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Supplementary material

A threatened ecological community: research advances and priorities for Banksia woodlands

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Table S1. Priority research actions for (1) floristics and weeds, (2) geology and soils, (3) water relations and groundwater management, (4) invertebrates, (5) vertebrates, (6) disease, (7) fire, (8) mining and restoration and (9) urban development in Banksia woodlands (BWs)

Topic	Priority research actions			
1) Floristics and weeds	1) Characterise BWs species turnover patterns and relationships with soil or landform.	Mapping of BWs floristic communities as currently understood.		3) Consolidation of the existing floristic data available across disparate sources in a publicly accessible information system.
2) Geology and soils	1) Develop a regional classification of plant composition as it relates to landform and soil physical and chemical properties	2) Study the small-scale patterns of soils within the soil chrono-sequence		3) Develop greater understanding of the ecological functioning and responses to disturbance by soil microbial communities
3) Water relations and groundwater management	a) Increase understanding of soil-plant-atmosphere interactions	b) Identify management triggers to mitigate threshold-type responses in vegetation	c) Study the interactions between water deficit and fire, weeds and other ecological pressures.	d) Study the resilience and restoration of ecohydrological habitats
4) Invertebrates	a) Conduct a census of the BWs invertebrate fauna (identity, abundance, distribution, fidelity, function and reliance on BWs)	b) Increase understanding of invertebrate biology and their interactions with other species.	c) Improve management of threatened and endangered invertebrates, including stygofauna.	d) Identify impacts and biology of invasive invertebrates
5) Vertebrates	a) Improve our ability to conserve vertebrate populations through understanding of concomitant threats	b) Improve understanding of species traits, particularly those persisting in remnants	c) Identify mechanisms underpinning species responses to fragmentation, and develop strategies to ameliorate fragmentation effects	d) Knowledge of the permeability of the urban matrix to individual species, as this has implications for habitat restoration and landscape connectivity.
	e) Study extinction debt in BW remnants and its relationships with remnant size i) Investigations of how vertebrates in urban BWs remnants, especially feral cats, spread animal diseases.	f) Increase knowledge of bat ecology in BW	g) Examine the genetic structure of vertebrate populations	h) Identify human–wildlife interactions, including those related to reintroductions and develop local urban community support and engagement
6) Disease Key areas for investigation include:	Whether the effectiveness of eradication treatments in spot infestations will result in suppression or significant spread if not managed.	Response of *P. cinnamomi* in its different life cycle stages to hotter and drier conditions.	Response of flora, fauna, and fungi to the effects of *P. cinnamomi* and climate change.	Response of flora to interactions between drought + heavy summer rainfall and *P. cinnamomi*
	The biology, ecology and pathology of native and introduced species of *Phytophthora* present in BWs, their host ranges, ecological roles and their interactions with *P. cinnamomi.*	The response of *P. cinnamomi* – affected woodlands to restoration that aim to provide ecosystem services and functions similar to those before impact. Opportunities exist to select resistant or tolerant species	Response of *P. multivora* to a wide range of disturbance types and climatic conditions, as this species seems to be displacing *P. cinnamomi* in urban bushland.	Response of flora, fauna and fungi to increased frequency, intensity of fire and *P. cinnamomi*. A better understanding of other plant diseases and disease-causing organisms present in

