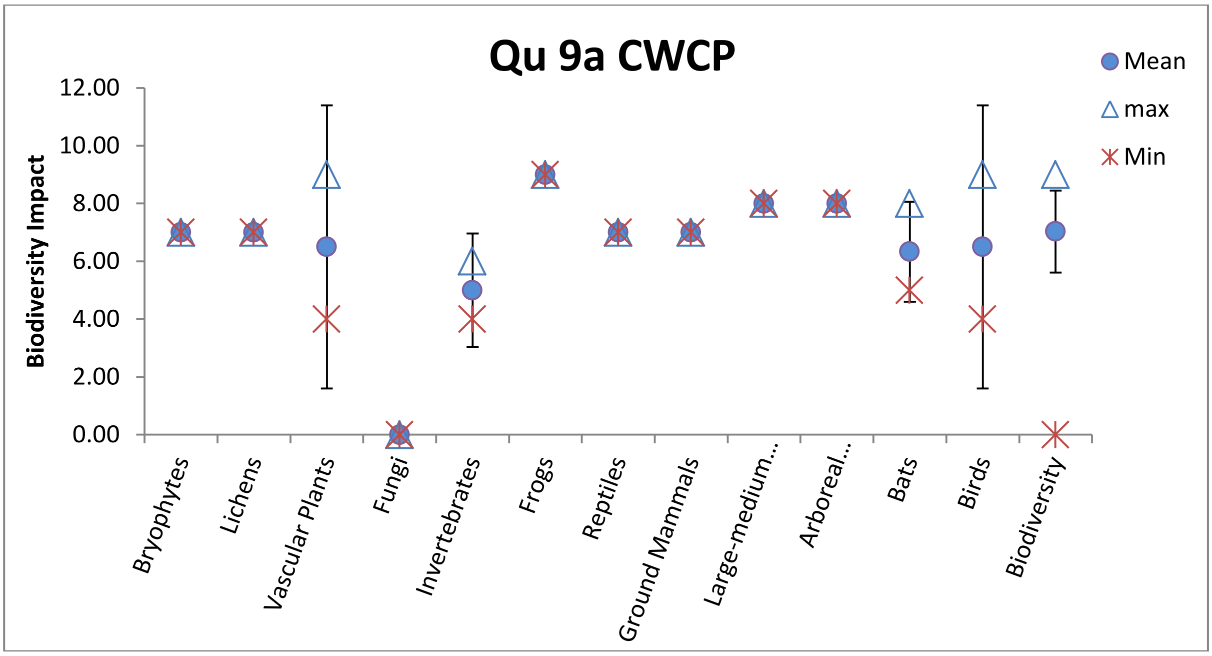
Literature and survey scores

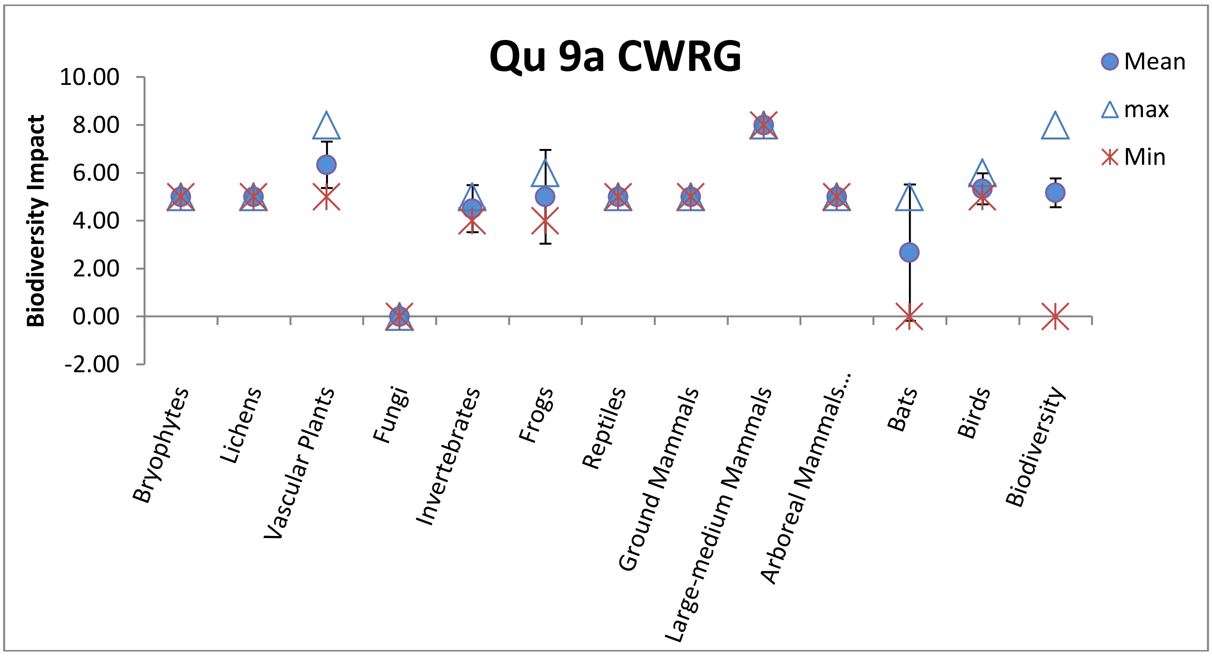


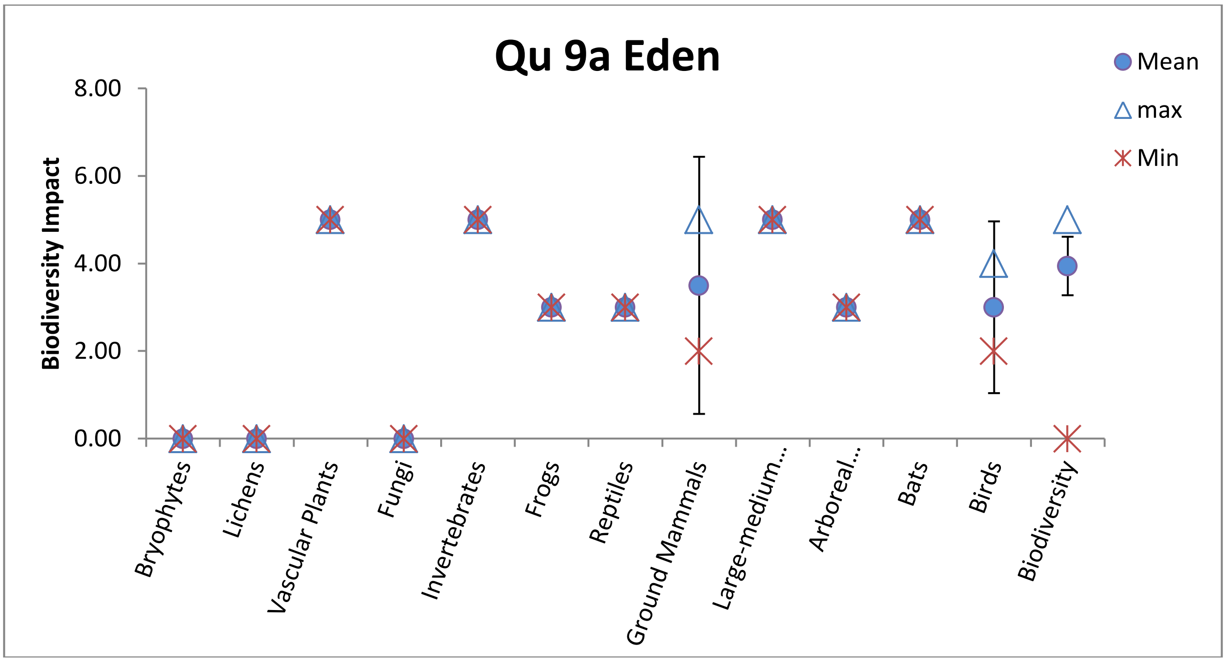
QUESTION 9
To what extent does the process alter habitat structure?

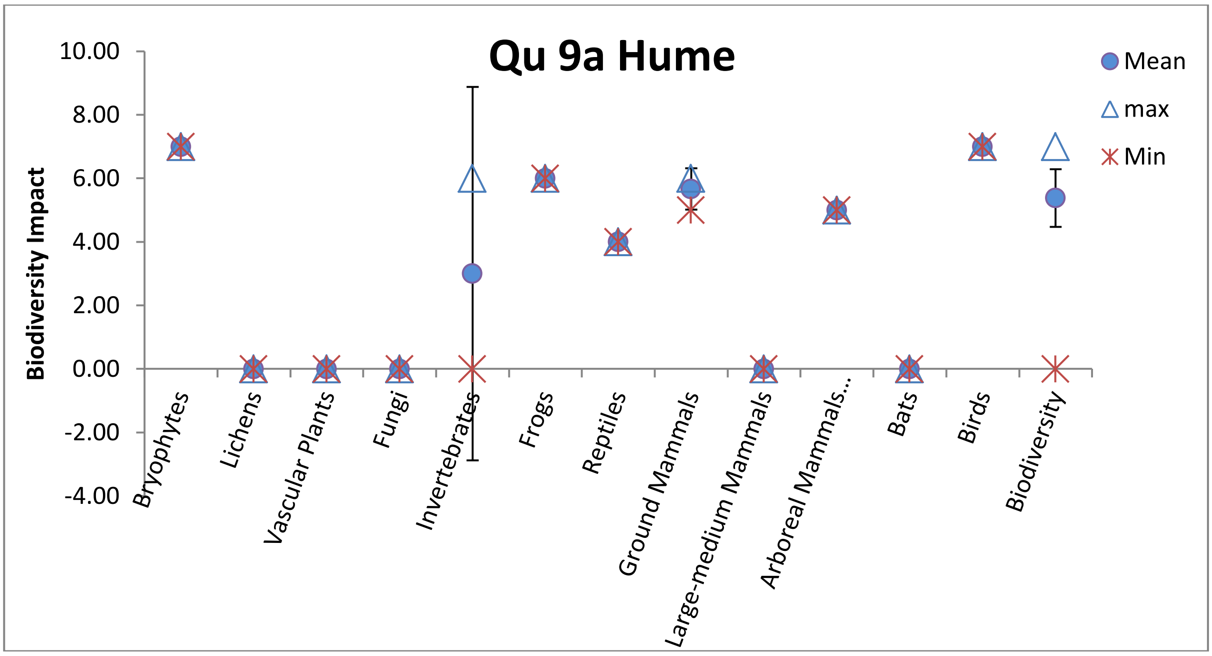
a. compared to a benchmark state (e.g. pre-1750 vegetation) appropriate for the region in question

Literature scores





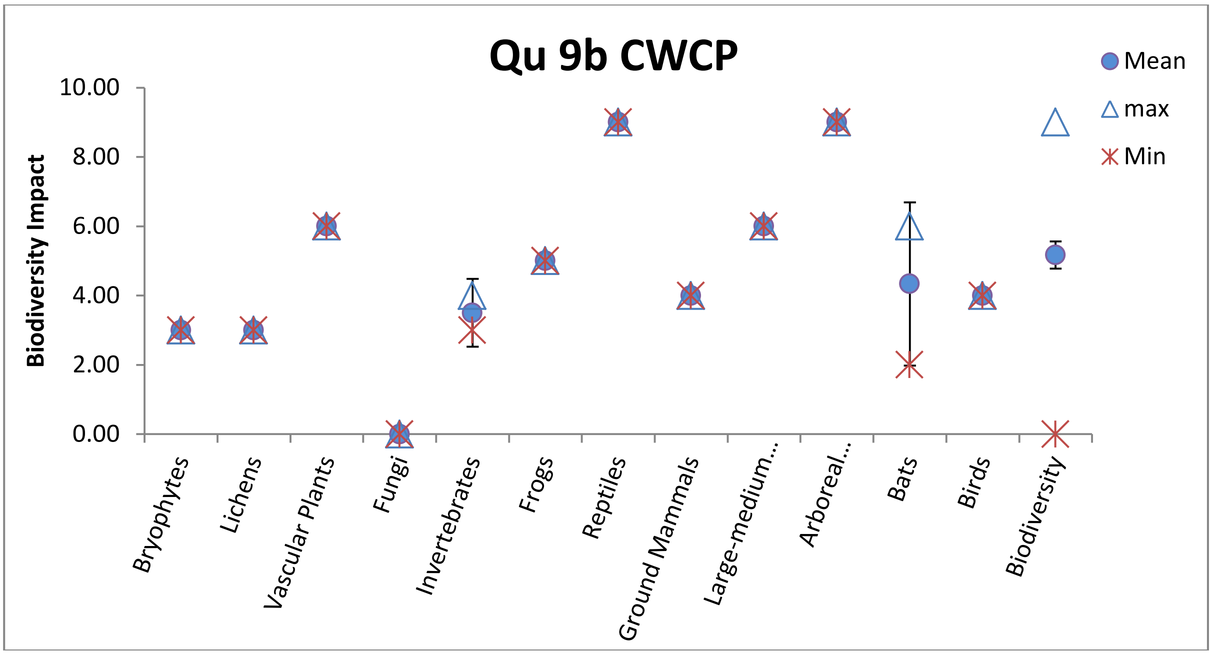

Qu 9a Eden
Mean
max
Min
Biodiversity Impact
8.00
6.00
4.00
2.00
0.00
Bryophytes
Lichens
Vascular Plants
Fungi
Invertebrates
Frogs
Reptiles
Ground Mammals
Large-medium...
Arboreal...
Bats
Birds
Biodiversity

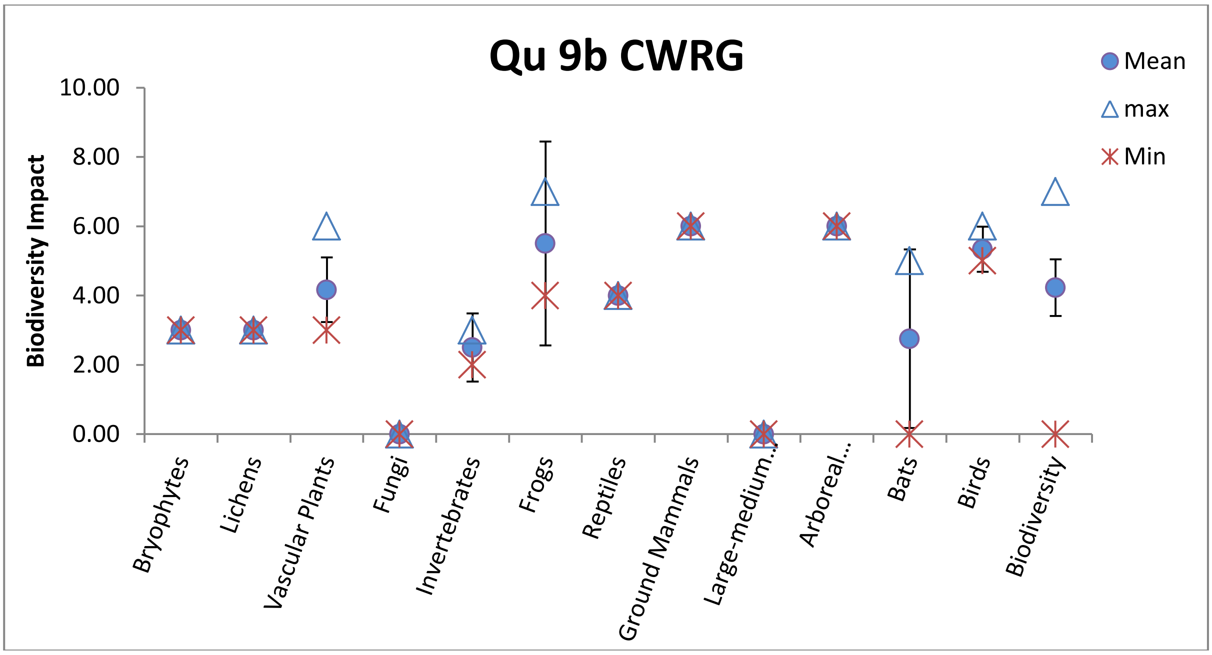

Qu 9a Hume
Mean
max
Min
Biodiversity Impact
10.00
8.00
6.00
4.00
2.00
0.00
-2.00
-4.00
Bryophytes
Lichens
Vascular Plants
Fungi
Invertebrates
Frogs
Reptiles
Ground Mammals
Large-medium Mammals
Arboreal Mammals...
Bats
Birds
Biodiversity

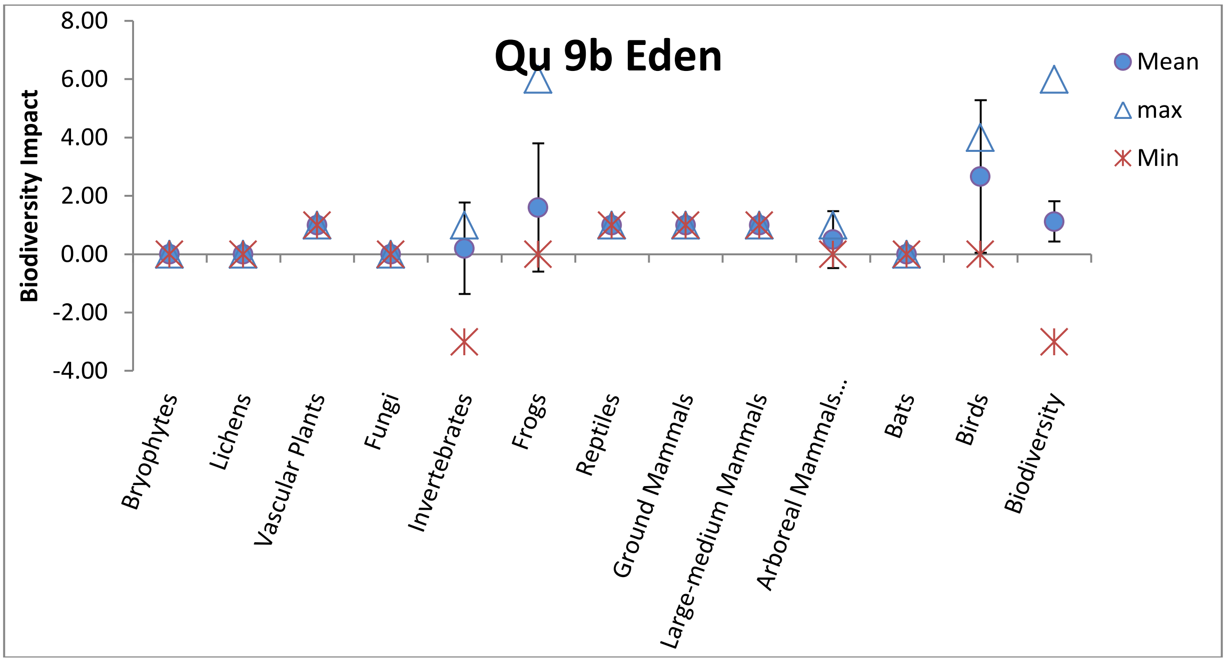
QUESTION 9
To what extent does the process alter habitat structure?

