Clarification of Definitions in the *Water Act 2007*

The Murray~Darling Freshwater Research Centre

Prepared by: Helen Gigney, Ben Gawne, Christine Reid-Piko, Sally Hladyz, Giri Kattel, Michelle Kavanagh, Shaun Meredith and Rochelle Petrie

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Clarification of Definitions in the *Water Act 2007*

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Murray-Darling Basin Authority
51 Allara Street Canberra ACT
Ph: 02 6279 0100; **Fax**: 02 6248 8053

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For further information contact:

Ben Gawne
The Murray-Darling Freshwater Research Centre
PO Box 991
Wodonga Vic 3689
Ph: 02 6024 9650
Fax: 02 6059 7531
Web: www.mdfrc.org.au
Enquiries: info@mdfrc.org.au
Email: B.Gawne@latrobe.edu.au

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1.0 Introduction

The Murray-Darling Basin Authority (MDBA) is responsible for the overall preparation, implementation and enforcement of the Basin Plan. The Basin Plan is a strategic plan for the integrated and sustainable management of water resources in the Murray–Darling Basin.

The *Water Act 2007* specifies some content of the Basin Plan, including:

- limits on the amount of water (both surface water and groundwater) that can be taken from Basin water resources on a sustainable basis;
- identification of risks to Basin water resources, such as climate change, and strategies to manage those risks;
- requirements that state water resource plans will need to comply with if they are to be accredited under this Act;
- an environmental watering plan to optimise environmental outcomes for the Basin;
- a water quality and salinity management plan; and
- rules about trading of water rights in relation to Basin water resources (MDBA 2010).

The documentation seeks to provide a review of literature regarding the terms used in the *Water Act 2007*, and provide further clarification and recommendations for undefined terms.

1.1 *Water Act 2007* Context

The objects of the *Water Act 2007* (Section 3) include:

a) to enable the Commonwealth, in conjunction with the Basin States, to manage the Basin water resources in the national interest; and

b) to give effect to relevant international agreements (to the extent to which those agreements are relevant to the use and management of the Basin water resources) and, in particular, to provide for special measures, in accordance with those agreements, to address the threats to the Basin water resources; and

c) in giving effect to those agreements, to promote the use and management of the Basin water resources in a way that optimises economic, social and environmental outcomes; and

d) without limiting paragraph b) or c):

   i. to ensure the return to environmentally sustainable levels of extraction for water resources that are overallocated or overused; and

   ii. to protect, restore and provide for the ecological values and ecosystem services of the Murray-Darling Basin (taking into account, in particular, the impact that the taking of water has on the watercourses, lakes, wetlands, ground water and water-dependent ecosystems that are part of the Basin water resources and on associated biodiversity); and (Refer *Water Act 2007* from remaining Objects Section 3).

The *Water Act 2007* states that the long-term average sustainable diversion limit (SDL) “must reflect an environmentally sustainable level of take” and defines environmentally sustainable level of take as the level at which water can be taken from that water resource which, if exceeded, would compromise *key environmental assets* of the water resource; *key ecosystem functions* of the water resource; the *productive base* of the water resource; or *key environmental outcomes* for the water resource.

Although the Water Act clarifies some of the terms relating to environmental assets (water-dependent ecosystems; ecosystem services; and sites with ecological significance) and environmental outcomes (ecosystem function; biodiversity; water quality; and water resource health) the Act will be difficult to implement or administer for those terms which have not been defined.

This report provides a review and recommendations of key terms used in the development of the Basin Plan. Many of the terms are already defined within the *Water Act 2007*, however, the current interpretation and usage of terms are explored. It is advantageous to recognise that with future development in scientific knowledge and understanding, that the ability to further define these terms will also be enhanced.

2.0 Terms

2.1 Environmental Assets

Review of definitions

The *Water Act 2007* defines environmental assets as including:

(a) Water-dependent ecosystems; and

(b) Ecosystem services; and

(c) Sites with ecological significance.

The term asset implies an attributed value, whether that asset is tangible (a physical resource) or intangible (e.g. aesthetics). Therefore the definition of environmental asset is mostly utilised in economic terms. Other similar terms include ecological assets and natural assets.