Topic	Priority research actions			
		through seed collection following impact and reintroduction by tube stock or broadcast seeding.		BW and how they may be affected by disturbances such as climate change and fire.
7) Fire Many issues raised by Hopkins and Griffin (1989) remain relevant today. In particular, the development of an effective fire behaviour model and an understanding of the effectiveness and impacts of prescribed burning on both wildfire risk and biodiversity values requires the following:	Fuel dynamics and variation according to fire history and spatial extent of BWs. Quantification of the grass-fire cycle, including its impacts on wildfire and native biodiversity, and documentation of effective management options that interrupt this cycle.	Fuel dynamics under a warming and drying climate. Integration of fire science, fine-scale meteorology and remote sensing, and human health impacts to reveal potential trade-offs in differing fire management strategies.	Explicit description of fire behaviour and a model suitable to predict fire behaviour in BWs. Detailed species traits and responses to varying fire regime elements, including: o Fire season, including effects of spring or winter burning; o Fire intensity; o Fire interval (or frequency); and o Fire patchiness under different conditions.	The role of environmental variables (including varying weed cover, herbivory, digging animals, climate, and soil types) on fire responses, fuel characteristics, fire behaviour, and wildfire risk. Interactions between all of these elements are complex and largely unstudied, but as they likely determine population and community outcomes research incorporating interactions is required to support land managers to avoid unwanted fire effects.
8) Mining and restoration Research is required in the following areas:	Develop a complete understanding of what processes (physical, chemical or biological) are driving subsurface soil hardening in restoration sites.	Determine the conditions for the successful germination and establishment of many species within BW that are unknown.	Investigate and develop seed enhancement technologies to maximise seed use for restoration of BWs (Brown *et al*. 2019).	Identify faunal species that passively recolonise restoration areas to identify species that will, and will not, benefit from restoration activities.
	Investigate new opportunities that exist from the rapid development of high-throughput DNA sequencing technologies. These include rapid and comprehensive eDNA assessment of above- and below-ground biological communities (e.g. soil biota) pre and post restoration, as well as gene expression analysis for assessment of genetic resilience to environmental stressors of targeted plant species or communities.	Restoration sites provide a powerful opportunity to refine best practise seed-sourcing guidelines using provenance trials to test if ‘local-is-best’, and therefore warrant further study.		Develop techniques to move towards holistic restoration of BWs that specifically facilitates the recolonisation of soil biota and fauna, particularly keystone and threatened species and those critical for ecosystem services (e.g. pollinators).
9) Urban development Research is required in the following areas:	Model the integration of conservation and reserve planning scenarios with alternative growth patterns to optimise	Research strategies and scenarios to include securing land tenure for remaining BWs, directing	The development of alternative strategies for achieving urban densification	Overcoming social and environmental barriers (and identifying enablers) for

Topic	Priority research actions			
	protection of BWs. Analyse the growth patterns of the dominant urban development types outlined in Bolleter (2018) for use and application in Perth.	development towards already cleared areas.	in Perth's existing suburbs that are reconciled with suburban lifestyle aspirations of both existing and future residents.	expansion of BW flora into streetscapes and urban landscaping as a coordinated approach across the Perth metropolitan area.

Banksia Woodland Review questions, using extracts from the Banksia Woodlands Symposium (Pate 1989)

Geology & Soils

> The geomorphology, stratigraphy and soils of the Bassendean and Spearwood dunes, have not been documented in sufficient detail, using modern systematic approaches, at the full range of large to fine scales.

Q1. Has the geomorphology, stratigraphy, and soils of Bassendean and Spearwood dunes been documented at the full range of large to fine scales?

> To date, there has not been a systematic description of the dunes in terms of their landforms, stratigraphy, soils, inter-relationships and age structure specifically for the purposes of landscape ecology, i.e. for delineation of vegetation habitats.

Q2. Has a regional systematic description of the dunes been described according to the above characteristics?

> The development of an adequate descriptive framework of these physical features of the dune terrains should be an essential first stage requirement both for purpose of landscape ecological studies and for the identification for resource variability within Banksia woodland systems.

Q3. Has resource variability (e.g. water, nutrient and soil physical properties) within Banksia woodland systems been quantified in relation to dune physical features?

> The development of an adequate descriptive framework of these physical features of the dune terrains should be an essential first stage requirement both for purpose of landscape ecological studies and for the identification for resource variability within Banksia woodland systems.

Q4. Are there landscape ecology studies of Banksia woodlands and do they utilise dune physical characteristics as a means of characterising vegetation distributions?

Essay question. How has our understanding of the age, development, and geomorphology of the Swan Coastal Plain dune systems been informed by geological/pedological research in the last 30 years? What have been the largest changes in our understanding since 1989?