b. compared to the land-use immediately prior to the process in question

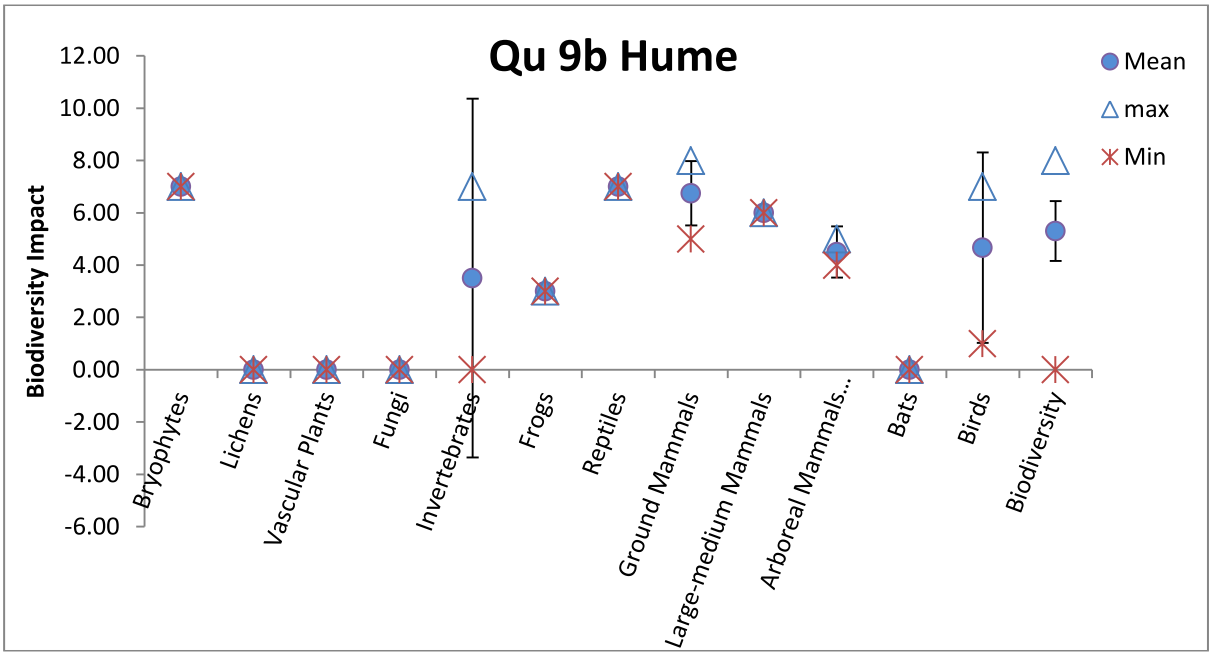
Literature scores







Qu 9b Eden
Biodiversity Impact
8.00
6.00
4.00
2.00
0.00
-2.00
-4.00
Mean
max
Min
Bryophytes
Lichens
Vascular Plants
Fungi
Invertebrates
Frogs
Reptiles
Ground Mammals
Large-medium Mammals
Arboreal Mammals...
Bats
Birds
Biodiversity

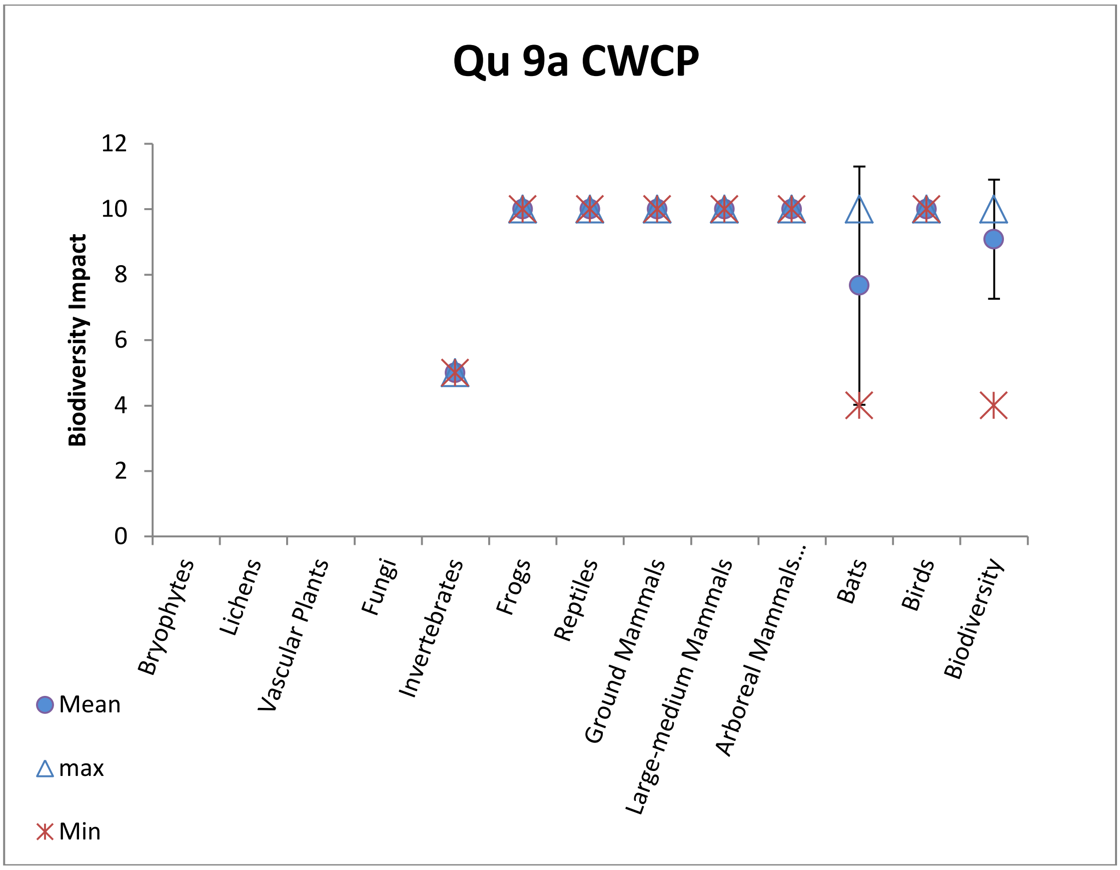


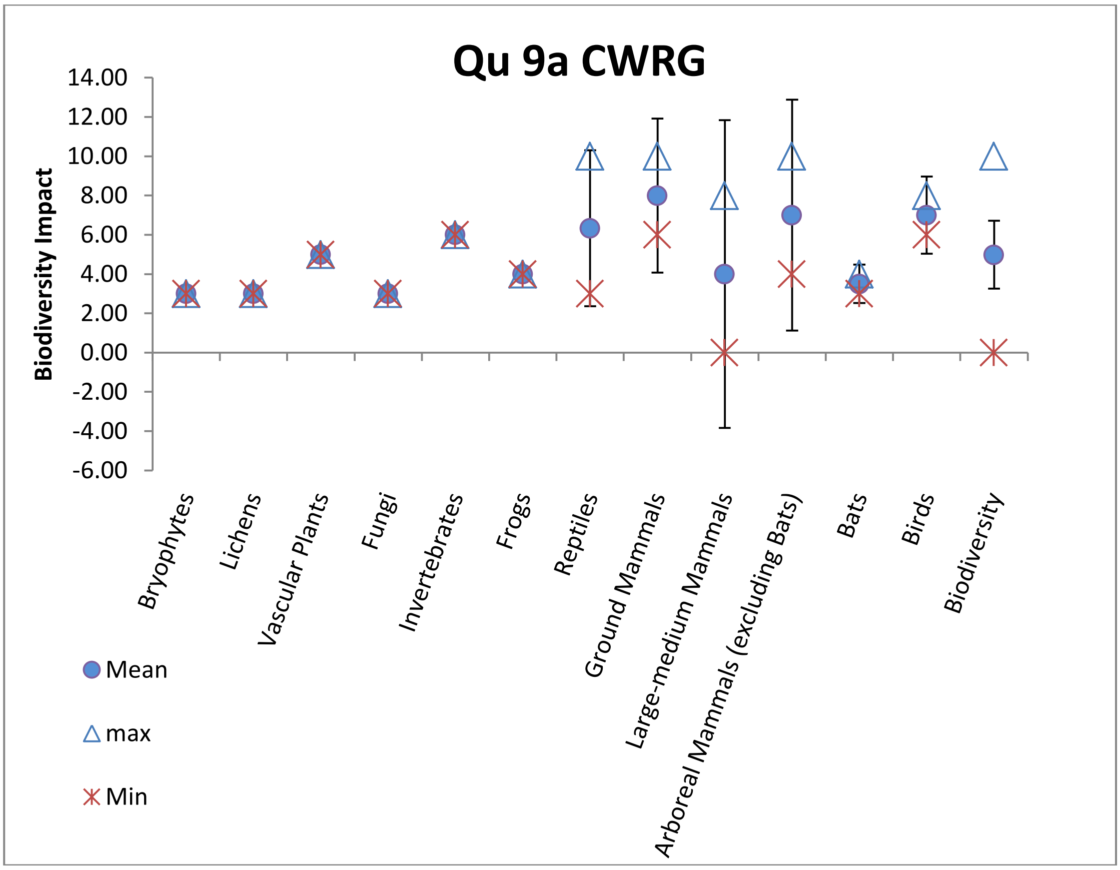
Qu 9b Hume
Biodiversity Impact
12.00
10.00
8.00
6.00
4.00
2.00
0.00
-2.00
-4.00
-6.00
Mean
max
Min
Bryophytes
Lichens
Vascular Plants
Fungi
Invertebrates
Frogs
Reptiles
Ground Mammals
Large-medium Mammals
Arboreal Mammals...
Bats
Birds
Biodiversity

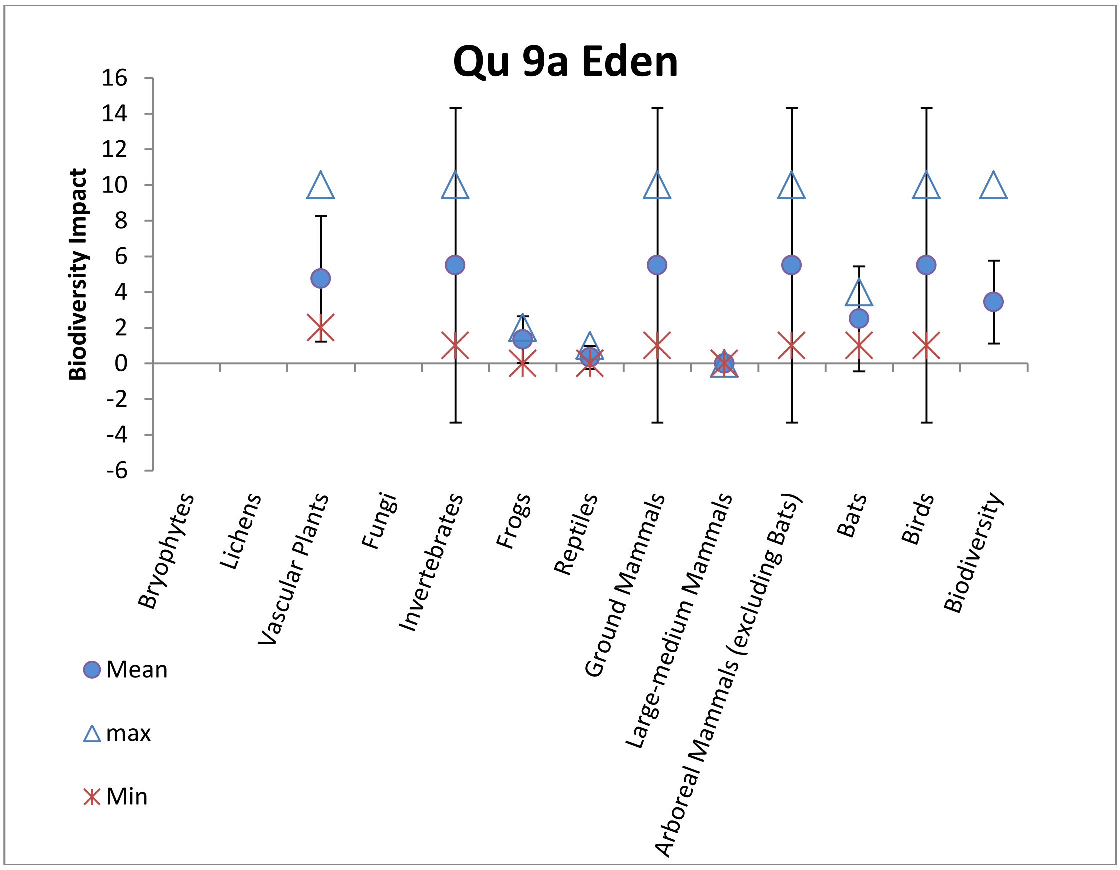
QUESTION 9
To what extent does the process alter habitat structure?

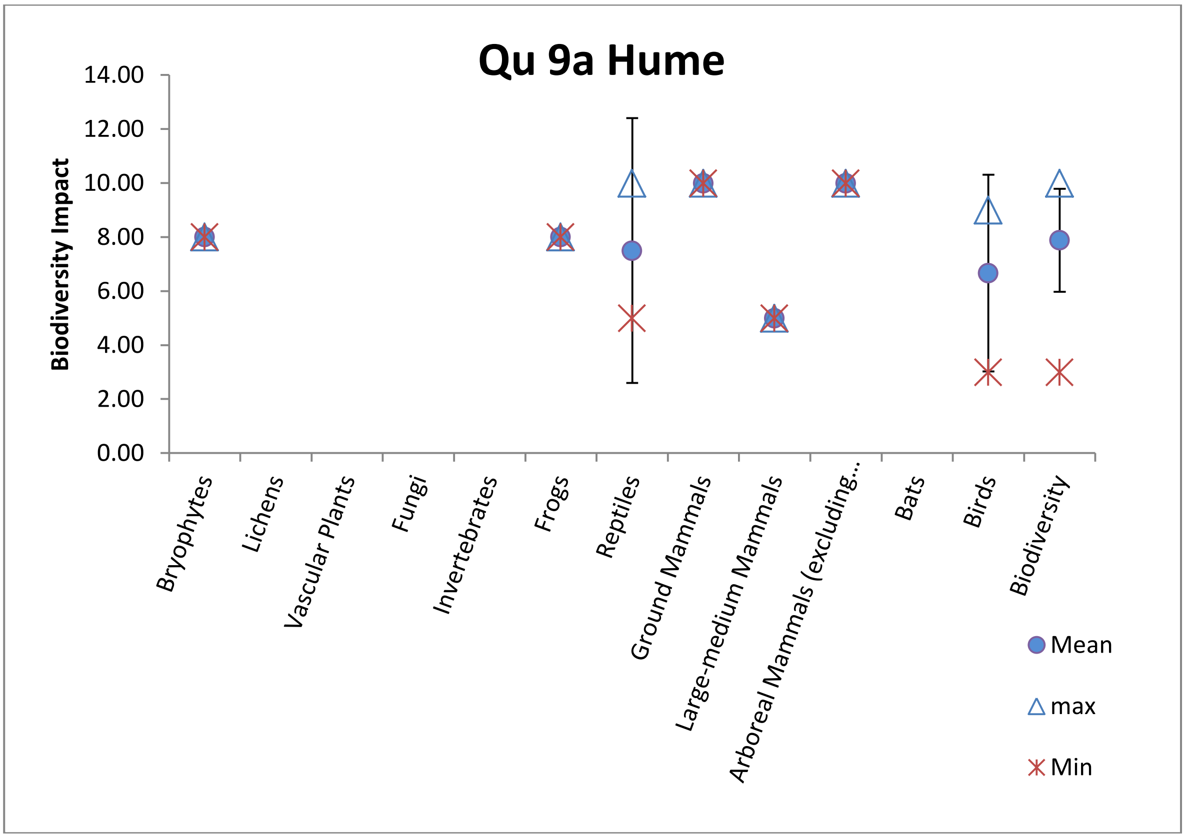
a. compared to a benchmark state (e.g. pre-1750 vegetation) appropriate for the region in question

Survey scores




Qu 9a CWRG
Biodiversity Impact
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
-2.00
-4.00
-6.00
Bryophytes
Lichens
Vascular Plants
Fungi
Invertebrates
Frogs
Reptiles
Ground Mammals
Large-medium Mammals
Arboreal Mammals (excluding Bats)
Bats
Birds
Biodiversity
Mean
max
Min

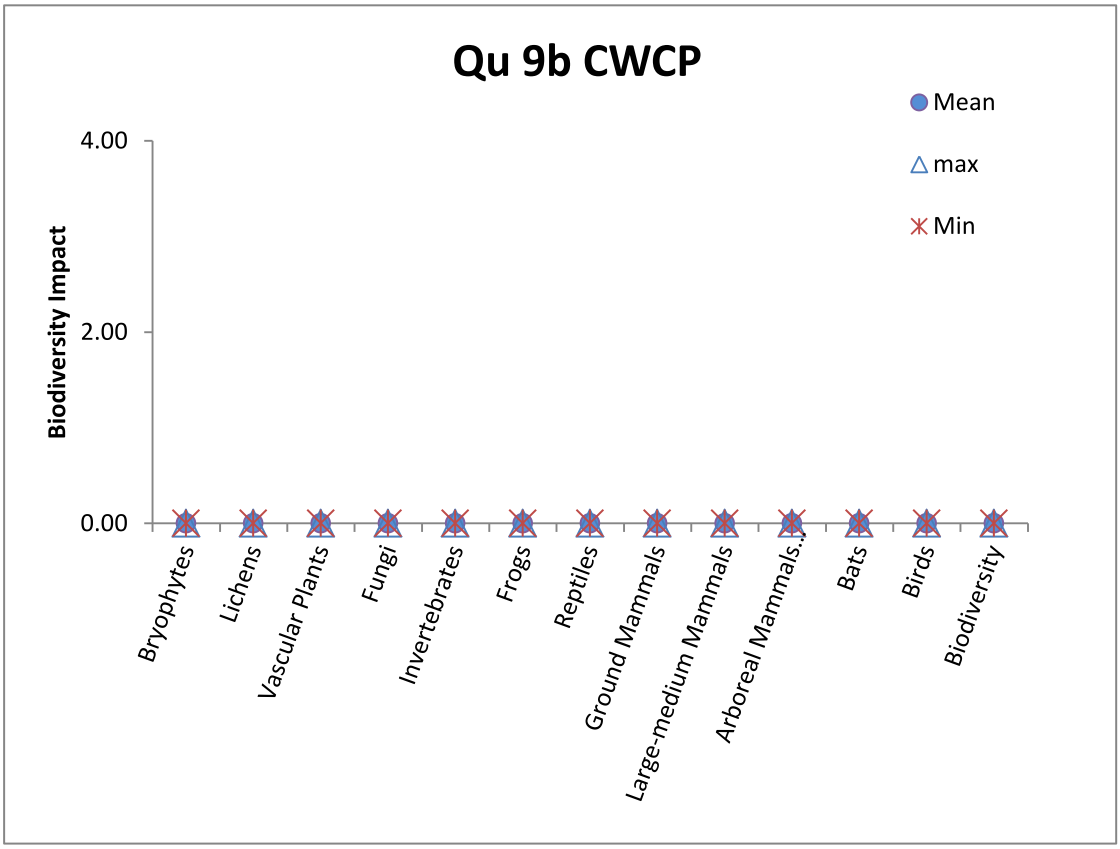

Qu 9a Eden
Biodiversity Impact
16
14
12
10
8
6
4
2
0
-2
-4
-6
Bryophytes
Lichens
Vascular Plants
Fungi
Invertebrates
Frogs
Reptiles
Ground Mammals
Large-medium Mammals
Arboreal Mammals (excluding Bats)
Bats
Birds
Biodiversity
Mean
max
Min