Assets according to the OECD (2007) are entities functioning as stores of value and over which ownership rights are enforced by institutional units, individually or collectively, and from which economic benefits may be derived by their owners by holding them, or using them, over a period of time.

Environmental assets are defined by the OECD (2007) as “naturally occurring entities that provide environmental functions or services and include assets ‘which have no economic values, but bring indirect uses benefits, options and bequest benefits or simply existence benefits which cannot be translated into a present day monetary value”. The OECD (2007) also goes further in defining natural assets as “assets of the natural environment” which “consist of biological assets (produced or wild), land and water areas with their ecosystems, subsoil assets and air”.

There has been much written on methods and the philosophy of assigning value to environmental assets. For example, to Farber et al. (2002) ecosystem valuation represents the process of expressing a value for ecosystem goods or services (i.e. biodiversity, flood protection, recreational opportunity), thereby providing the opportunity for scientific observation and measurement. However, this only takes into account the instrumental value of the environmental assets and the distinction between intrinsic and instrumental value is an important one (Goulder & Kennedy 1997). It can be argued that ecosystems or species have intrinsic rights to a healthy, sustaining condition irrespective of human satisfaction (Farber et al. 2002).

When using the term environmental assets, we are classifying environmental entities in terms of their value to us. These entities will always need to be specified if we are seeking to protect them. Using examples and identifying environmental assets removes some of the ambiguity that may arise from the use of the classification term. In the *Water Act 2007* key environmental assets of the water resource are specifically included: water-dependent ecosystems; ecosystem services and sites with ecological significance, indicating that from the Water Act's perspective these three entities have value to the people of Australia. By the use of the term "includes", we can assume that in defining 'environmental assets' we are not limited to the three dot points, and that there is the potential for definition of assets to be more inclusive.

Recommendation

It is recommended that future review of the *Water Act 2007* consider a definition for environmental assets that incorporates not only the Water Act but also the OECD definitions for assets, environmental assets and natural assets. Specifically, *environmental assets* are sites consisting of biological assets (produced or wild), which are land and water areas with ecosystems that provide environmental functions or services, which may bring indirect or direct uses, benefits, options and bequest benefits or simply existence benefits which cannot necessarily be translated into a present day monetary value.

2.2 Water Dependent Ecosystems

Review of definitions

The concept of an 'Ecosystem' was expressed as early as 1916 by well-known German limnologist August Thienemann, however the term "Ecosystem" was first used by British Plant Ecologist Arthur Tansley, who in 1935 called a unit composed of living and non-living parts of nature an "ecosystem" (Jax 1998). The ecosystem is a familiar and fundamental ecological concept and is quite complex (Pickett & Cadenasso 2002). Likens (1992) defined an ecosystem as 'a spatially explicit unit of the Earth that includes all of the organisms, along with all components of the abiotic environment within its boundaries'. The term "Water Dependent Ecosystems" is used throughout the literature however it is mostly referring to "Groundwater Dependent Ecosystems".

The term ‘Water Dependent Ecosystems’ is defined in the Australian *Water Act 2007* as:

> “a surface water ecosystem or a ground water ecosystem, and its natural components and processes, that depends on periodic or sustained inundation, waterlogging or significant inputs of water for its ecological integrity and includes an ecosystem associated with:
>
> (a) a wetland; or
>
> (b) a stream and its floodplain; or
>
> (c) a lake or a body of water (whether fresh or saline); or
>
> (d) a salt marsh; or
>
> (e) an estuary; or
>
> (f) a karst system; or
>
> (g) a ground water system;
>
> and a reference to a water-dependent ecosystem includes a reference to the biodiversity of the ecosystem.”

A similar definition is used by the Agriculture and Resource Management Council of Australia and New Zealand (ARMCANZ) and Australian and New Zealand Environment and Conservation Council (ANZECC) in 1996 when developing a set of National Principles for the Provision of Water for Ecosystems:

> “Water Dependent Ecosystems are those parts of the environment, the species composition and natural ecological processes of which are determined by the permanent or temporary presence of flowing or standing water. The instream areas of rivers, riparian vegetation, springs, wetlands, floodplains and estuaries are all water dependent ecosystems.”