Floristics and Weeds

While the Banksia woodlands of the Swan Coastal Plain have been described in detail in recent vegetation surveys (e.g. Beard, the symposium, Heddle et al. 1980), there is little published information on their floristic composition.

On the basis of their understorey composition Banksia woodlands can be divided into a number of floristic types (mostly undefined as yet) in terms of topography, soil type and moisture status and geographic location.

Q1. Has the understorey of Banksia woodlands been divided into floristic types according to topography, soil type, moisture availability (e.g. distance to ground water), or geographic location?

Two main factors that determine floristic composition, namely the degree of soil leaching and the moisture availability of the site, have been found to apply to Banksia woodlands throughout the coastal plain.

Q2. Does this statement hold true today, and has this information been published?

Endemic and rare species have not been assessed fully for Banksia woodlands.

Q3. Since 1989, have endemic and rare species been assessed according to habitat, reproductive potential, natural distribution and conservation?

Until the regional variation of Banksia woodlands has been documented fully, the adequacy of existing reserves for encompassing the variation remains unknown.

Q4. Have regional assessments of floristic composition been conducted?

If regional assessments of floristic composition have been conducted, do existing reserves encompass the full floristic diversity of Banksia woodlands?

Floristic studies of Banksia woodlands usually mention introduced species, but no comprehensive survey has been undertaken of these taxa.

Q5. Have comprehensive surveys of invasive species been conducted?

Floristic studies of Banksia woodlands usually mention introduced species, but no comprehensive survey has been undertaken of these taxa. Management of Banksia woodlands should aim to lower disturbance and prevent further introductions occurring.

Q6. Do we have a detailed understanding of the biological invasion characteristics of exotic species?

The development of an adequate descriptive framework of these physical features of the dune terrains should be an essential first stage requirement both for purpose of landscape ecological studies and for the identification for resource variability within Banksia woodland systems.

Q7. Are there landscape ecology studies of Banksia woodlands and do they utilise dune physical characteristics as a means of characterising vegetation distributions?

Essay questions. How has our understanding of the floristics of the Swan Coastal Plain developed over last 30 years? What have been the largest changes in our understanding since 1989?

Are existing reserves sufficient in extent to maintain existing floristic diversity?

Water relations

Many of the vegetational changes likely to be associated with groundwater pumping have already been observed as a response to long-term, regional drought. The major differences would relate to the rapidly, extent and permanence of groundwater draw-down, which would affect the banksias and a number of understorey species.

Q1. Have we learned about groundwater drawdown and drying impacts on phreatophytic vegetation (largely Banksia species)?

The majority of species are independent of groundwater, however, and should be little affected by pumping.

Q2. Has subsequent work verified that understorey species are not influenced by groundwater pumping?

Even when adult trees are killed, replacement from seed and from supressed seedlings will occur, leading eventually to restoration of woodland. The resulting vegetation would probably have fewer and smaller trees and would resemble undisturbed woodland on dry, upland sites.

Q3. Has tree density changed over the last 30 years in banksia woodland? Can this be related to groundwater or climate? Have woodlands shifted to a sparser, shorter vegetation structure?

In order to predict the effects of groundwater extraction and table lowering in greater detail, further information is needed on the extent of groundwater use by the plants on the SCP.

Q4. Have we extended our knowledge of groundwater use by BW plants since 1989?

Water use by existing vegetation is a major component of the water balance of the SCP and is, therefore, of direct relevance to planning the development and management of the plain's groundwater resources.

Q5. Has this statement been supported by research since 1989?

Essay question. How has our understanding of water relations and groundwater-vegetation interactions of banksia woodland changed since 1989? What major shifts in understanding have occurred and what major knowledge gaps remain?

Groundwater management

The increasing demand for these groundwater resources among competing users is requiring more effective planning and management strategies.

Q1. Have planning and management strategies around groundwater changed since 1989?

The proximity of groundwater to the urban demand centres is seeing pressure for the urban development to move onto primary groundwater source areas with the consequential threats of degradation of these sources. The need to maintain groundwater levels within limits necessary to support environmental requirements is requiring the Water Authority to review its used of unconfined groundwater as a drought protection strategy and to review its policy of firm licence allocations to private users.