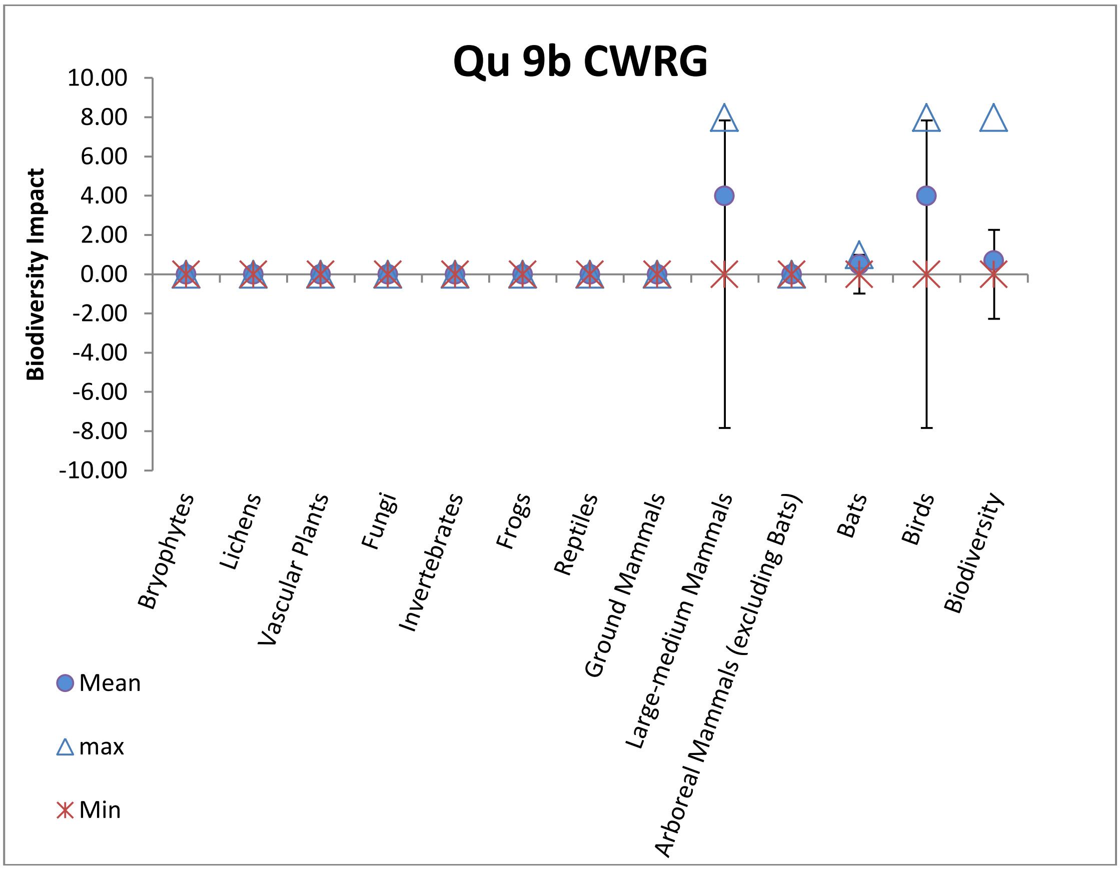


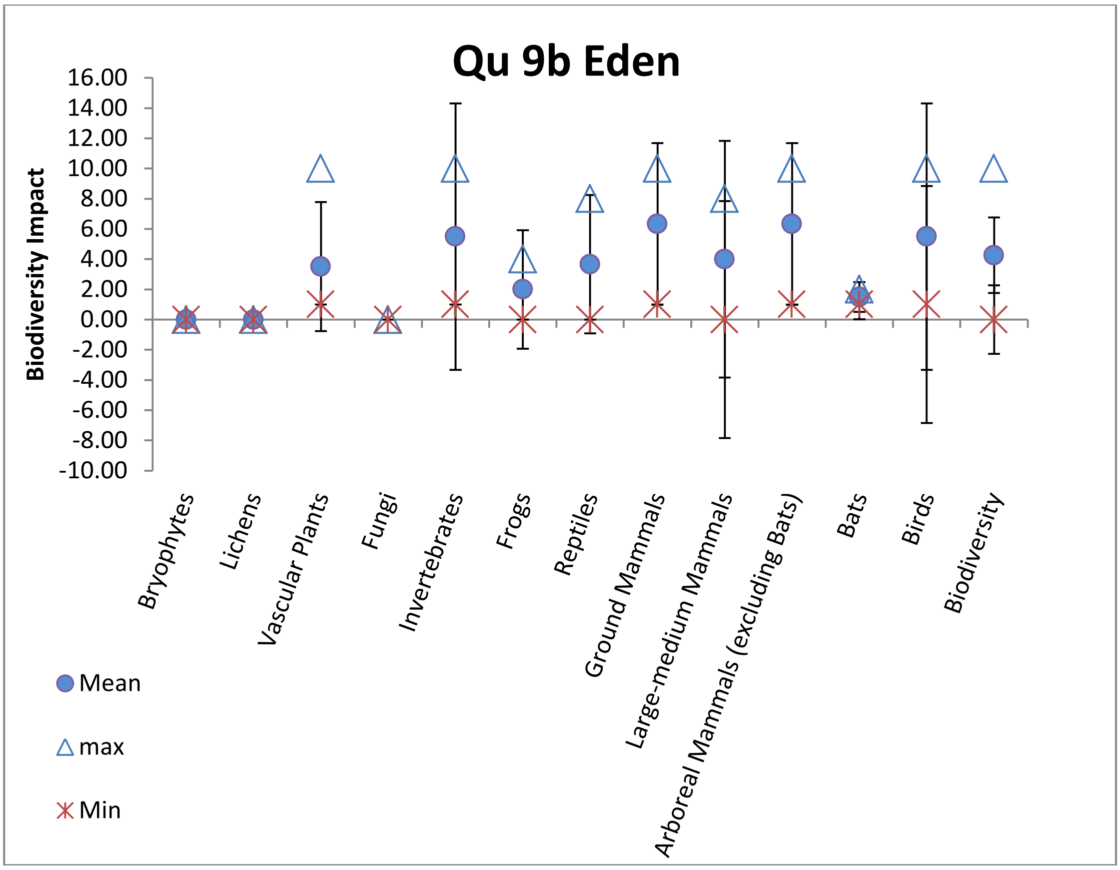
QUESTION 9
To what extent does the process alter habitat structure?

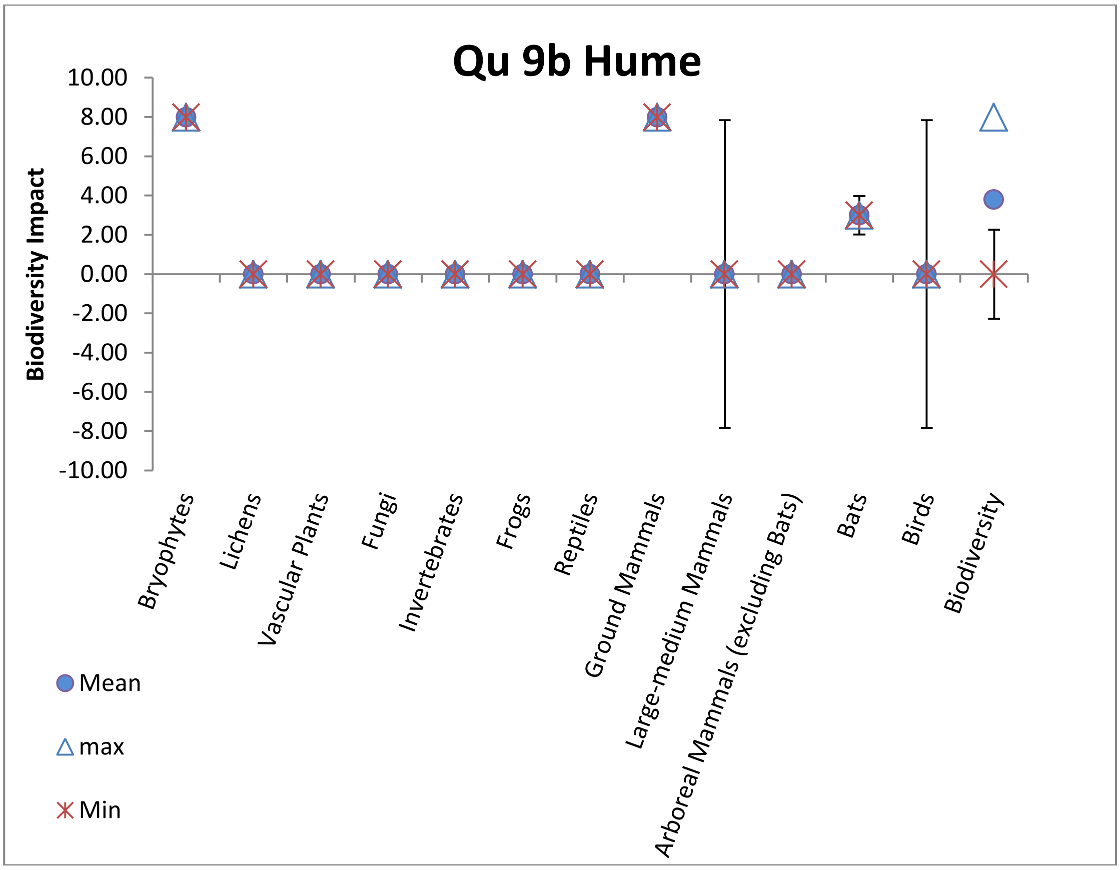
b. compared to the land-use immediately prior to the process in question

Literature scores




Qu 9b CWRG
Biodiversity Impact
10.00
8.00
6.00
4.00
2.00
0.00
-2.00
-4.00
-6.00
-8.00
-10.00
Bryophytes
Lichens
Vascular Plants
Fungi
Invertebrates
Frogs
Reptiles
Ground Mammals
Large-medium Mammals
Arboreal Mammals (excluding Bats)
Bats
Birds
Biodiversity
Mean
max
Min

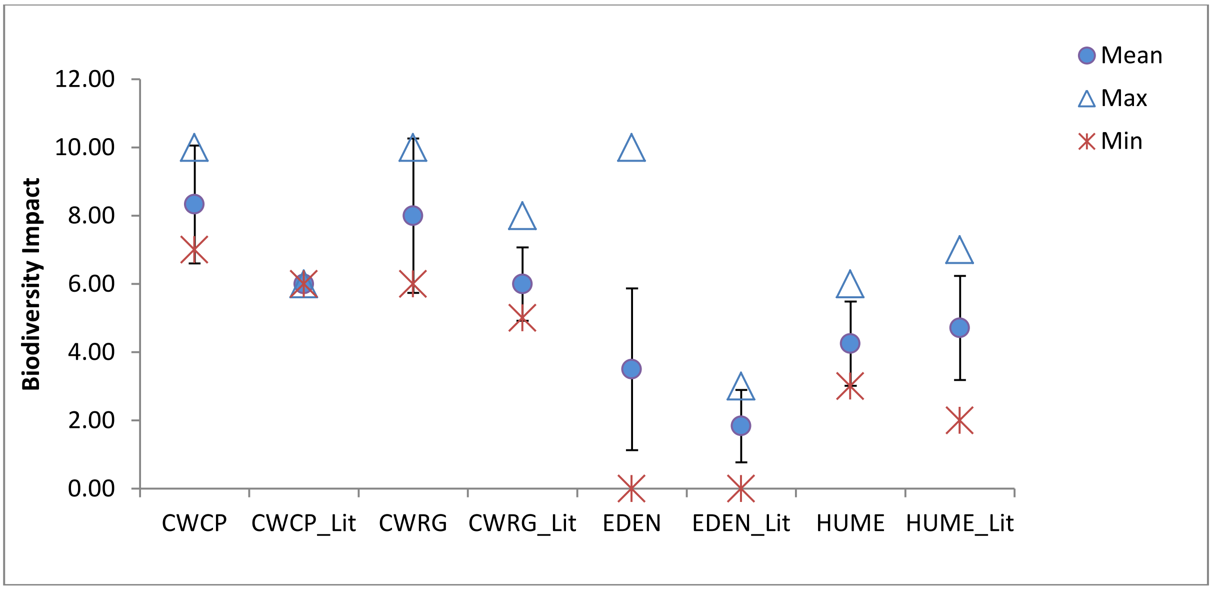

Qu 9b Eden
Biodiversity Impact
16.00
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
-2.00
-4.00
-6.00
-8.00
-10.00
Bryophytes
Lichens
Vascular Plants
Fungi
Invertebrates
Frogs
Reptiles
Ground Mammals
Large-medium Mammals
Arboreal Mammals (excluding Bats)
Bats
Birds
Biodiversity
Mean
max
Min



Question 10

To what extent does the process reduce the resilience of the system – capacity to absorb stochastic disturbance – flood, fire, drought?