Two large monitoring frameworks completed in Australia used the term and their definitions are very similar to that used in the *Water Act 2007*. In their Best Practice Framework for the Monitoring and Evaluation of Water Dependent Ecosystems, Wilkinson et al. (2007) defined the term as:

> “Those parts of the environment, the species composition and natural ecological processes, which are determined by the permanent or temporary presence of flowing or standing water, above or below ground. The in-stream areas of rivers, riparian vegetation, springs, wetlands, floodplains, estuaries and lakes are all water-dependent ecosystems.”

In the Tasmanian Conservation of Freshwater Ecosystems Values (CFEV) Assessment Framework (DPIW 2008), ‘Freshwater Dependent Ecosystems’ is defined as:

> “…those systems that depend on periodic or sustained inundation, or on significant inputs of freshwater, for their ecological integrity. Freshwater Dependent Ecosystems include the following themes: rivers, wetlands, lakes and other waterbodies, saltmarshes, estuaries, karst and other groundwater dependent ecosystems.”

The National Water Commission has a project which was due to be completed in September 2008, which is designed to progress understanding of high priority issues relating to aquatic ecosystems in Australia. They define 'Water Dependent Ecosystems' as including:

> "wetlands, floodplains, riparian areas, estuaries and springs. They provide many important services including provision of good quality water for irrigation and domestic use, habitat for fish and other aquatic fauna and flora, removal of wastes and contaminants, and aesthetic, cultural and recreational benefits."

The Objects of the *Water Act 2007* include giving effect to relevant international agreements –e.g. Biodiversity/Ramsar (to the extent to which those agreements are relevant to the use and management of the Basin water resources), to protect, restore and provide for the ecological values and ecosystem services of the Murray-Darling Basin and to improve water security for all uses of Basin water resources.

The Basin Plan will be complemented by water resource plans prepared by Basin states and provided to the Commonwealth Minister for accreditation. The term 'Water Dependent Ecosystems', or similarly worded terms, is not used specifically within Acts or Plans, but can be found in policy documents or other interpretation of law documents. Even then, this term is not always fully defined.

The two key pieces of legislation for the management of water in NSW are the *Water Management Act 2000* and the *Water Act 1912*, neither contain the term "Water Dependent Ecosystems". The NSW *Water Act 1912* only refers to water related ecosystems in the context of the need to maintain natural flood regimes in "wetlands and related ecosystems and the preservation of any habitat, animals (including fish) or plants that benefit from periodic flooding", however does not specifically define the term 'related ecosystems'. This NSW *Water Act 1912* is being progressively phased out and replaced by the *Water Management Act 2000* but some provisions are still in force (Bureau of Rural Sciences 2006).

The NSW *Water Management Act 2000* refers to the protection, enhancement and restoration of water sources and their dependent or associated ecosystems, but again does not define the term specifically. Instead, it focuses on the water source and throughout the text refers to certain types of ecosystems and later defines each of these in the dictionary e.g.

> "**lake** includes:
>
> (a) a wetland, a lagoon, a saltmarsh and any collection of still water, whether perennial or intermittent and whether natural or artificial, and
>
> (b) any water declared by the regulations to be a lake, whether or not it also forms part of a river or estuary, but does not include any water declared by the regulations not to be a lake."

However, importantly the NSW State Groundwater Dependent Ecosystems Policy (2002) does refer to “water dependent ecosystems”. This policy was developed under the *Water Management Act 2000*. This policy agrees with the ARMCANZ and ANZECC (1996) definition of water dependent ecosystems, being the ‘species composition and their natural ecological processes determined by groundwater” This document also provides details of this term’s interpretation, the ecological processes involved, and the associated policy frameworks and management principles.

In Victoria, the way water entitlements are issued and allocated is governed by the *Water Act 1989* and environmental entitlements have only recently been included. The introduction of the *Water (Resource Management) Act 2005* amended the *Water Act 1989*, to create the legal foundation for water to be set aside for environmental entitlements (Our Water, Our Future 2009).