Q2 How have groundwater demands changed since 1989 both spatially and in terms of volume? What changes have been put in place RE: pumping?

These conflicting requirements of the groundwater resource increase the need for management of not only the water resources but of the land uses in the surrounding areas.

Q3 Has there been published documentation of changing land uses aimed at reducing impacts on groundwater?

…It appears the main reason for Banksia deaths were the sudden drop in water table level occurring soon after the commissioning wells….5 vegetation transects have recently been established on the Jandakot Mound to provide a baseline monitoring as part of the Environmental Impact Assessment for the Jandakot

> Groundwater Scheme Stage 2. Developing environmental criteria for valued areas of the environment including Banksia woodlands in Jandakot areas is a key component of the early stages of this environmental assessment.

Q4 Has research been conducted since 1989 documenting tree death in BW in relation to reducing groundwater availability (acute or chronic)?

Essay Question: How has our understanding of groundwater resource management within banksia woodlands changed since 1989? What major shifts in understanding have occurred and what major knowledge gaps remain?

Fire

> …have constructed fuel accumulation curves on the basis of extensive sampling on the Banksia woodlands near Wanneroo area…The curves, together with information on fire behaviour in these fuel types, suggest that repeated fuel reduction burning on broad acre basis would be of limited practical value…

Q1. Has repeated fuel reduction burning been evaluated for its efficacy in BW?

> The plant communities that now make up Banksia woodlands of the SCP contain very few long-lived perennial plant species that regenerate only from seed following 100% crown scorch.

Q2. Has the proportion of non-resprouting species in BW been documented?

> Only 6 of 13 species identified are in the most venerable category, being fire sensitive and having seed storage on the plant in bradyspores. This feature, together with the general observation that significant areas of Banksia woodlands apparently are in good condition still exist, indicate that the present- day plant communities comprising these woodlands must be tolerant to a wide range of fire regimes.

Q3. Has the tolerance of Banksia woodland to varying fire season, frequency, and intensity been evaluated since 1989?

> Generalisations about the impact of recurrent fire on the Banksia woodlands communities could be developed by collecting data on the time it takes for species from germination of seed to production of sufficient, viable seed to permit population replacement in the event of a further fire.

Q4. Has the tolerance of species in Banksia woodland been evaluated from a demographic perspective?

In the absence of detailed data, a rough guide of 2.5 to 3 times the time from germination to first flowering can be applied as a minimum between-fire interval if local extinctions are to be avoided.

Q5. Has the presumption of 2.5–3× flowering time been evaluated as a guide to minimum fire interval?

There are no data from these Banksia woodlands that indicate best season of burn for conservation but the study of *Banksia burdetti* at Watheroo National Park may be indicative. The study shows best seed release, germination and establishment after a hot fire in late summer–autumn. In respect to fire alone, the present-day plant and animal communities of the Banksia woodlands appear to be relatively robust.

Q6. Has season of burn been evaluated for Banksia woodlands?

Season of burn also has some bearing on fire intensity. Hotter fires are expected to kill more stems.

Q7. Has stem mortality been measured across a range of fire intensities in Banksia woodlands?

They contain few plant species that we could describe as vulnerable.

Q8. Has vulnerability to fire been characterised in Banksia woodlands?

It would be a really simple matter to develop fire management guidelines for these Banksia woodlands stating with the gathering of data on rates of regeneration of vulnerable plant species provided that we are prepared to accent the rule of thumb suggested here as the basis for those guidelines.

Q9. Have biodiversity-based burning plans been developed for Banksia woodland since 1989?

However, such an approach does not take into account the important interaction that we have identified here – that is the interaction between fire (or any other form of disturbance) and weed invasion. ('A conspicuous, complicating factor in the process of developing management guidelines is the likely invasion of burnt areas by weeds'). Fire has the potential to promote weed invasion which in turns leads to increases in flammability of the vegetation and the loss of nature conservation values. The fire-weed interaction is probably the most important issue to be taken into account on the development of any fire management strategies in the future.