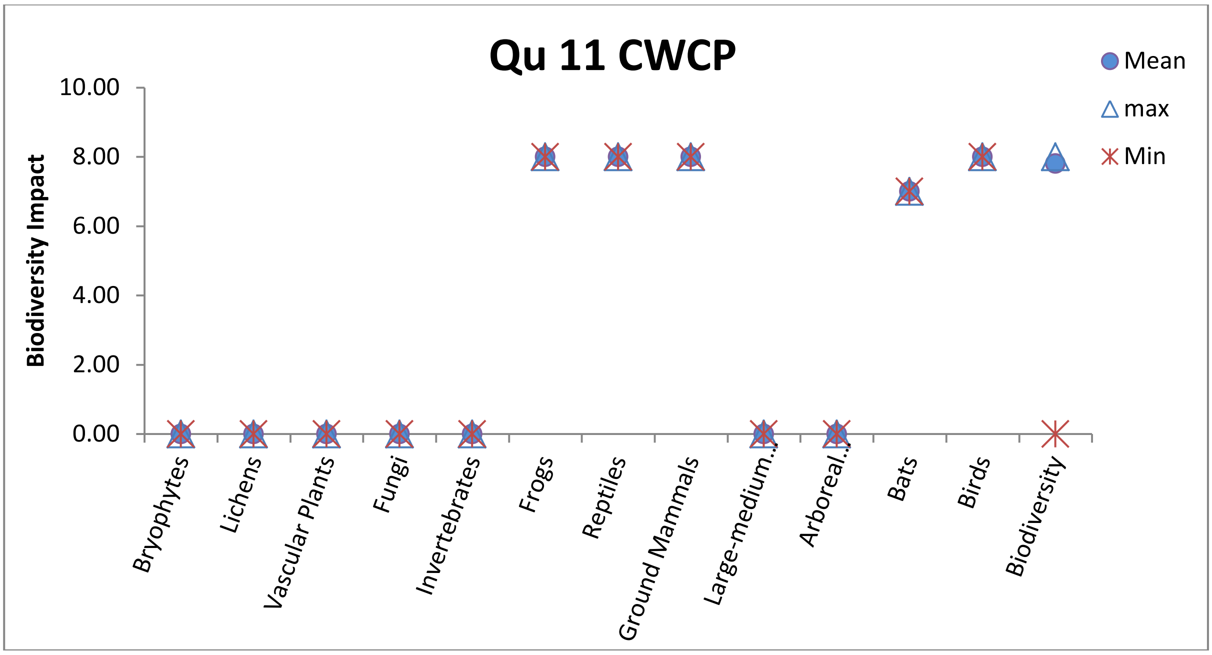
Literature and survey scores

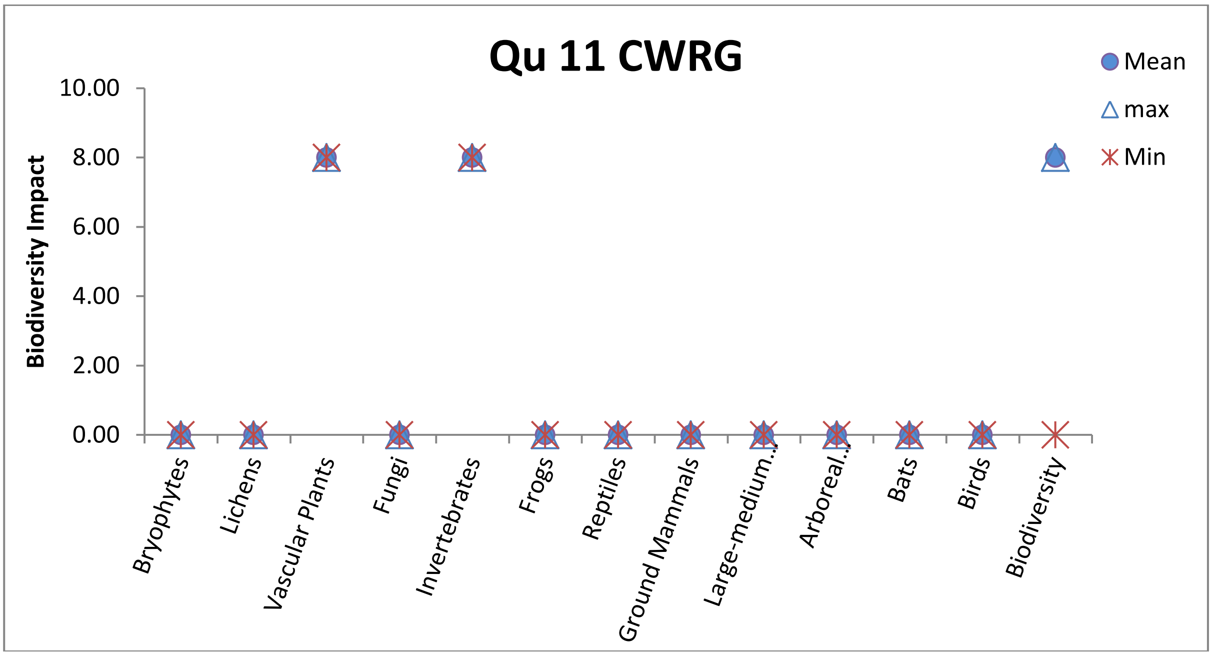


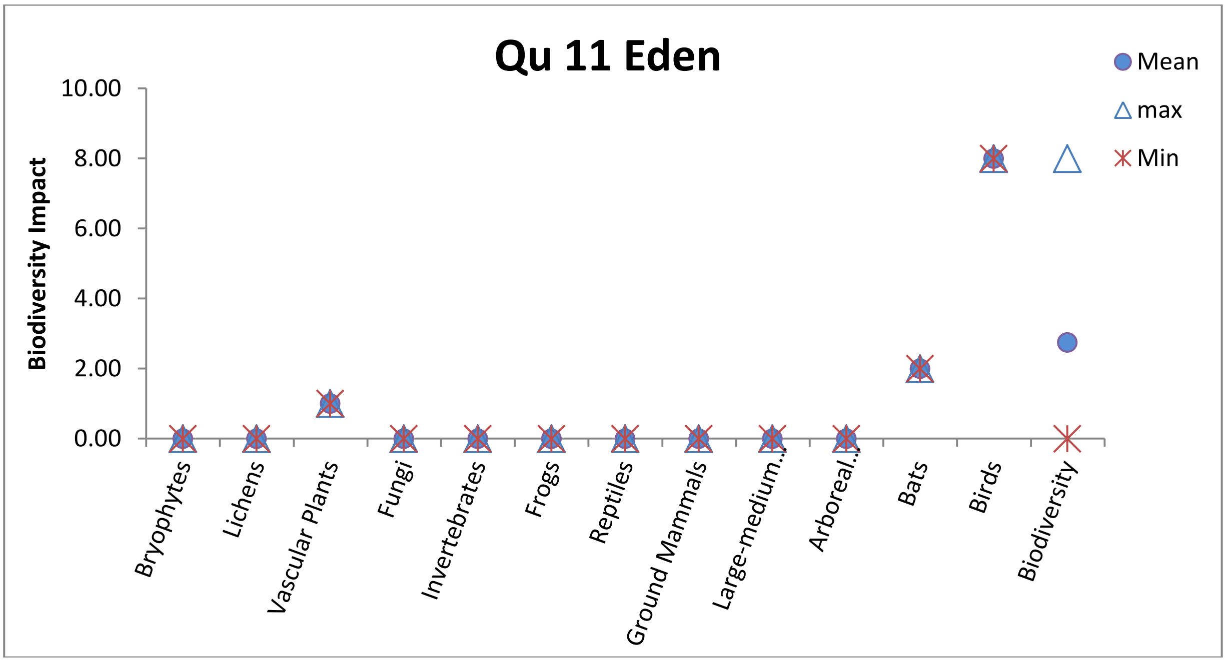
Question 11

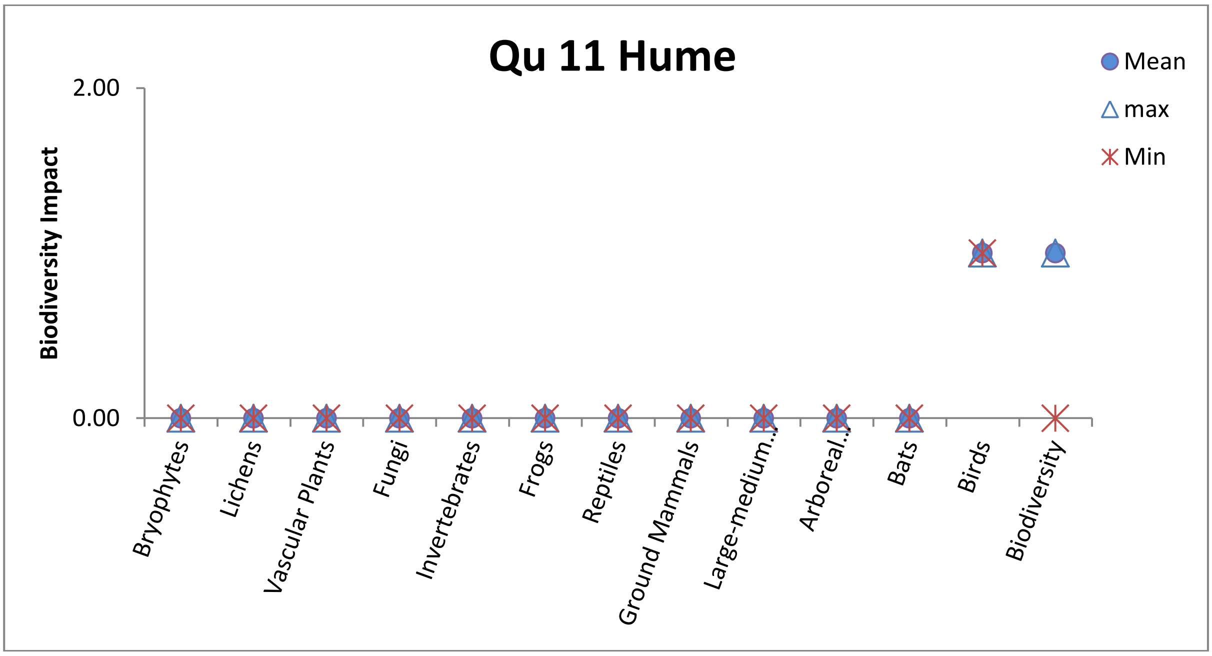
To what extent does the disturbance have a negative impact on keystone species?

Literature scores

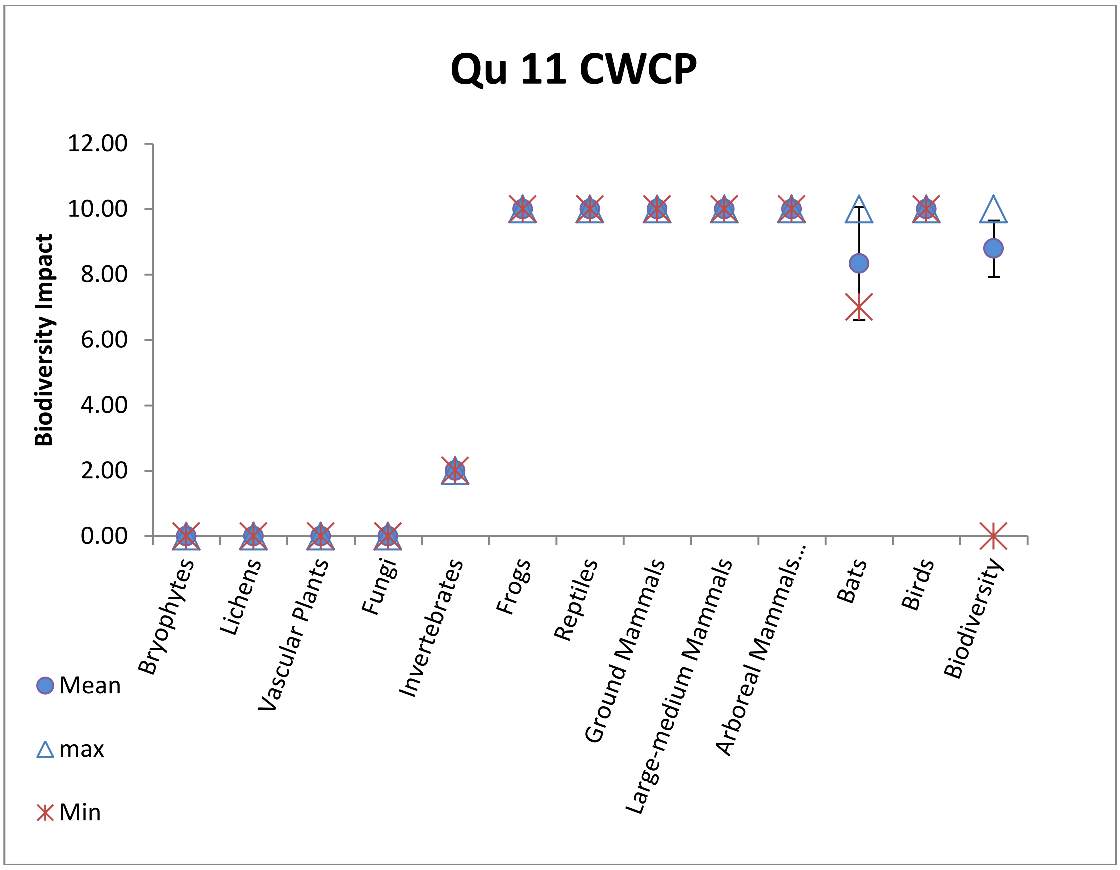


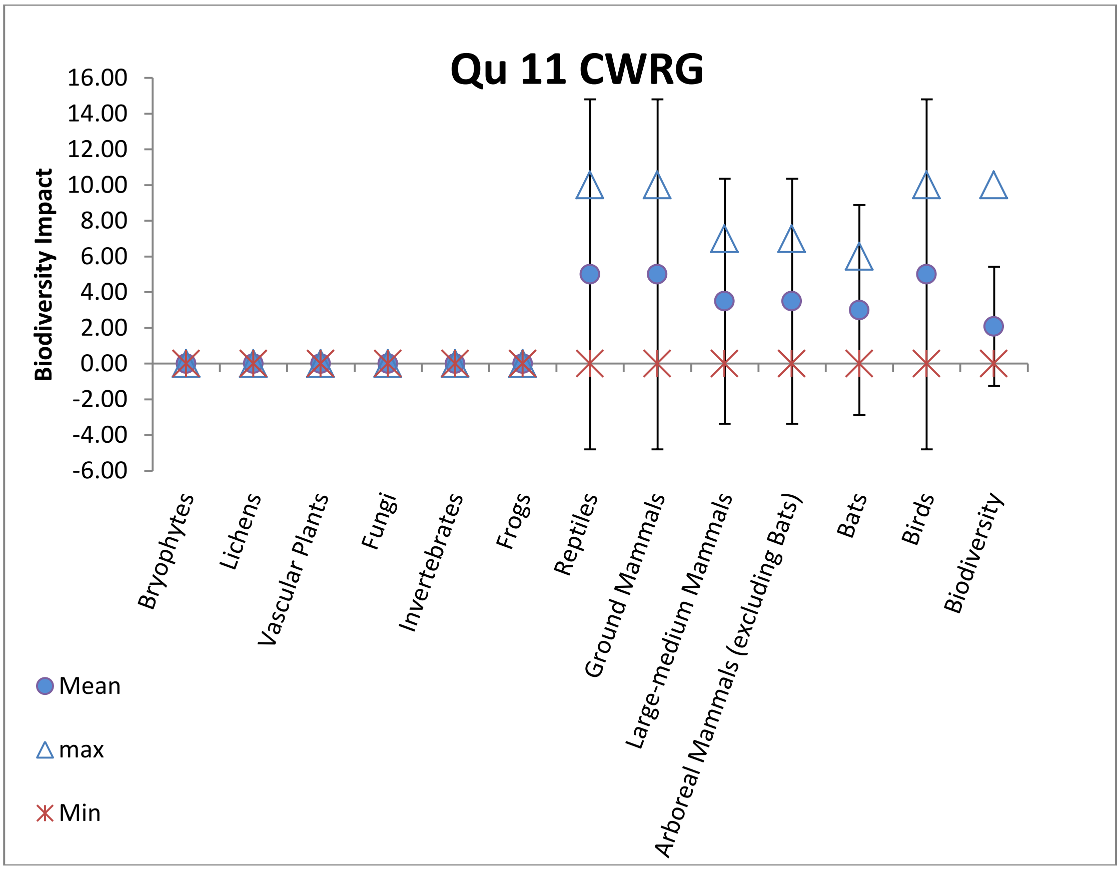


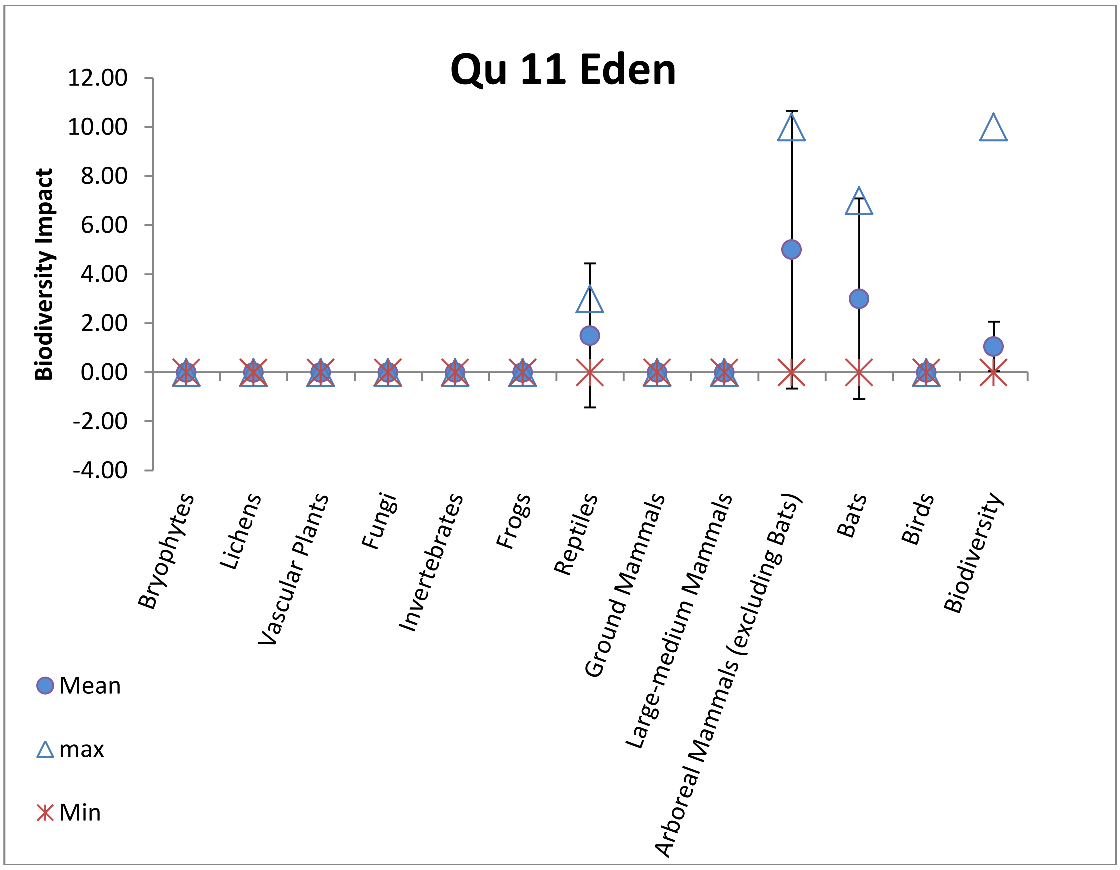

Qu 11 Eden
Mean
max
Min
Biodiversity Impact
10.00
8.00
6.00
4.00
2.00
0.00
Bryophytes
Lichens
Vascular Plants
Fungi
Invertebrates
Frogs
Reptiles
Ground Mammals
Large-medium...
Arboreal...
Bats
Birds
Biodiversity

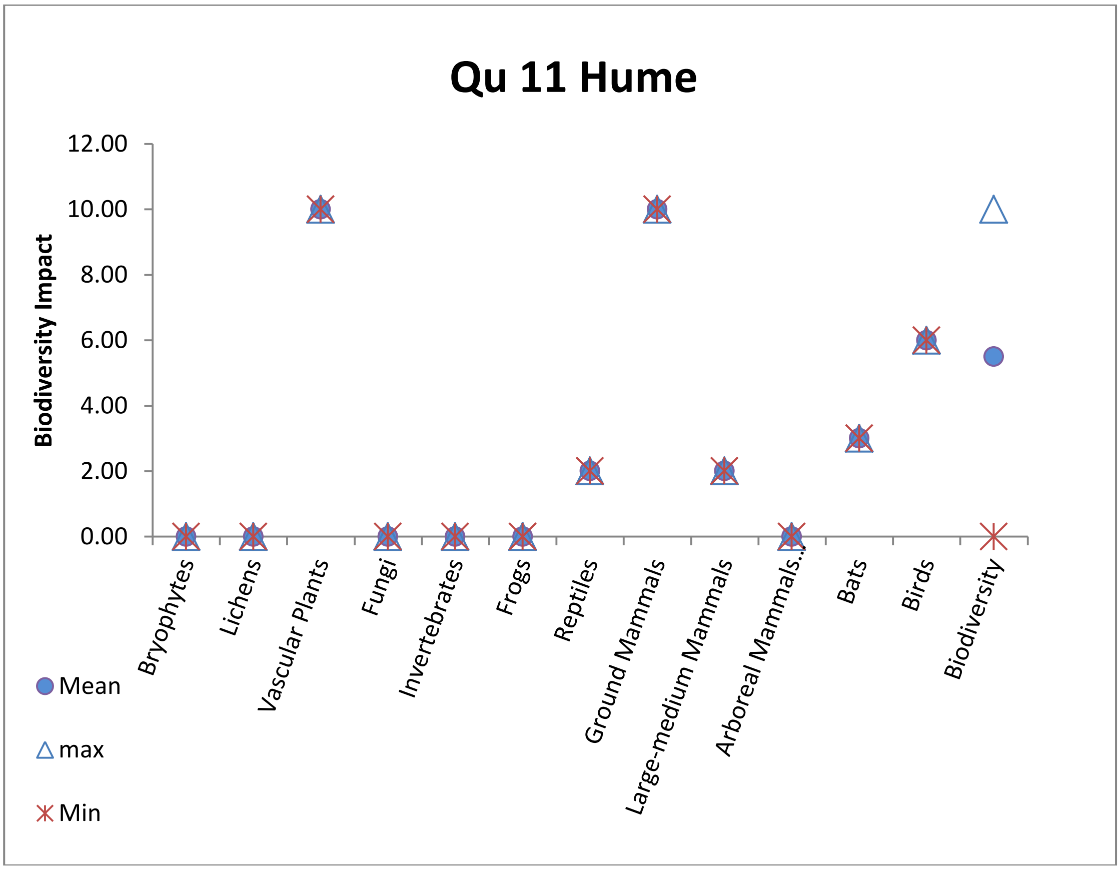

Qu 11 Hume
Mean
max
Min
Biodiversity Impact
2.00
0.00
Bryophytes
Lichens
Vascular Plants
Fungi
Invertebrates
Frogs
Reptiles
Ground Mammals
Large-medium...
Arboreal...
Bats
Birds
Biodiversity

Survey scores





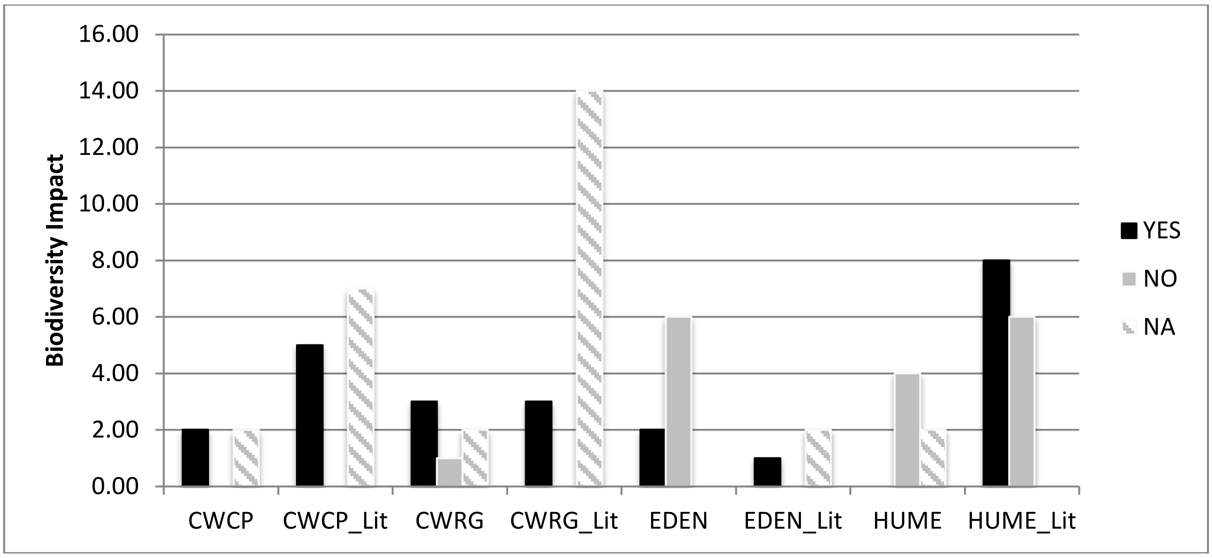

Qu 11 Eden
Biodiversity Impact
12.00
10.00
8.00
6.00
4.00
2.00
0.00
-2.00
-4.00
Bryophytes
Lichens
Vascular Plants
Fungi
Invertebrates
Frogs
Reptiles
Ground Mammals
Large-medium Mammals
Arboreal Mammals (excluding Bats)
Bats
Birds
Biodiversity
Mean
max
Min


Qu 11 Hume
Biodiversity Impact
12.00
10.00
8.00
6.00
4.00
2.00
0.00
Bryophytes
Lichens
Vascular Plants
Fungi
Invertebrates
Frogs
Reptiles
Ground Mammals
Large-medium Mammals
Arboreal Mammals...
Bats
Birds
Biodiversity
Mean
max
Min

Question 12

Will the process result in at risk species becoming eligible for IUCN listing or upgrading existing listings under IUCN?