Neither of these pieces of legislation use the term ‘Water Dependent Ecosystems’, however, the *Victorian Water Act 1989* constantly refers to ‘Water Systems” but does not define the term; instead it refers to ‘Waterways’ within the water system and defines it as:

> “waterway means —
>
> (a) a river, creek, stream or watercourse; or
>
> (b) a natural channel in which water regularly flows, whether or not the flow is continuous; or
>
> (c) a channel formed wholly or partly by the alteration or relocation of a waterway as described in paragraph (a) or (b); or
>
> (d) a lake, lagoon, swamp or marsh, being—
>
> (i) a natural collection of water (other than water collected and contained in a private dam or a natural depression on private land) into or through or out of which a current that forms the whole or part of the flow of a river, creek, stream or watercourse passes, whether or not the flow is continuous; or
>
> (ii) a collection of water (other than water collected and contained in a private dam or a natural depression on private land) that the Governor in Council declares under Section 4(1) to be a lake, lagoon, swamp or marsh; or
>
> (e) land on which, as a result of works constructed on a waterway as described in paragraph (a), (b) or (c), water collects regularly, whether or not the collection is continuous; or
>
> (f) land which is regularly covered by water from a waterway as described in paragraph (a), (b), (c), (d) or (e) but does not include any artificial channel or work which diverts water away from such a waterway; or
>
> (g) if any land described in paragraph (f) forms part of a slope rising from the waterway to a definite lip, the land up to that lip.”

The *Water Act 1989* also refers to improving the environmental values and health of water ecosystems in the Environmental Water Reserve Objective, but does not go further to define 'water ecosystems':

> "The environmental water reserve objective is the objective that the environmental water reserve be maintained so as to preserve the environmental values and health of water ecosystems, including their biodiversity, ecological functioning and quality of water and the other uses that depend on environmental condition."

The Environmental Water Reserve Objective is also found in the *Water (Resource Management) Act 2005*.

South Australian water policy includes two pieces of legislation; the *Water Resources Act 1997* and the *Natural Resources Management Act 2004*. The *Water Resources Act 1997* was repealed by the *Natural Resources Management Act 2004* in July 2005 (Water Resources Act 1997).

The *Water Resources Act 1997* does not use the term 'Water Dependent Ecosystems, nor does it use the term 'Ecosystem'. 'Ecosystem' is used however in the *Natural Resources Management Act 2004* in reference to the effect of water use on ecosystems that depend on water:

> "When making a decision under this Chapter that is based wholly or partly on an assessment of the quantity of water available or the period or periods during which water is available from a water resource, the Minister or other person or body making that decision must take into account the needs of the ecosystems that depend on that resource for water"

It also puts it in the context of creating a water allocation plan:

> "A water allocation plan must—
>
> (a) include—
>
> (i) an assessment of the quantity and quality of water needed by the ecosystems that depend on the water resource and the times at which, or the periods during which, those ecosystems will need that water"

Through a series of definitions, it is possible to determine what is meant by "ecosystems that depend on water". It goes on to define terms related to water resources:

> "Water resource means a watercourse or lake, surface water, underground water, stormwater (to the extent that it is not within a preceding item) and effluent".

Further defining water resource:

> "A reference to a water resource includes all aspects of a water resource, including the water, organisms and other components and ecosystems that contribute to the physical state and environmental, social and economic value of a water resource".

And finally defining the term ‘Watercourse’:

> “watercourse means a river, creek or other natural watercourse (whether modified or not) in which water is contained or flows whether permanently or from time to time and includes—
>
> (a) a dam or reservoir that collects water flowing in a watercourse;
>
> (b) a lake through which water flows;
>
> (c) a channel (but not a channel declared by regulation to be excluded from the ambit of this definition) into which the water of a watercourse has been diverted;
>
> (d) part of a watercourse;
>
> (e) an estuary through which water flows;
>
> (f) any other natural resource, or class of natural resource, designated as a watercourse for the purposes of this Act by an NRM plan.”

In Queensland, the *Water Act 2000* deals with water and does not separate surface water from groundwater. The Act also allows for specifying groundwater and base flow water as one resource (Bureau of Rural Sciences 2006).

Under the *Water Act 2000*, one of the Commission’s guiding principles is to manage water from its source to its end-use, to ensure the health of catchments, aquifers and their ecosystems. It defines ecosystem as:

> “Ecosystem means a dynamic combination of plant, animal and micro-organism species and communities and their non-living environment and the ecological processes between them interacting as a functional unit.”

The *Water Resources Act 1998* provides for the sustainable management of surface water and groundwater within the Australian Capital Territory (ACT). The Act requires that the Water Resources Management Plan and Environmental Flow Guidelines be developed to meet the environmental needs of the waterways and aquifers of the ACT, the allocation requirements for supply and to ensure protection of aquatic ecosystems through adequate environmental flows (Bureau of Rural Sciences 2006).