Q10. Has the role of weeds in fire and fire management been characterised in Banksia woodlands?

Essay question. Describe advances in the knowledge of fire ecology of BW since 1989. What major uncertainties and knowledge gaps should be prioritised for research?

Terrestrial Invertebrates

> The fragmentation of the remaining woodlands by agriculture, road, urbanisation, and other lands uses is also a reason for concern. **However, unlike vertebrates, the conservation of relict areas of only a few hectares in size can be adequate to preserve almost all the invertebrate species of the community.** This, of course, assumes that the relict areas are managed in an appropriate way to maintain the environmental quality.

Q1. Does this statement hold true today, and has this statement been supported by research since 1989?

> There are few published accounts of the composition of individual invertebrate faunas in Banksia woodlands and nearby plant formations. (earthworms, ants).

Q2. Have there been studies of the composition of individual invertebrate fauna in Banksia woodlands since 1983?

> A number of studies have looked at the effect of habitat modification on selected invertebrate groups in what was formerly Banksia woodland. (species richness and pop density of soil microarthropods in 3 pine sites v. native woodland; ant fauna in 33 Perth gardens of which were situated in former woodlands; spider fauna in Kings Park with veldt grass invasion).

Q3. Has the effect of habitat modification on invertebrate groups been researched in what was formerly Banksia woodlands since 1989?

> A widespread influence on Banksia woodlands is burning so, not surprisingly, a number of studies have been performed on this phenomenon.

Q4. Have there been studies on the effect of fire on invertebrates since 1986?

> …study of the herpetological community of a Banksia woodland near Jandakot included an analysis of the diets of the various frogs and lizards.

Q5. Have there been studies on herpetological communities since 1979?

> The remaining Banksia woodlands are subject to a number of pressures. One is the invasion of woodland by veldt grass (*Ehrharta calycina*) …the spider fauna of King's Park and found that areas colonised by veldt grass harboured a spider fauna of low abundance and species richness. Presumably this is either because the veldt grass occupies the feeding space which is normally used by spiders or because it harbours less invertebrate prey items than the native vegetation.

Q6. Has there been studies on the impact of weed invasion on the terrestrial invertebrate fauna in Banksia woodlands since 1989?

> This review of the literature on terrestrial invertebrates has indicated how community composition can be altered by urbanisation, veldt grass invasion, the frequency and season of burning, as well as by clearing of the original woodland for some new land use. Therefore, if the conservation of invertebrates in Banksia woodlands is to be catered for, we need to consider if, when, and how frequently to burn such areas and we also need more information on the impact of weed invasion on the terrestrial invertebrate fauna. The fragmentation of the remaining woodlands by agriculture, roads, urbanisation and other land uses is also reason for concern.

Essay question. Describe advances in the knowledge of terrestrial invertebrate fauna of BW since 1989. What major uncertainties and knowledge gaps should be prioritised for research?

Vertebrates

> Banksia woodlands with their floristic richness, extensive flowering regimes, juxtaposition to other vegetation formations and extensive distribution on deep near-coastal sands are important for vertebrates. However, no vertebrate species is unique to banksia woodlands.

Q1. Does this statement hold true today, and has this statement been supported by research since 1989?

> Nine species may occur in Banksia woodlands. Most require water for larval development, consequently their entire life cycle cannot occur in Banksia woodlands; they are captured throughout the year after rain, but activity peaks in spring.

Q2. Have we increased our knowledge since 1989 of amphibians within Banksia woodlands?

> Studies of major geographic regions list that few, if any, reptile species have disappeared since European settlement.

Q3. Does this statement hold true today, and has this statement been supported by research since 1989?

The goannas *Varanus gouldii*, *V. rosenbergi* and *V. tristis* have become less numerous in Banksia woodlands due to habitat fragmentation and changing resource availability and there are no recent records of the carpet python *Morelia spilota*.