Literature and survey scores



Question 13

Does the process affect threatened species or endangered ecological communities?

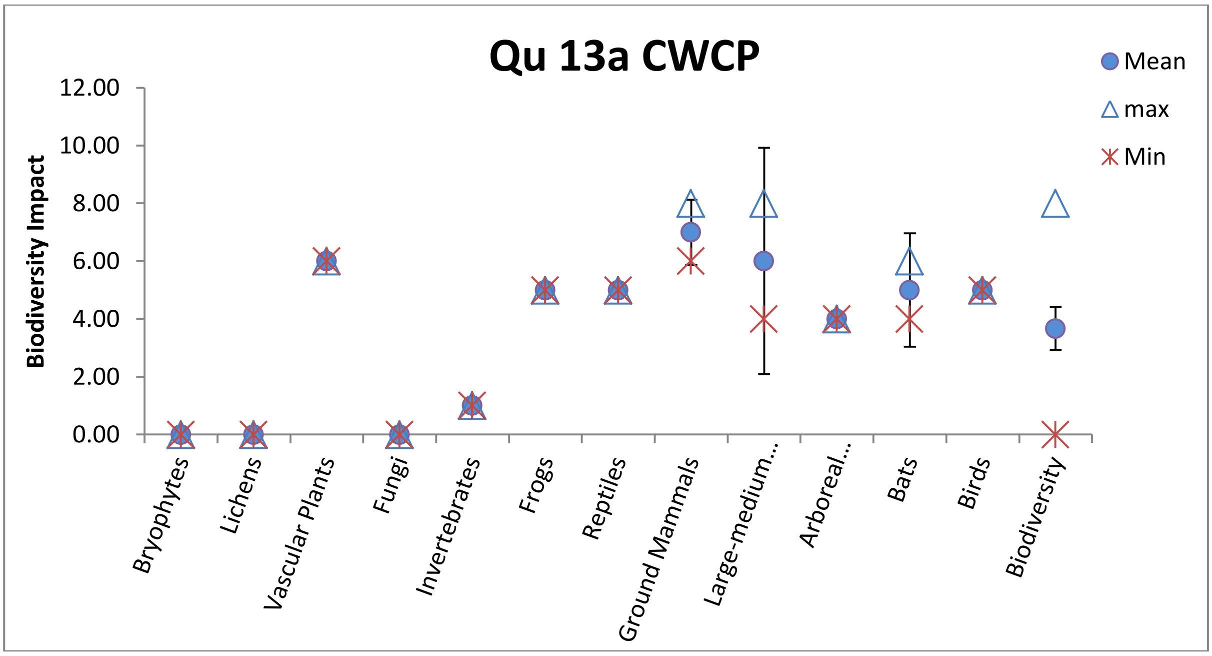
a. – an individual threatened species?

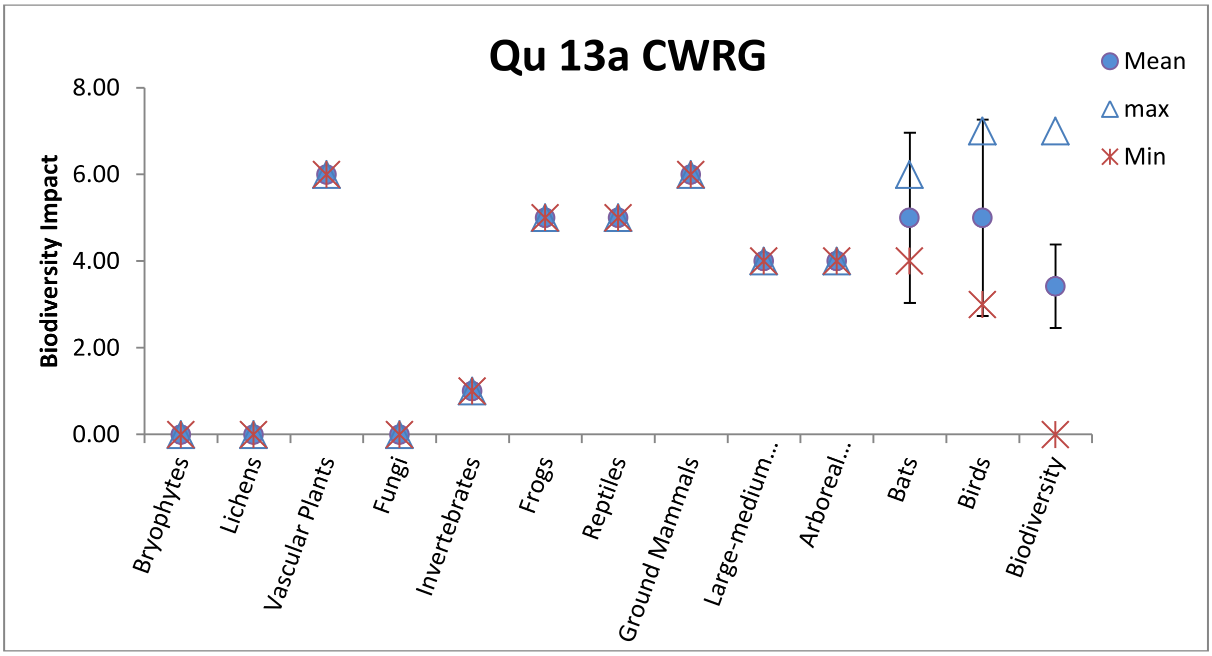
b. – an endangered ecological community?

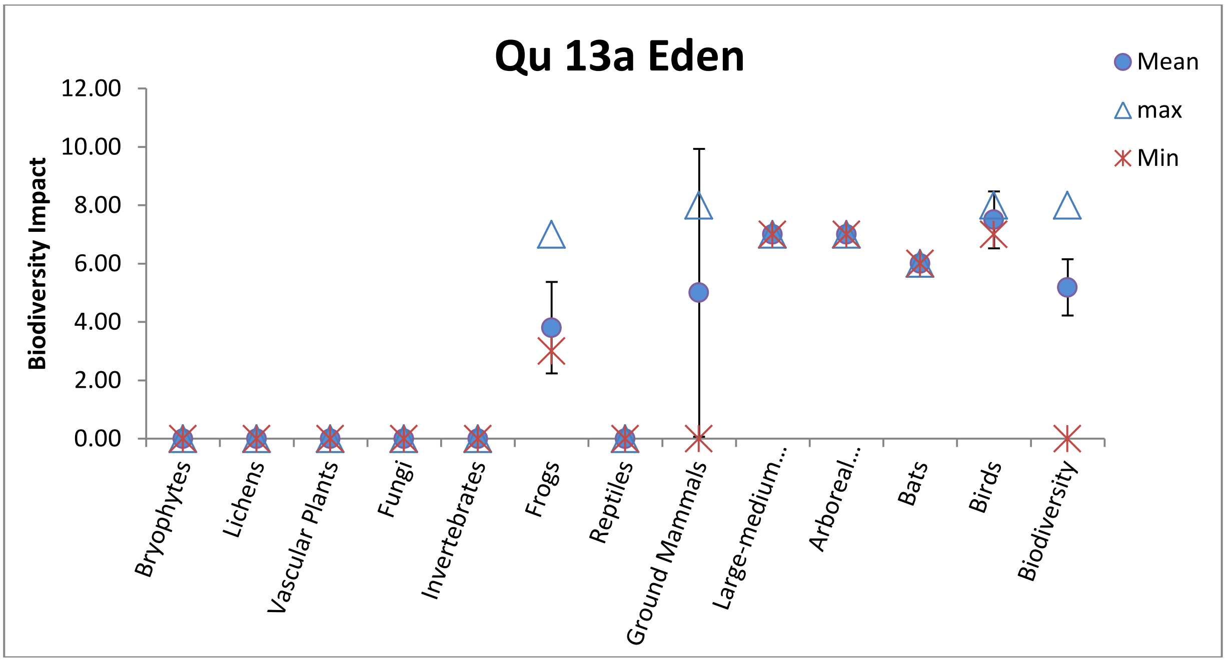
c. – more than one threatened species?

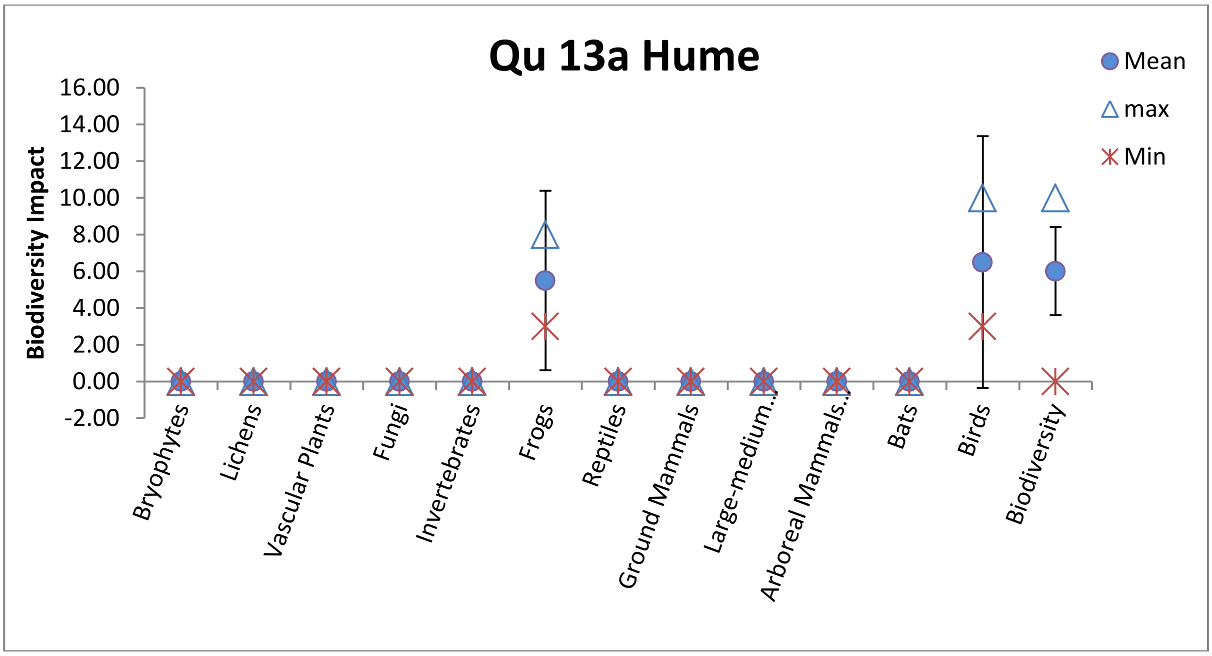
d. – more than one endangered ecological community?

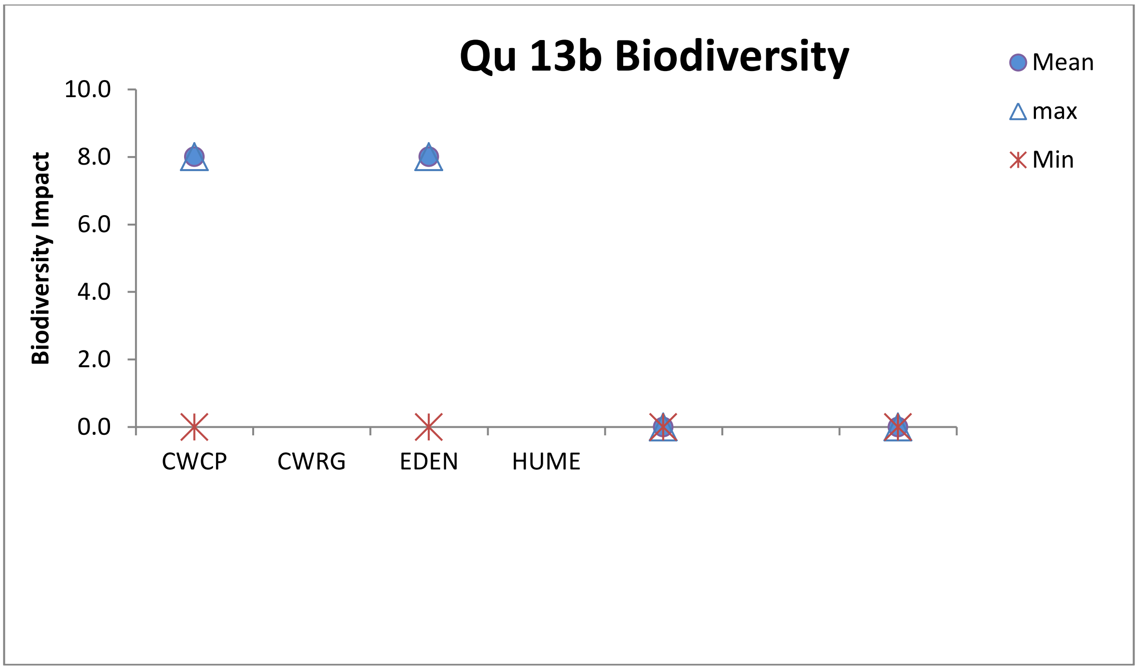
Literature scores




Qu 13a CWRG
Mean
max
Min
Biodiversity Impact
8.00
6.00
4.00
2.00
0.00
Bryophytes
Lichens
Vascular Plants
Fungi
Invertebrates
Frogs
Reptiles
Ground Mammals
Large-medium...
Arboreal...
Bats
Birds
Biodiversity


Qu 13a Eden
Mean
max
Min
Biodiversity Impact
12.00
10.00
8.00
6.00
4.00
2.00
0.00
Bryophytes
Lichens
Vascular Plants
Fungi
Invertebrates
Frogs
Reptiles
Ground Mammals
Large-medium...
Arboreal...
Bats
Birds
Biodiversity


Qu 13a Hume
Mean
max
Min
Biodiversity Impact
16.00
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
-2.00
Bryophytes
Lichens
Vascular Plants
Fungi
Invertebrates
Frogs
Reptiles
Ground Mammals
Large-medium...
Arboreal Mammals...
Bats
Birds
Biodiversity