Within the Act, reference to ecosystems which depend on water resources is made; but not defined;

> “The objects of this Act are to ensure that the use and management of the water resources of the Territory sustain the physical, economic and social well being of the people of the Territory while protecting the ecosystems that depend on those resources.”

In summary, the definition found in the Australian *Water Act 2007* appears to be the most clearly defined term which also takes into consideration groundwater resources. This is also supported by national principles developed by ARMCANZ & ANZECC, and the Monitoring and Assessment Frameworks by DPIW (2008) and Wilkinson et al. (2007) who use a very similar definition to the *Water Act 2007*.

Most of the States within the Murray Darling Basin refer to each of their individual Water Policies and legislation to manage their water resources, all of which do not refer to 'Water Dependent Ecosystems' directly. In using terms such as 'waterways', 'water sources', 'ecosystems', there is a lack of clear definition as to what is classified as an ecosystem and which are dependent on water.

Recommendation

We recommend that the definition of a water dependent ecosystem used in the *Water Act 2007* is sufficiently suitable for the use within the current development of the Basin Plan.

Thus, specifically, a *water dependent ecosystem* is:

> "a surface water ecosystem or a ground water ecosystem, and its natural components and processes, that depends on periodic or sustained inundation, waterlogging or significant inputs of water for its ecological integrity and includes an ecosystem associated with:
>
> (a) a wetland; or
>
> (b) a stream and its floodplain; or
>
> (c) a lake or a body of water (whether fresh or saline); or
>
> (d) a salt marsh; or
>
> (e) an estuary; or
>
> (f) a karst system; or
>
> (g) a ground water system;
>
> and a reference to a water-dependent ecosystem includes a reference to the biodiversity of the ecosystem."

2.3 Ecosystem Services

Review of definitions

Despite a long history of use and development of the concept of ecosystem services[1], the literature does little to delineate exactly how ecosystem services should be defined (Boyd 2007; Barbier 2007; Fisher et al. 2009). More recently, Fisher et al. (2009) state that "while there have been several attempts to come up with a classification system for ecosystem services as of yet there has not been an agreed upon, meaningful and consistent definition for ecosystem services".

Three definitions that are commonly cited in the literature are:

- the conditions and processes through which natural ecosystems, and the species that make them up, sustain and fulfil human life (Daily 1997).
- the benefits human populations derive, directly or indirectly, from ecosystem functions (Costanza et al. 1997).

[1] See Daily (1997) for a more complete history of the concepts and terminology of ecosystem services

- the benefits people obtain from ecosystems. These include provisioning, regulating, and cultural services that directly affect people and the supporting services needed to maintain other services (MEA 2005).

These definitions are in broad agreement on the general concept of ecosystem services, however important differences can be found. Fisher et al. (2009) state that "in Daily (1997) ecosystem services are the "conditions and processes," as well as the "actual life-support functions". In Costanza et al. (1997) ecosystem services represent the goods and services derived from the functions utilized by humanity. In the MEA (2005) services are benefits, writ large".

Boyd and Banzhaf (2007) have another definition that is different to the ones above. They state that ecosystem services are not the benefits humans obtain from ecosystems, but rather the ecological components directly consumed or enjoyed to produce human well-being**.** Boyd and Banzhaf (2007) explicitly state:

> "Final ecosystem services are components of nature, directly enjoyed, consumed, or used to yield human well-being".

This definition acknowledges three features that services are directly enjoyed or used, that they are components, and that they are a quantity to be paired with a price (value).

(1) Therefore, "for Boyd and Banzhaf services are directly consumed components (structure included), meaning indirect processes and functions are not ecosystem services" (Fisher et al. 2009). An important difference is that Boyd and Banzhaf suggest that services and benefits are not the same. For example, "recreation, which is sometimes called an ecosystem service, can be a benefit of many inputs; often human, social and built capital inputs are necessary for recreation – the ecosystem services that may help produce a recreational benefit could be a number of ecological components including a forest, meadow, or a vista" (Fisher et al. 2009).