Two arboreal geckos, *Diplodactylus spinrgerus* and *Phyllodactylus marmoratus* are widespread and abundant, while the terrestrial, *D. polyophthalmus* and *D. omatus* are infrequently recorded. Agamids whose distributions encompass the extent of Banksia woodlands (*Pogona minor* and *Tympanocryptis adelaidensis*) are recorded on most sites, however, Banksia woodlands occur outside the main geographical distribution of most geckos and agamids.

Skinks are the richest family with 10 genera. The arboreal *Cryptoblepharus plagiocephalus* is widespread and common as are the terrestrial *Ctenotus fallens, C. lesueurii, Lerista elegans, Menetia greyi, Morethia obscura, M. lineoocellata, Tiliqua rugosa* and the fossorial *Lerista praepedita*. Several species in Banksia woodlands are near the limits of their range; these include *Ctenotus impar, C. schomburgkii, Egernia multiscutata, Lerista christinae,* and the rare *L. lineata*. It is probable that *Leiolopismo trilineatum. Egernia napoleonis* and *Omolepida branchialis* only occupy those woodlands adjacent to denser and moister vegetation types. *Hemiergis quadrilineata* and *Lerista lineopunctulata*, appear to be more common in woodlands occupying the coastal Spearwood Dune systems.

The blind snake *Ramphotyphlops australis* occurs in many Banksia woodlands and elapid snakes are recorded in most Banksia woodlands that have been sampled for more than 1 year. …recorded *Demansia reticulata, Notechis curtus, Rhinoplocephalus gouldii, Vermicella calonotus* and *V. bertholdi* at Mooliabeenie while at Bold Park (How & Dell unpubl) *V. bertholdi, V. calonotus, V. bimaculata. V. Jasciolata* occur sympatrically with *Pseudonaja alfinis*. The diversity of *Vermicella* can be explained by the abundance of fossorial and epigaic lizards which constitute their principal food source. The composition of the reptile assemblage reflects the sandy substrates of Banksia woodlands. Genera that are fossorial (e.g. *Lerista* and *Vermicella*) are well represented, while those that use burrows (e.g. *Diplodactylus* and *Egernia*) are poorly represented. Litter inhabiting genera (*Hemiergis, Morethia, Menetia*) occur in most habitats, although this is correlated with time since fire.

Q4. Are there more recent records of Banksia woodland reptiles?

In some isolated patches of Banksia woodlands extensive weed invasion covers the ground between shrubs. This has severely impinged on reptiles which forage in the open between bushes e.g. *Tympanocryptis adelaidensis* and *Ctenotus lesueurii*. Dense rooting patterns may also inhibit the movement of near-surface fossorial species.

Q5. Do we have published accounts on the impact of weed invasion on reptiles?

> …a list of birds of the Swan Coastal Plain and commented on status changes since European settlement. Unlike birds of other associations, such as Tuart forests and woodlands fringing lakes, Banksia woodland birds have not declined to the same extent

Q6. Does this statement hold true today, and has this statement been supported by research since 1989?

> Land clearing and fire have both affected the composition of vertebrate species occupying Banksia woodlands. The frequency and time since burning can be shown to have a pronounced effect on species composition; species dependent on vegetation that has been unburnt for long periods have been greatly reduced since European settlement

Q7. Do we have more recent data on the impact of fire on vertebrates?

> Range reductions of mammals since European settlement have been attributed to several causes, principally habitat alteration, changed fire frequency and predation. Consequently, the fauna of Banksia woodlands has probably changed substantially since European settlement

Q8. Do we have published records of the historic and current distribution of Banksia woodland mammals?

> Of the small native semi-arboreal mammals, the honey possum *Tarsipes rostratus* occupies many Banksia woodlands, while the western pigmy possum *Cercartetus concinnus* may also occur in woodlands that have remained unburnt for a long period. Small native terrestrial mammals are never abundant in this habitat, although 3 species of dunnart, *Sminthopsis dolichura*, *S. griseouenter*, *S. granulipes* and the ashy-grey mouse, *Pseudomys albocinereus*, have been recorded in the more northern woodlands.