Qu 13b Biodiversity
Mean
max
Min
Biodiversity Impact
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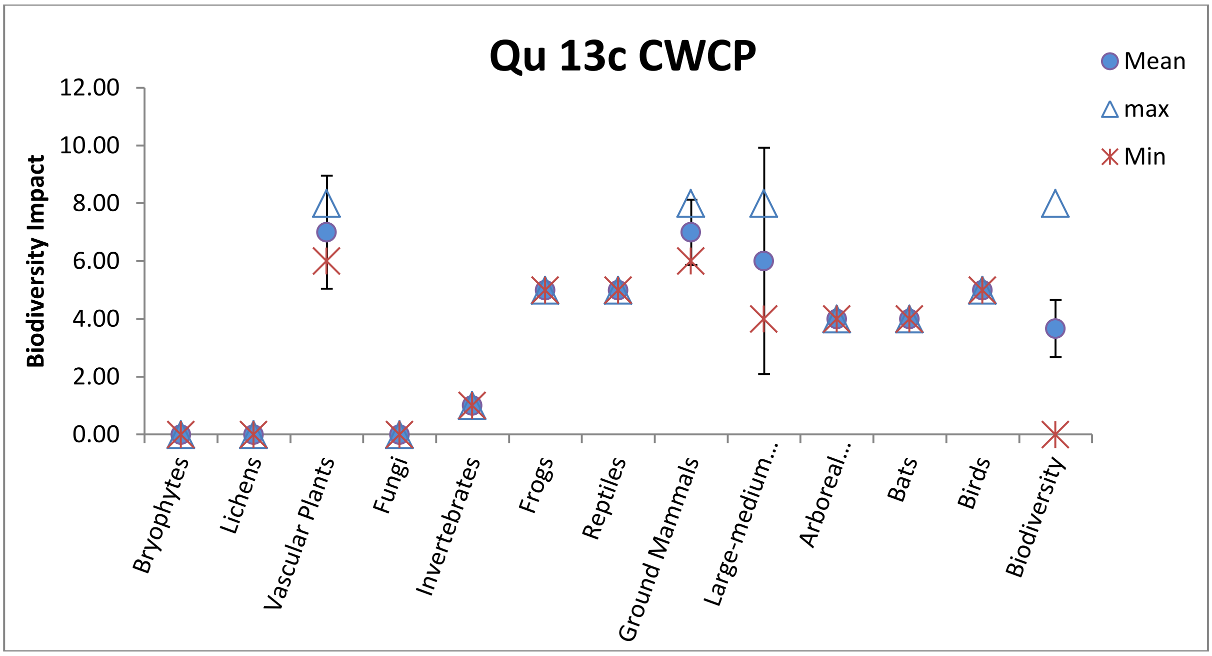
8.0
6.0
4.0
2.0
0.0
CWCP
CWRG
EDEN
HUME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Mean
max
Min
Biodiversity Impact
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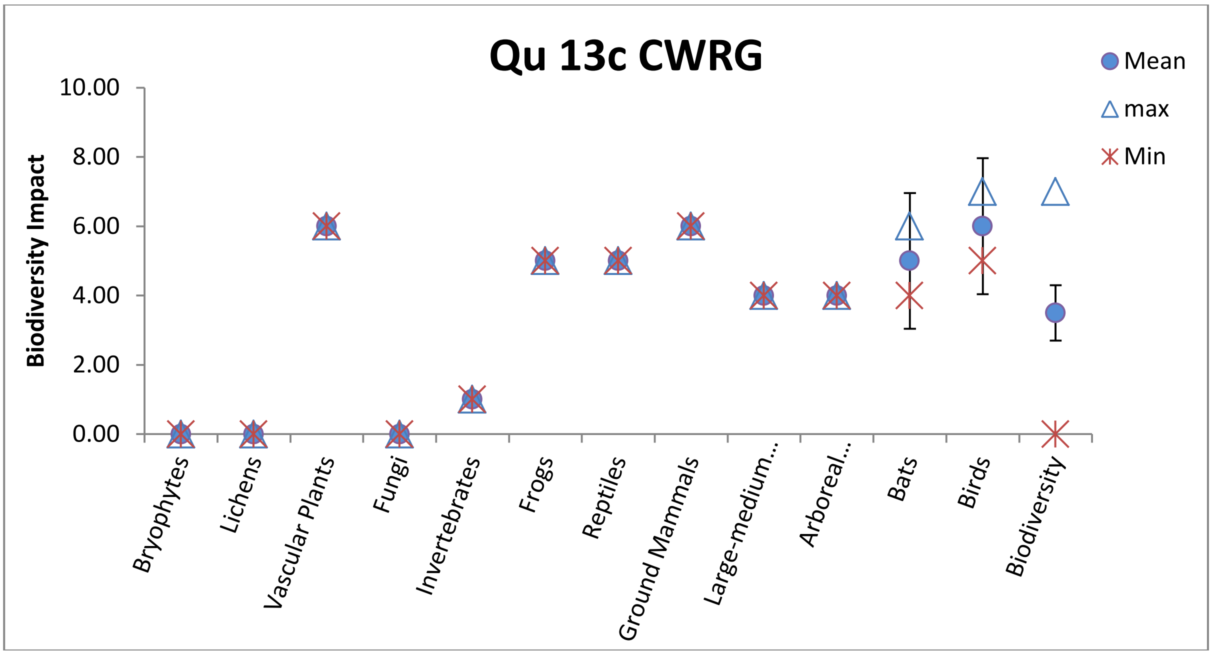
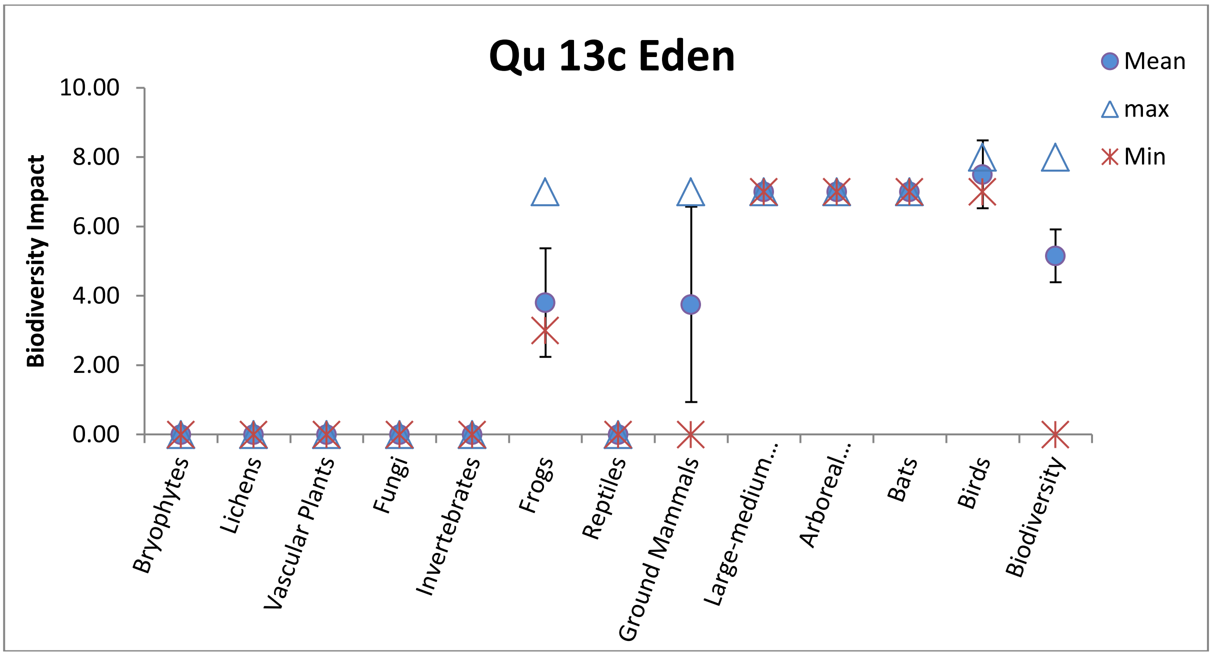
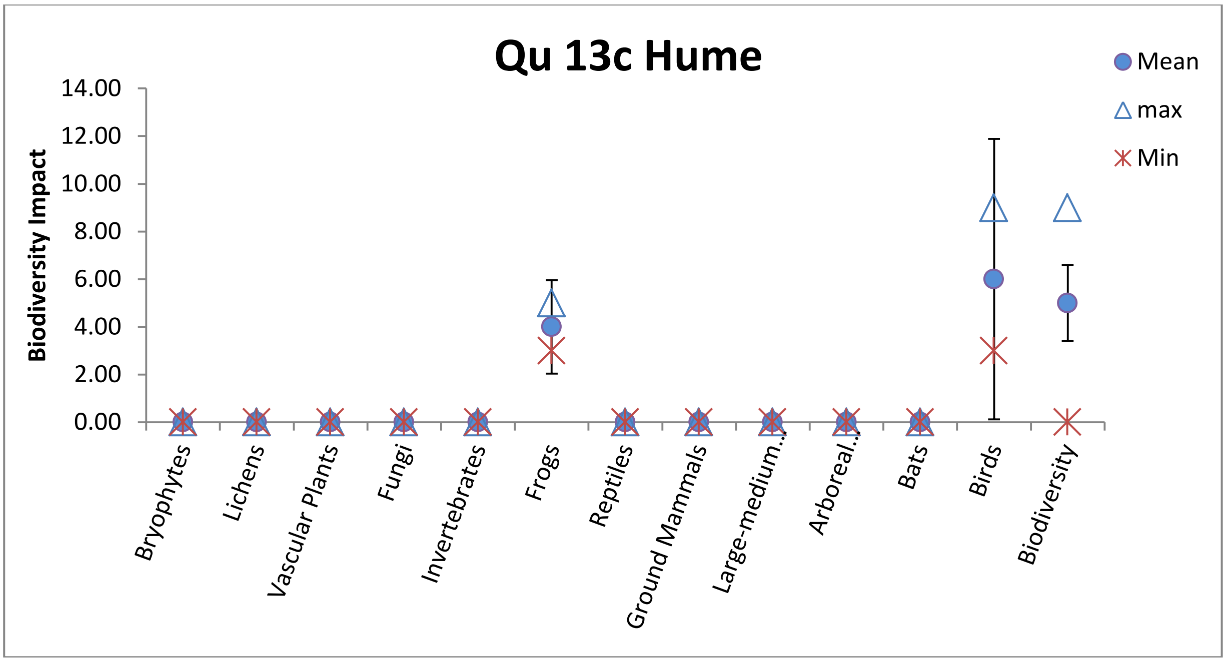
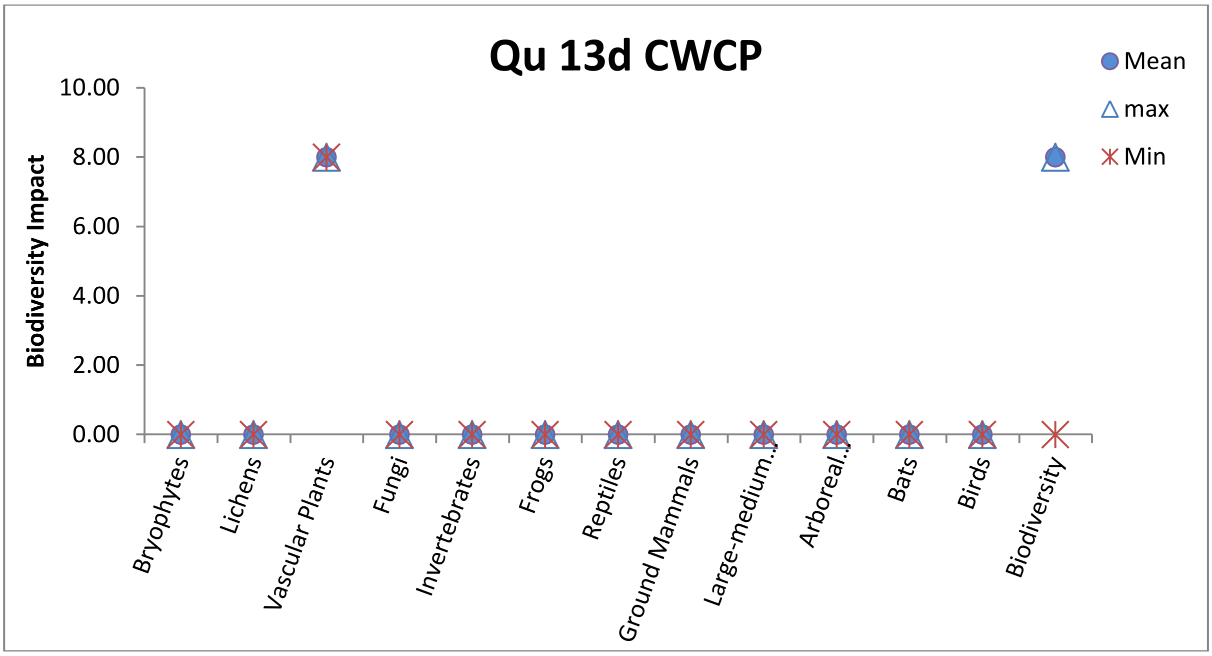
8.00
6.00
4.00
2.00
0.00
Bryophytes
Lichens
Vascular Plants
Fungi
Invertebrates
Frogs
Reptiles
Ground Mammals
Large-medium...
Arboreal...
Bats
Birds
Biodiversity


Qu 13c CWRG
Mean
max
Min
Biodiversity Impact
10.00
8.00
6.00
4.00
2.00
0.00
Bryophytes
Lichens
Vascular Plants
Fungi
Invertebrates
Frogs
Reptiles
Ground Mammals
Large-medium...
Arboreal...
Bats
Birds
Biodiversity


Qu 13c Eden
Mean
max
Min
Biodiversity Impact
10.00
8.00
6.00
4.00
2.00
0.00
Bryophytes
Lichens
Vascular Plants
Fungi
Invertebrates
Frogs
Reptiles
Ground Mammals
Large-medium...
Arboreal...
Bats
Birds
Biodiversity


Qu 13c Hume
Mean
max
Min
Biodiversity Impact
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
Bryophytes
Lichens
Vascular Plants
Fungi
Invertebrates
Frogs
Reptiles
Ground Mammals
Large-medium...
Arboreal...
Bats
Birds
Biodiversity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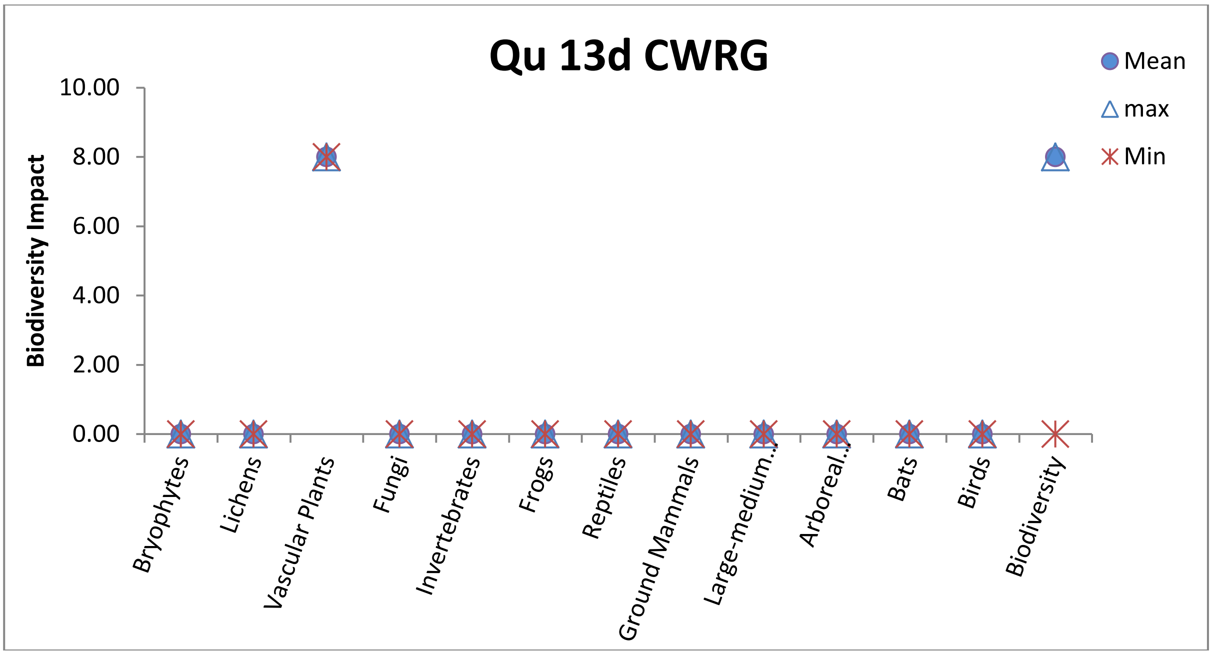
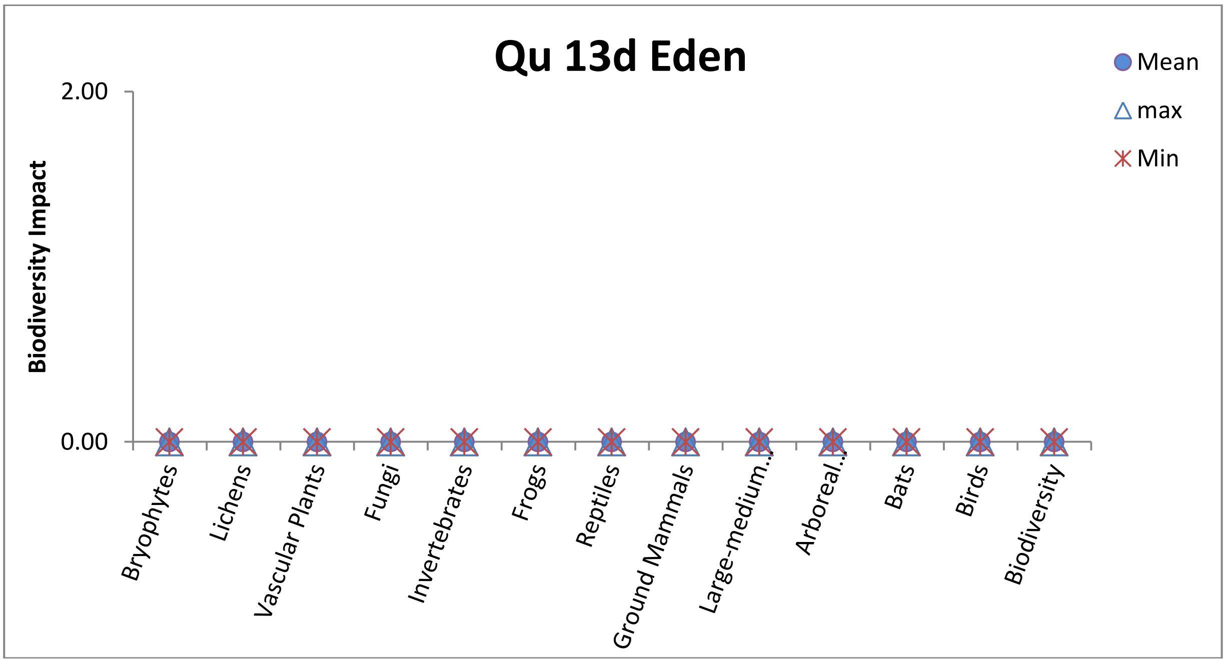
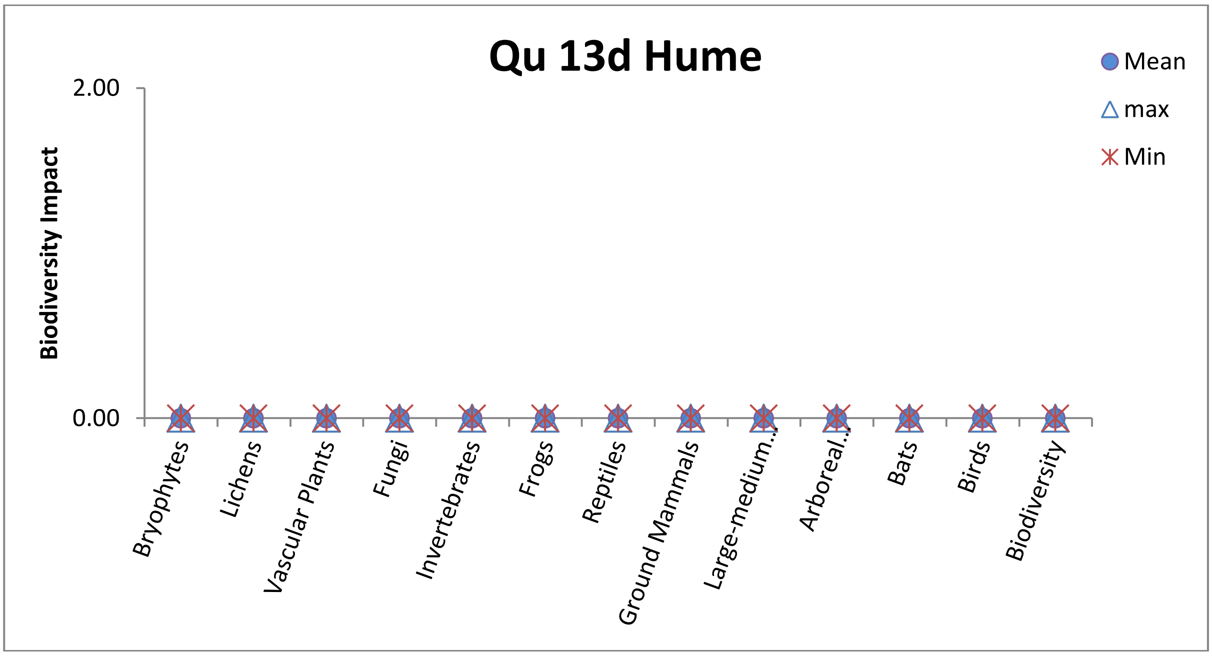
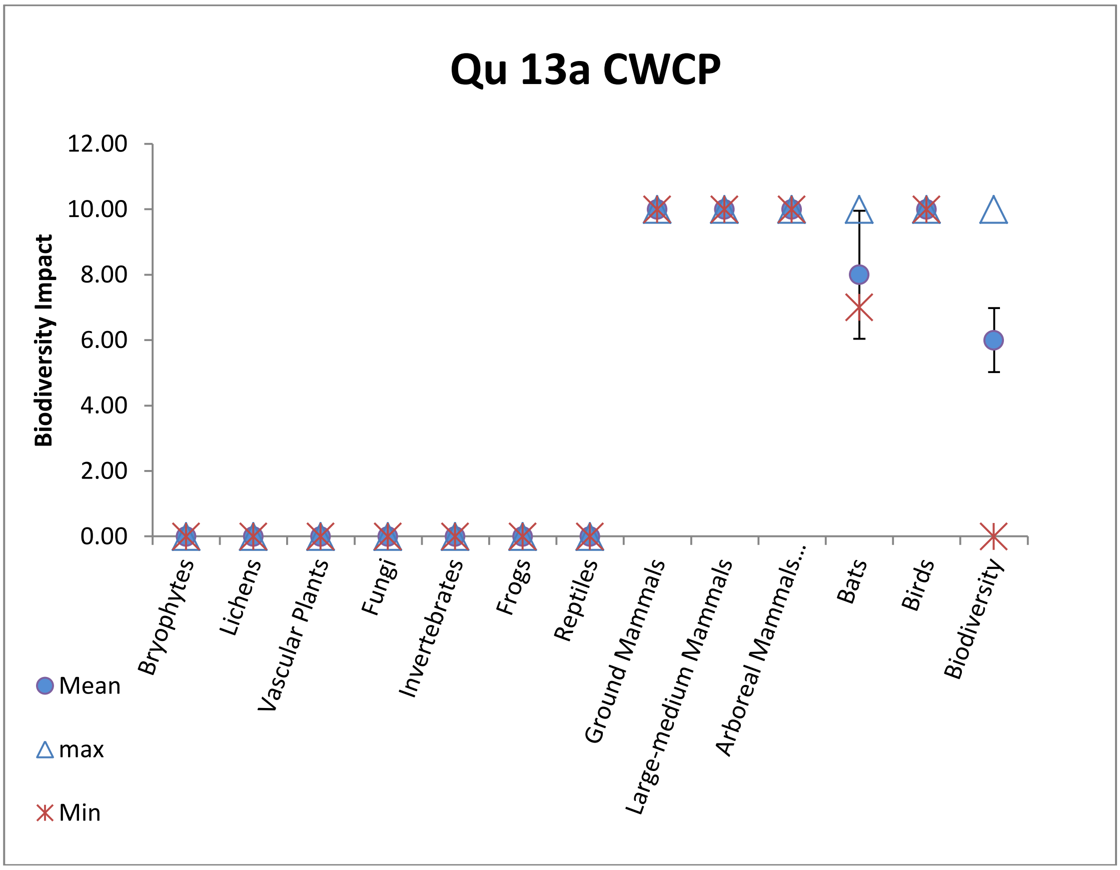
Mean
max
Min
Biodiversity Impact
10.00
8.00
6.00
4.00
2.00
0.00
Bryophytes
Lichens
Vascular Plants
Fungi
Invertebrates
Frogs
Reptiles
Ground Mammals
Large-medium...
Arboreal...
Bats
Birds
Biodiversity