(2) They argue that "services are ecological things or characteristics, not functions or processes". They state "ecosystem components include resources such as surface water, oceans, vegetation types, and species populations". Whereas "ecosystem processes and functions are the biological, chemical, and physical interaction between ecosystem components. They state that functions and processes are not end-products but they are intermediate to the production of final ecosystem services".

(3) Another feature of their definition is that "it facilitates a distinction between the quantity (or physical measure) of ecosystem services and the value of those services".

Fisher et al. (2009) build on Boyd and Banzhaf (2007) definition with

> "Ecosystem services are the aspects of ecosystems utilized (actively or passively) to produce human well-being".

> The key points for their definition are that services must be ecological phenomena and that they do not have to be directly utilized. They argue "ecosystem services defined this way include ecosystem organization or structure as well as process and/or functions if they are consumed or utilized by humanity either directly or indirectly (whereas Boyd and Banzhaf see services as only the directly consumable end points)". "The functions or processes become services if there are humans that benefit from them. Without human beneficiaries they are not services" (Fisher et al. 2009).

There are three important characteristics of this definition (the following is extracted from Fisher and Turner 2008).

(1) *"Services are not benefits*. As deftly pointed out by Boyd and Banzhaf (2007) services and benefits are different. They argue that recreation is not a service provided by ecosystems, but rather a benefit of which ecosystems provide important inputs. A benefit is something that has an explicit impact on changes in human welfare, like more food, better hiking, less flooding. Wallace (2007) and the MEA (2005) consider services and benefits to be the same. For valuation, this is a problem and could lead to a problem of double counting. For example, adding values for primary production to values for recreational hiking would ''double count'' the value that say forests add to the hikers experience.

(2) *Ecosystem services are ecological in nature*. Again, similar to Boyd and Banzhaf (2007) in that aesthetic values, cultural contentment and recreation are not ecosystem services. They are benefits, and are not just a function of ecosystems, but include other inputs like human capital, built capital, etc. They are benefits also because they directly relate to changes in human welfare. For Wallace (2007) and the MEA (2005) these things are services. We differ here with Boyd and Banzhaf (2007) in that they see services as ecological components, i.e. things you can count like lakes, forests, fish populations. We think that functions and/or processes are ecosystem services as long as there are human beneficiaries. This is important because it connects human welfare to nature throughout an ecosystem, not just the endpoint. This is in line with Daily (1997) and the MEA (2005) which both make this connection explicit through the word service, not obscure it in ecological lexicon (i.e. processes, functions). For example, flood regulation is an ecosystem service here, as in Daily (1997) and the MEA (2005), but is considered a process in Boyd and Banzhaf (2007) and Wallace (2007).

(3) *Ecosystem services do not have to be utilized directly*. Here we take the opposite view of Boyd and Banzhaf (2007) and Wallace (2007) who argue that only the direct endpoints are ecosystem services. We argue that as long as human welfare is affected by ecological processes or functions (somewhere down the line) they are services. Carbon sequestration is an ecosystem service because there are net human benefits derived for this process in a world of changing climate. This is in line with much of Daily's original text (1997). Another example, pollination is an ecosystem service since it is an ecological phenomenon that we utilize (indirectly) to enjoy certain food benefits. For us it makes more sense to call pollination an ecosystem service than say the almonds are an ecosystem service as suggested by both Boyd and Banzhaf (2007) and Wallace (2007).

Kremen (2005) defines ecosystem services as:

> "the set of ecosystem functions that are useful to humans."

The United Nations definition is different in that it does not explicitly state that ecosystems services are of human benefit but of benefit to biodiversity.

> "Ecosystem services cover the provision of ecosystem inputs, the assimilative capacity of the environment and the provision of biodiversity".

Other more local definitions from the Government of South Australia define ecosystem services so that it includes the function of maintaining biodiversity.

> "All biological, physical or chemical processes that maintain ecosystems and biodiversity and provide inputs and waste treatment services that support human activities".

To summarise in the area of ecosystem services from the discussion above, it seems most definitions (except the UN) define ecosystem services as of some benefit to humans. The definition of ecosystem services is difficult as there is no agreed upon definition so this makes characterising ecosystems and services and using a meaningful and appropriate classification system difficult. In spite of this a recommendation for the Basin would be to use the Millennium Ecosystem Assessment (2005) definition which was created from a large number of expert scientists in the field and seems to be the most common one in use:

> "the benefits people obtain from ecosystems" (MEA, 2005).