Q9. Does this information hold true today, and has this statement been supported by research since 1989?

> Little is known of the bats occupying Banksia woodlands as no systematic surveys have been done

Q10. Do we have data on bat species occupying Banksia woodlands? Have systematic surveys been done since 1989?

Essay question. Describe advances in the knowledge of terrestrial vertebrate fauna of BW since 1989. What major uncertainties and knowledge gaps should be prioritised for research?

Urban development

> …increases in population, affluence and leisure time are likely to cause growth in demand for other regional-scale open space (as distinct from local open space) and for recreational facilities in general.

Q1. Since 1989, has there been an increase in demand for regional-scale open space (as distinct from local open space) for recreation?

> Cultural influences, including greater awareness of the natural environment and health-based life-styles, are likely to result in greater political support for such facilities.

Q2. Has cultural awareness of the natural environment and health-based lifestyles resulted in greater political support for recreational facilities increased in 30 years?

> The key issues for the future are the need for acquisition of more open space the better co-ordination of the planning and development of the regional open space system, and the introduction of a metropolitan system of management and administration. Funds will be needed for acquisition, development and maintenance of the metropolitan park system. Some revenue may be obtained from user charges in future.

Q3. Does this information hold true today, and has this statement been supported by research since 1989?

> In broader terms, the Perth coastal plain is a delicately balanced environment, far less able to withstand the impact of long-term urbanisation than the sites of most other Australian cities. This fact has been recognised in the formulation of the Corridor Plan and by Stephenson and Hepburn in their 1955 Plan on which the Metropolitan Region Scheme was based. It is through the recognition of environmental constraints that the sandy coastal plain can be separated into patterns of urban and non-urban land, and that a continuously sprawling metropolitan area may be avoided in the long term.

Q4. Since 1989, has there been any specific metropolitan regional scheme that have preserved Banksia woodlands in light of development?

> The following gives a broad basis for understanding the growth rates applicable to the Perth region.
>
> • The region's population will continue to grow at a rate of between 1.5 and 2% or some 30 000 people per year. This means an increase in excess of 800 000 people by the year 2021.
>
> • Residential development is the largest consumer of land, requiring some 12 000 lots per annum or 1500 ha.
>
> • There will be a need for up to 50 000 extra ha of land by the year 2021.

• 97% of the metropolitan population lives in the urban zone.

• There is expected to be a decline in the average number of persons per household from 2.84 in 1986 to 2.51 in 2001 and 2.38 in 2021.

• The North west corridor is experiencing the highest rate of lot consumption comprising nearly 25% of the metropolitan total.

• Increased population and urban expansion will place further pressure on the finely balanced and limited capacity of the metropolitan environment.

Q5. Were these predictions accurate? Does this information hold true today, and has this statement been supported by research since 1989?

Essay question. How has our understanding of the political (e.g. conservation legislation) and physical (e.g. infrastructure and city planning) development of Perth been informed by sociocultural research in the last 30 years? What have been the largest changes in our understanding since 1989?

Mining

The major use of sand in Perth is for land fill – freeway construction, bridges, housing pads and rubbish disposal by sanitary land fill all require sand filling.

Q1. Have quantity and type of demands for mineral resources mined from banksia woodlands changed since 1989? For example, are sands used locally, or is a higher percentage of extracted minerals shipped internationally?

Deposits of sand and limestone have always been thought to be abundant and freely available in the metropolitan area.

Q2. Are sand and limestone resources still considered abundant and freely available?

In 1989 there were 49 actively worked sand pits in the metropolitan area. These were worked by a total of 32 operators, many of whom operated pits on a full-time basis.

Q3. Has mining activity (number of pits in operation, number of operators, total mineral resources extracted from the region) changed since 1989?

In all cases the proponent is required to prepare a mine plan, operational guidelines, final landform and a rehabilitation program. The final landform and method of rehabilitation depends very much on the final use envisioned for the site.

Q4. Have methods of and requirements for rehabilitation changed since 1989?