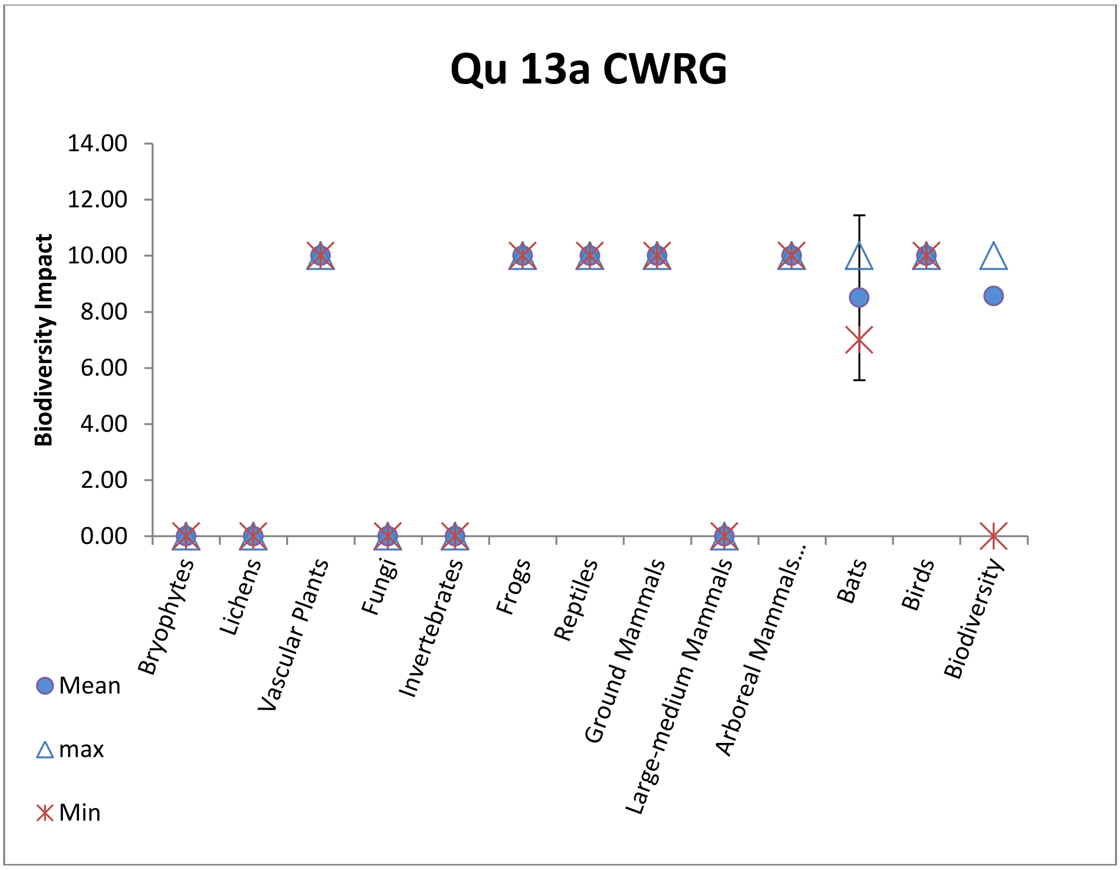

Qu 13d CWRG
Mean
max
Min
Biodiversity Impact
10.00
8.00
6.00
4.00
2.00
0.00
Bryophytes
Lichens
Vascular Plants
Fungi
Invertebrates
Frogs
Reptiles
Ground Mammals
Large-medium...
Arboreal...
Bats
Birds
Biodiversity

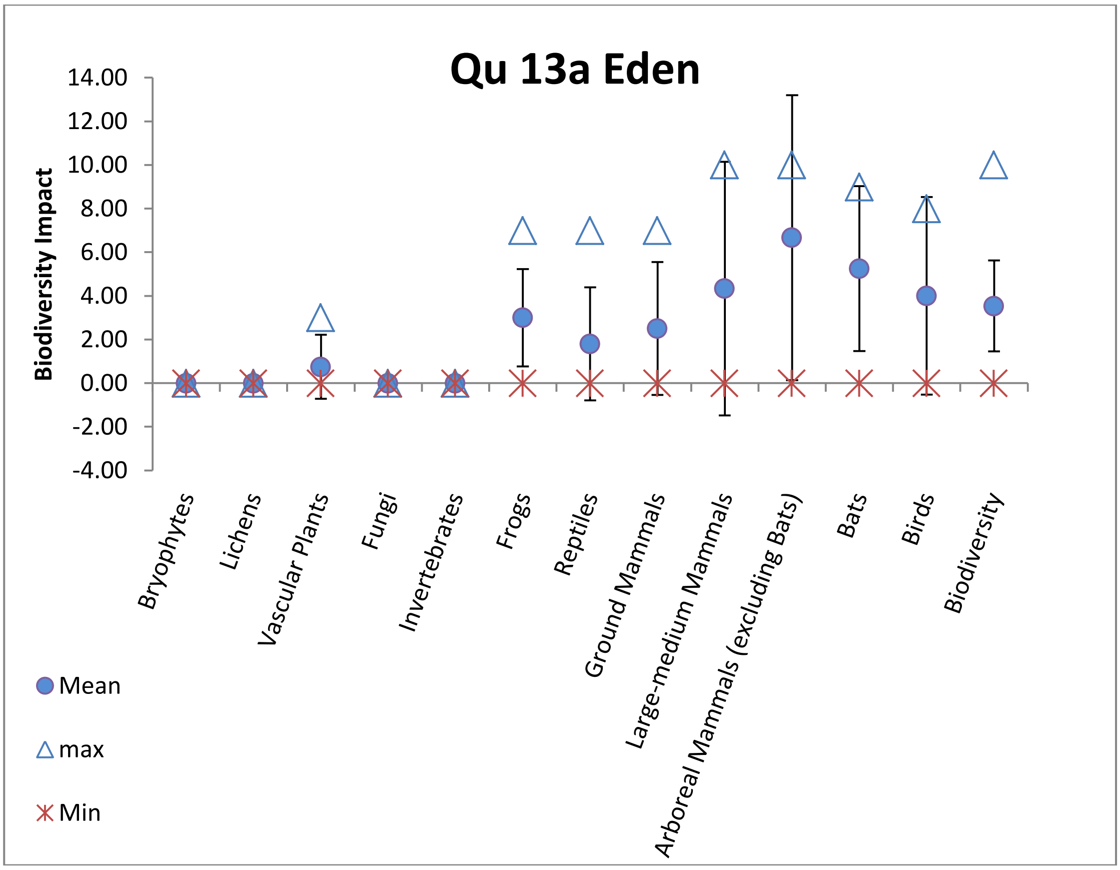

Qu 13d Eden
Mean
max
Min
Biodiversity Impact
2.00
0.00
Bryophytes
Lichens
Vascular Plants
Fungi
Invertebrates
Frogs
Reptiles
Ground Mammals
Large-medium...
Arboreal...
Bats
Birds
Biodiversity

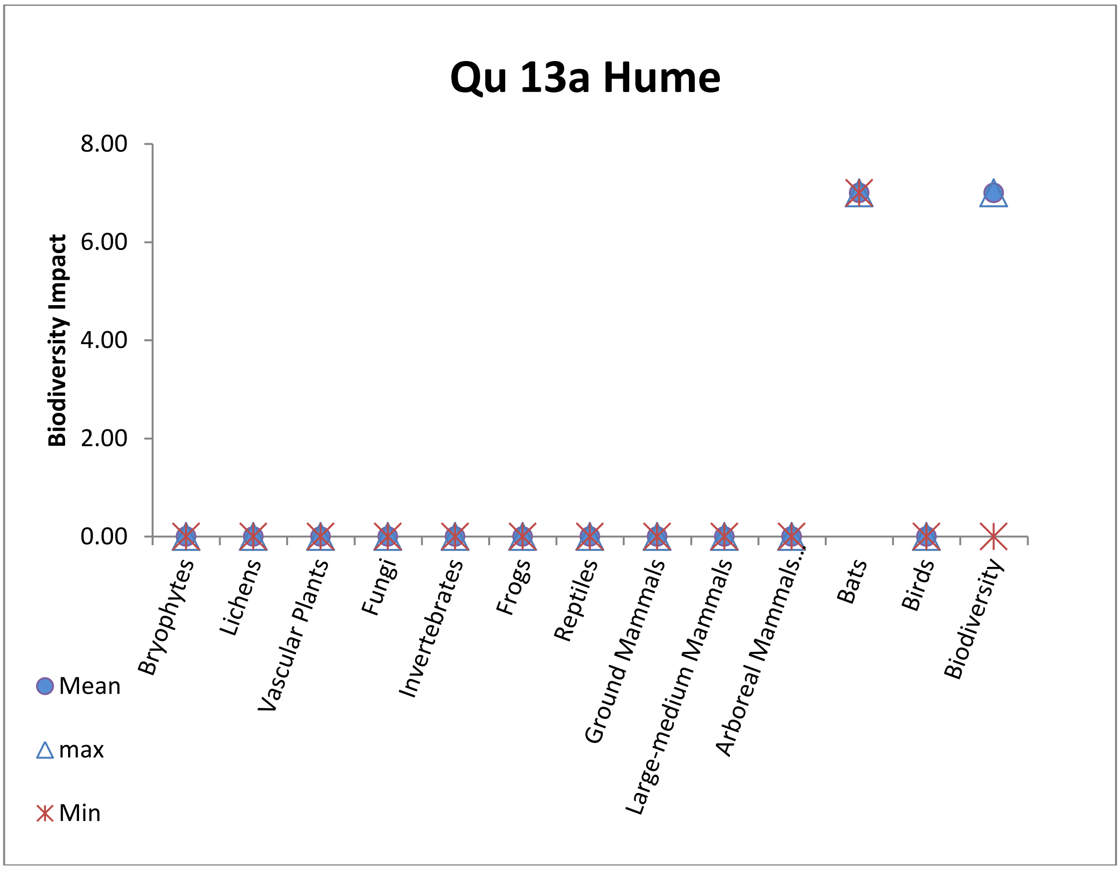

Qu 13d Hume
Mean
max
Min
Biodiversity Impact
2.00
0.00
Bryophytes
Lichens
Vascular Plants
Fungi
Invertebrates
Frogs
Reptiles
Ground Mammals
Large-medium...
Arboreal...
Bats
Birds
Biodiversity