This definition also includes a comprehensive classification scheme which defines four categories of ecosystem services which includes provisioning, regulating, and cultural services that directly affect people and the supporting services needed to maintain other services (Fig. 1; see below).

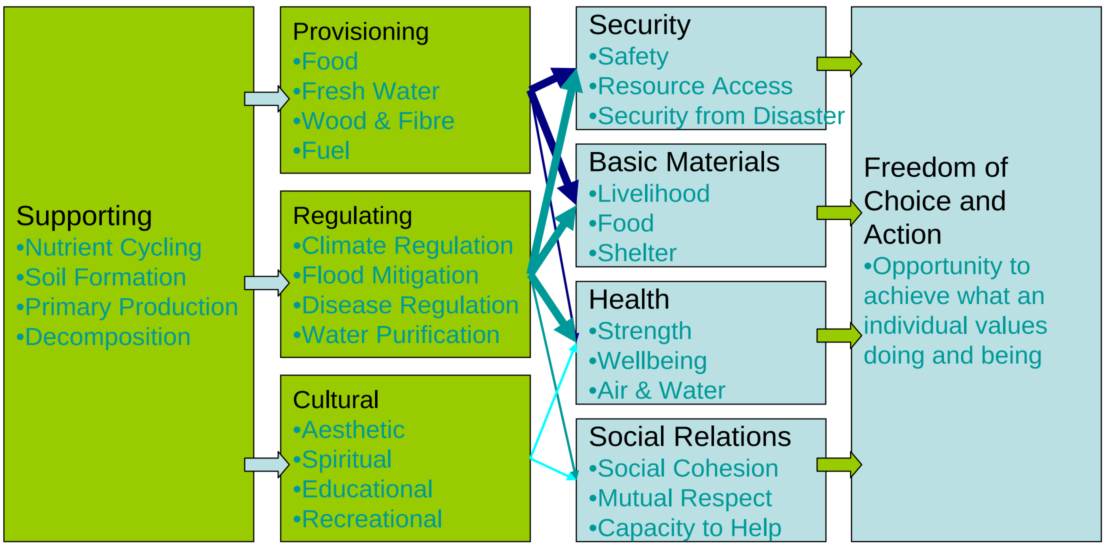

Figure 1. Diagrammatic representation of Ecosystem Services and their relationship to human wellbeing. Taken from MEA (2005).

“(i) Provisioning Services

These are the products obtained from ecosystems, including:

Food. This includes the vast range of food products derived from plants, animals, and microbes.

Fibre. Materials included here are wood, jute, cotton, hemp, silk, and wool.

Fuel. Wood, dung, and other biological materials serve as sources of energy.

Genetic resources. This includes the genes and genetic information used for animal and plant breeding and biotechnology.

Biochemicals, natural medicines, and pharmaceuticals. Many medicines, biocides, food additives such as alginates, and biological materials are derived from ecosystems.

Ornamental resources. Animal and plant products, such as skins, shells, and flowers, are used as ornaments, and whole plants are used for landscaping and ornaments.

Fresh water. People obtain fresh water from ecosystems and thus the supply of fresh water can be considered a provisioning service. Fresh water in rivers is also a source of energy. Because water is required for other life to exist, however, it could also be considered a supporting service.

(ii) Regulating Services

These are the benefits obtained from the regulation of ecosystem processes, including:

Air quality regulation. Ecosystems both contribute chemicals to and extract chemicals from the atmosphere, influencing many aspects of air quality.

Climate regulation. Ecosystems influence climate both locally and globally. At a local scale, for example, changes in land cover can affect both temperature and precipitation. At the global scale, ecosystems play an important role in climate by either sequestering or emitting greenhouse gases.

Water regulation. The timing and magnitude of runoff, flooding, and aquifer recharge can be strongly influenced by changes in land cover, including, in particular, alterations that change the water storage potential of the system, such as the conversion of wetlands or the replacement of forests with croplands or croplands with urban areas.

Erosion regulation. Vegetative cover plays an important role in soil retention and the prevention of landslides.

Water purification and waste treatment. Ecosystems can be a source of impurities (for instance, in fresh water) but also can help filter out and decompose organic wastes introduced into inland waters and coastal and marine ecosystems and can assimilate and detoxify compounds through soil and subsoil processes.