The environmental aspects of these types of extractive industries are presently under review by a Government Committee into Conservation and Rehabilitation in the Mining Industry. This committee will formulate recommendations aimed at ensuring that basic raw materials supplies are always available while ensuring that final landform objectives are met.

Q5. Have final landform objectives been met following recommendations by the Government Committee into Conservation and Rehabilitation in the Mining Industry?

Diseases

Diseases of Banksia woodlands have been a neglected area of plant pathology. Of the ~250 000 publications on plant diseases abstracted in the Review of Pant Pathology since 1922, only ~30 refer to diseases of Banksia. Only 6% of these 30 publications refer to diseases of Banksia woodlands compared with 55% of forest and 39% for Banksia species used in floriculture.

Observations on the impact and spread of *Phytophthora cinnamomi* …are the only published account of disease on Banksia woodlands of the Bassendean Dune system. Nevertheless, despite the lack of published information, disease is an important factor affecting the ecology of Banksia communities.

… initial monitoring of sites from Ravenswood to Moore River, little research has been done on the occurrence of *P. cinnamomi* in Banksia woodlands on the coastal plain. Investigations are now in progress to determine the factors influencing disease development, impact and methods of control of *P. cinnamomi* and other *Phytophthora* species in Banksia woodlands.

Long term effects of *Phytophthora* spp. on diversity clearly needs to be quantified.

Q1. Do we know the factors influencing disease development and impact of Phytophthora species in Banksia woodlands?

Q2. Have the long-term effects of Phytophthora spp. on diversity been quantified?

Q3. Have we identified effective methods of control for Phytophthora in Banksia woodlands?

Q4. Have other species of Phytophthora been identified that have as large an impact on Banksia woodlands as *P. cinnamomi*?

Eradication of *P. cinnamomi* from spot infections by Ridomil and fumigation with formaldehyde is being assessed in Jandakot sands of the Bassendean Dunes at Gnangara with promising results. In addition, the systematic fungicide phosphorous acid has arrested lesion extension in B. grandis. Evaluation of these control methods is continuing.

Q5. Is treatment of *P. cinnamomi* infected areas by Ridomil and fumigation with formaldehyde effective for eradication?

Q6. Is the systematic fungicide phosphorous acid effective in alleviating symptoms of *P. cinnamomi* in Banksia woodland species?

Q7. Have other methods of *P. cinnamomi* eradication been developed?

Systematic surveys of Banksia woodlands in southwestern Australia are needed to address the lack of information on diseases of Banksia. Information is lacking on the specific requirements for pathogen survival, sporulation and spread as well as host infection and susceptibility in sandy soils. Such information is essential for the development of hazard and risk systems to minimise introduction and spread of Phytophthora species.

Q8. Do we know the conditions under which pathogens in Banksia woodlands survive, sporulate and spread?

Knowledge of the diversity of Banksia woodlands, similar to the site-vegetation classification of Havel in 1979, is needed in the development and application of hazard and risk systems.

Q9. Is there detailed knowledge of Banksia woodland diversity for informing hazard and risk systems (e.g. in relation to pathogens and diseases)?

An understanding of the low incidence of *P. cinnamomi* on Spearwood Dunes may provide clues for the control of the disease. Control strategies must be developed and applied to prevent spread and intensification of disease favoured by disturbance caused by increasing urbanisation and sand mining. An understanding of the low incidence of *P. cinnamomi* on Spearwood Dunes may provide clues for the control of the disease. Control strategies must be developed and applied to prevent spread and intensification of disease favoured by disturbance caused by increasing urbanisation and sand mining.

Q10. Have we identified why there is lower incidence of *Phytophthora* spp. on Spearwood dunes?

Q11. Have control strategies been developed to prevent the spread and infestation of disease resulting from increasing urbanisation and sand mining?

If strategies for controlling the spread of disease due to urbanisation and sand mining have been developed, then have they been effective?

Essay question. How has our understanding of diseases in banksia woodland been informed by research in the last 30 years? What have been the largest changes in our understanding since 1989?

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