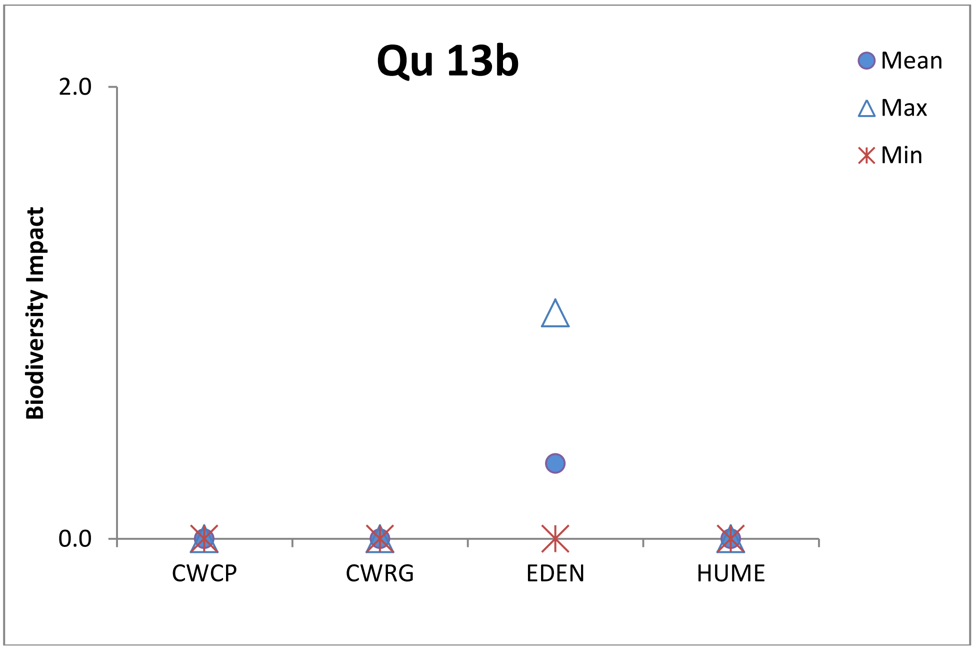
Question 13
Survey scores

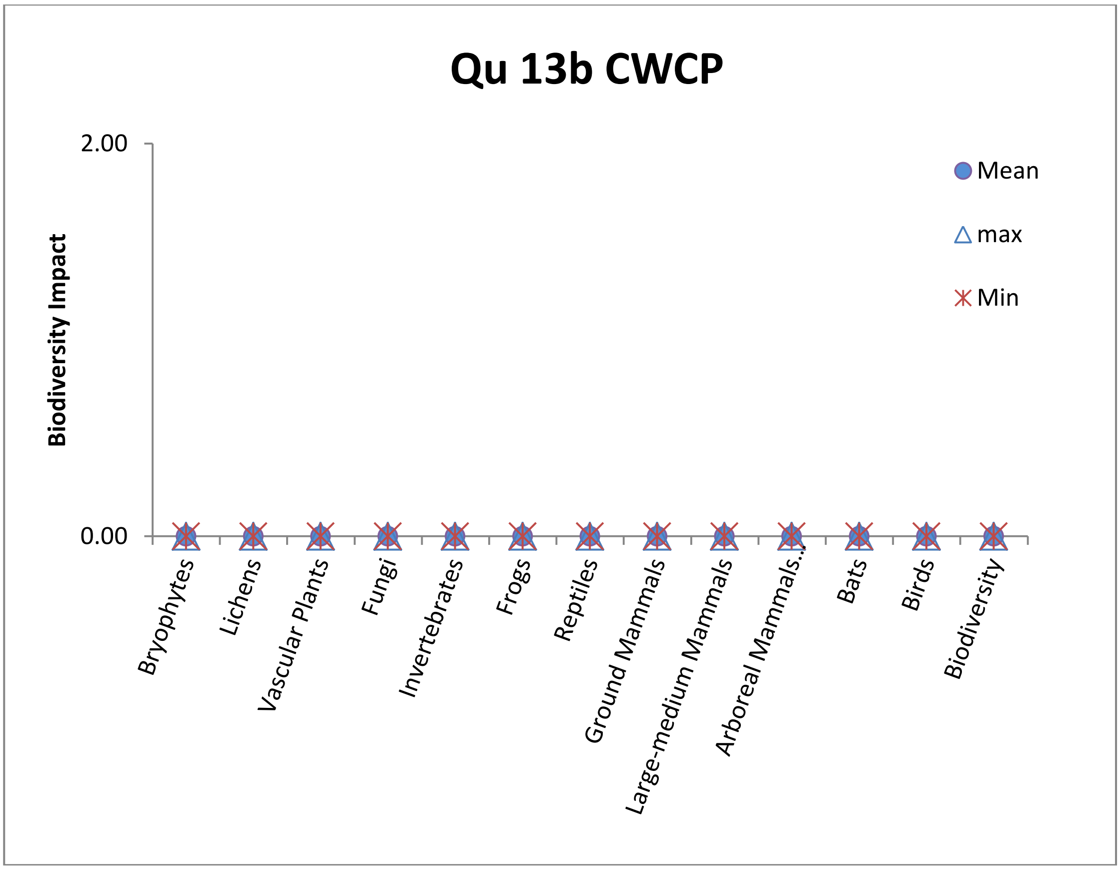


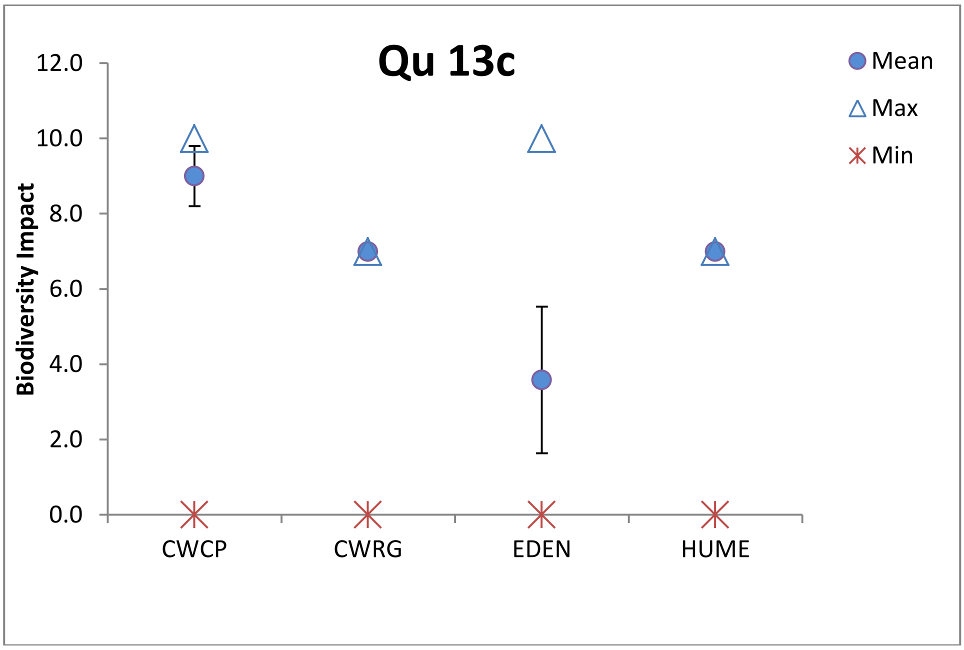


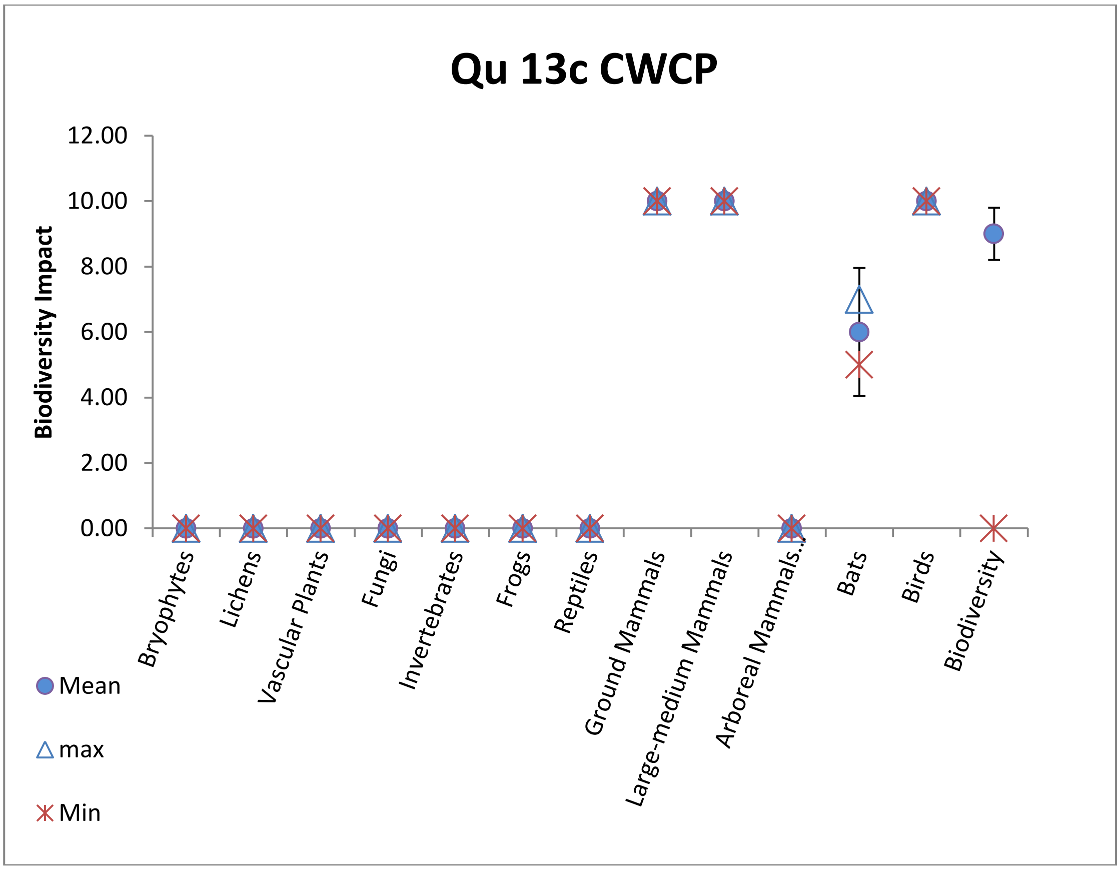

Qu 13a Eden
Biodiversity Impact
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
-2.00
-4.00
Bryophytes
Lichens
Vascular Plants
Fungi
Invertebrates
Frogs
Reptiles
Ground Mammals
Large-medium Mammals
Arboreal Mammals (excluding Bats)
Bats
Birds
Biodiversity
Mean
max
Min

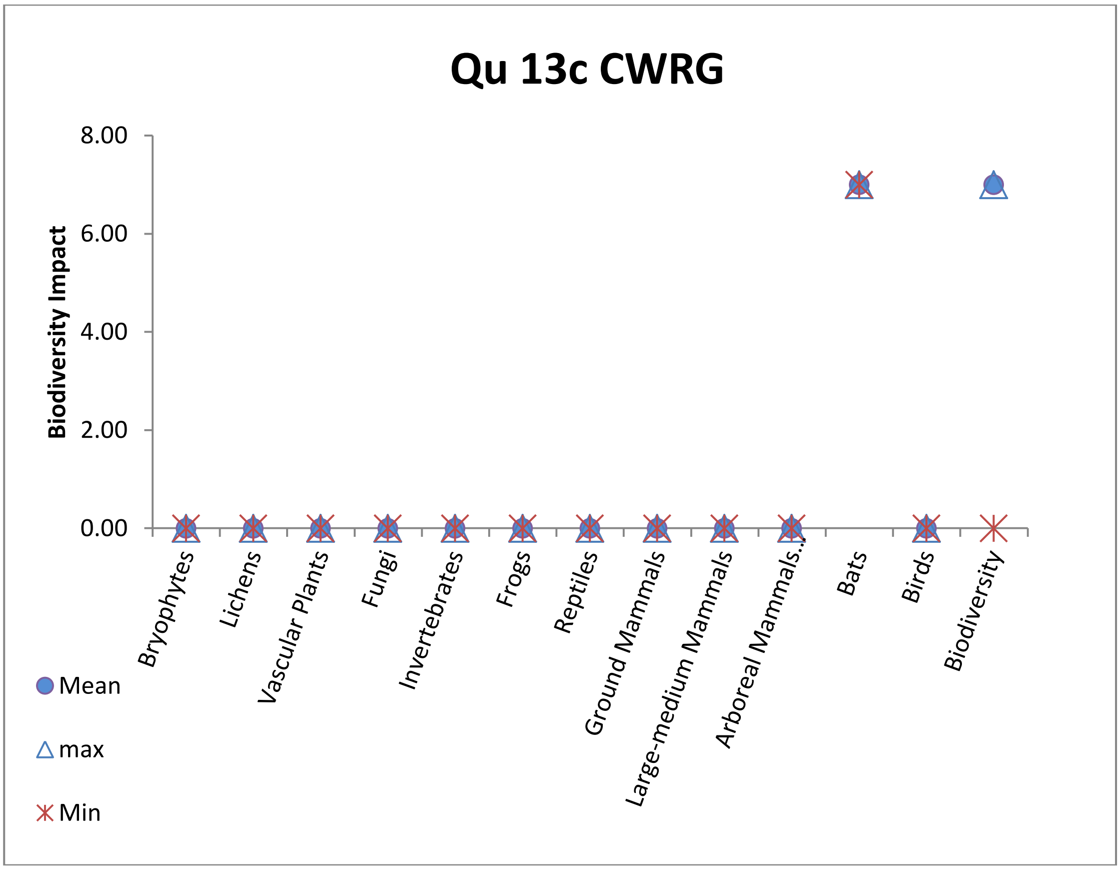

Qu 13a Hume
Biodiversity Impact
8.00
6.00
4.00
2.00
0.00
Bryophytes
Lichens
Vascular Plants
Fungi
Invertebrates
Frogs
Reptiles
Ground Mammals
Large-medium Mammals
Arboreal Mammals...
Bats
Birds
Biodiversity
Mean
max
Min

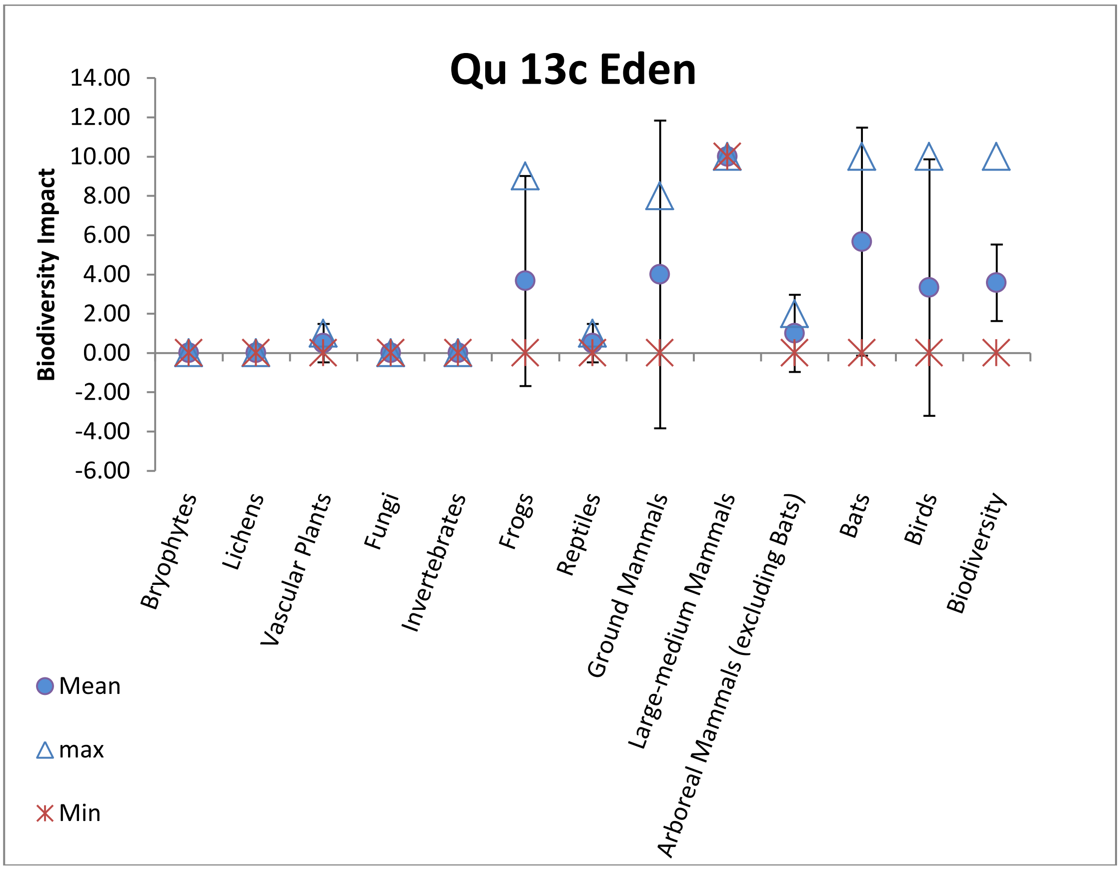

Qu 13b
2.0
0.0
Biodiversity Impact
Mean
Max
Min
CWCP
CWRG
EDEN
HUME

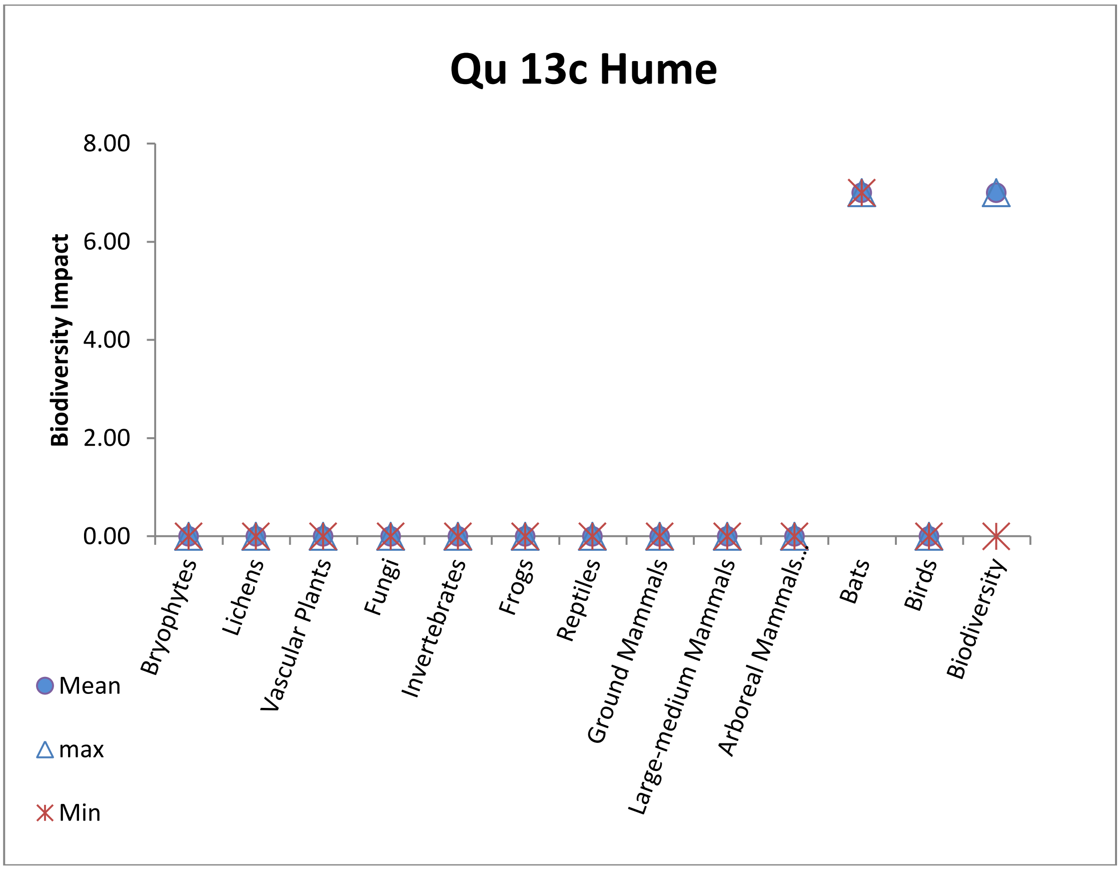

Qu 13b CWCP
2.00
0.00
Biodiversity Impact
Mean
max
Min
Bryophytes
Lichens
Vascular Plants
Fungi
Invertebrates
Frogs
Reptiles
Ground Mammals
Large-medium Mammals
Arboreal Mammals...
Bats
Birds
Biodiversity

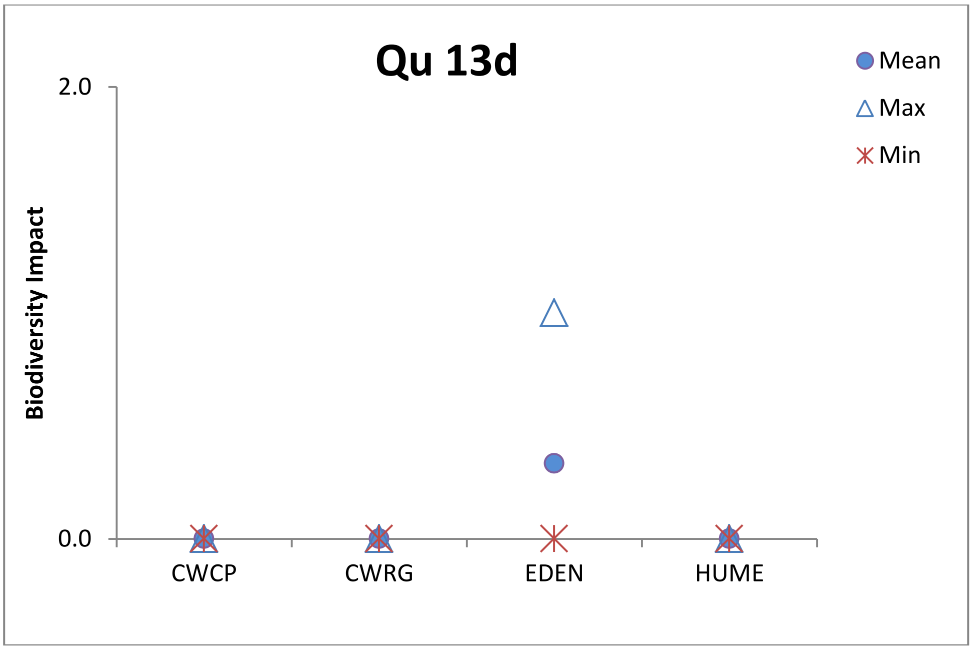

Qu 13c
Biodiversity Impact
12.0
10.0
8.0
6.0
4.0
2.0
0.0
CWCP
CWRG
EDEN
HUME
Mean
Max
Min


Qu 13c CWCP
Biodiversity Impact
12.00
10.00
8.00
6.00
4.00
2.00
0.00
Bryophytes
Lichens
Vascular Plants
Fungi
Invertebrates
Frogs
Reptiles
Ground Mammals
Large-medium Mammals
Arboreal Mammals...
Bats
Birds
Biodiversity
Mean
max
Min


Qu 13c CWRG
Biodiversity Impact
8.00
6.00
4.00
2.00
0.00
Bryophytes
Lichens
Vascular Plants
Fungi
Invertebrates
Frogs
Reptiles
Ground Mammals
Large-medium Mammals
Arboreal Mammals...
Bats
Birds
Biodiversity
Mean
max
Min


Qu 13c Eden
Biodiversity Impact
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
-2.00
-4.00
-6.00
Bryophytes
Lichens
Vascular Plants
Fungi
Invertebrates
Frogs
Reptiles
Ground Mammals
Large-medium Mammals
Arboreal Mammals (excluding Bats)
Bats
Birds
Biodiversity
Mean
max
Min


Qu 13c Hume
Biodiversity Impact
8.00
6.00
4.00
2.00
0.00
Bryophytes
Lichens
Vascular Plants
Fungi
Invertebrates
Frogs
Reptiles
Ground Mammals
Large-medium Mammals
Arboreal Mammals...
Bats
Birds
Biodiversity
Mean
max
Min


Qu 13d
Biodiversity Impact
2.0
0.0
CWCP
CWRG
EDEN
HUME
Mean
Max
Min