Disease regulation. Changes in ecosystems can directly change the abundance of human pathogens, such as cholera, and can alter the abundance of disease vectors, such as mosquitoes.

Pest regulation. Ecosystem changes affect the prevalence of crop and livestock pests and diseases.

Pollination. Ecosystem changes affect the distribution, abundance, and effectiveness of pollinators.

Natural hazard regulation. The presence of coastal ecosystems such as mangroves and coral reefs can reduce the damage caused by hurricanes or large waves.

(iii) Cultural Services

These are the nonmaterial benefits people obtain from ecosystems through spiritual enrichment, cognitive development, reflection, recreation, and aesthetic experiences, including:

Cultural diversity. The diversity of ecosystems is one factor influencing the diversity of cultures.

Spiritual and religious values. Many religions attach spiritual and religious values to ecosystems or their components.

Knowledge systems (traditional and formal). Ecosystems influence the types of knowledge systems developed by different cultures.

Educational values. Ecosystems and their components and processes provide the basis for both formal and informal education in many societies.

Inspiration. Ecosystems provide a rich source of inspiration for art, folklore, national symbols, architecture, and advertising.

Aesthetic values. Many people find beauty or aesthetic value in various aspects of ecosystems, as reflected in the support for parks, scenic drives, and the selection of housing locations.

Social relations. Ecosystems influence the types of social relations that are established in particular cultures. Fishing societies, for example, differ in many respects in their social relations from nomadic herding or agricultural societies.

Sense of place. Many people value the “sense of place” that is associated with recognized features of their environment, including aspects of the ecosystem.

Cultural heritage values. Many societies place high value on the maintenance of either historically important landscapes (“cultural landscapes”) or culturally significant species.

Recreation and ecotourism. People often choose where to spend their leisure time based in part on the characteristics of the natural or cultivated landscapes in a particular area.

(iv) Supporting Services

Supporting services are those that are necessary for the production of all other ecosystem services. They differ from provisioning, regulating, and cultural services in that their impacts on people are often indirect or occur over a very long time, whereas changes in the other categories have relatively direct and short-term impacts on people. (Some services, like erosion regulation, can be categorized as both a supporting and a regulating service, depending on the time scale and immediacy of their impact on people.) These services include:

Soil Formation. Because many provisioning services depend on soil fertility, the rate of soil formation influences human well-being in many ways.

Photosynthesis. Photosynthesis produces oxygen necessary for most living organisms.

Primary production. The assimilation or accumulation of energy and nutrients by organisms.

Nutrient cycling. Approximately 20 nutrients essential for life, including nitrogen and phosphorus, cycle through ecosystems and are maintained at different concentrations in different parts of ecosystems.

Water cycling. Water cycles through ecosystems and is essential for living organisms." (Extracted from MEA 2005).

Recommendation

It is recommended that the MDBA define ecosystem services as the benefits people obtain from ecosystems, which include the provisioning, regulating, and cultural services that directly affect people and the supporting services needed to maintain other services.

2.4 Sites with Ecological Significance

Review of definitions

The term "sites with ecological significance" is listed in the *Water Act 2007* under "environmental assets" in Part 1, Section 4, Definitions. Other environmental assets named in the Act are water dependent ecosystems and ecosystem services.

In the context of environmental assets, "ecological significance" is a term which ascribes relative value to a site, based on its ecological components. Ecological significance, or ecological value, does not require a monetary value assigned to it, for value to be recognised. It is only when assigning the significance to a site, to determine whether a site is more or less significant to another, that value then needs to become a more tangible entity, but this can be done on selection criteria and not necessarily on a monetary value.

To break down the term; ecology is the study of interactions between organisms and their environment (Wikipedia 2007) and in terms of ecology, a site's "significance" is a reflection of its importance or impact (including potential for negative impact) within an ecosystem or bioregion. Within the literature, assumed knowledge of the terms "ecologically" and "significance" are relied upon extensively.

References to "ecologically significant sites" or the "ecological significance" of sites are widespread. Examples include:

- "Hydrologically, the 'ecological significance' of backswamps is to take up some of the flood during the wet season peaks." (Australian Mekong Resource Centre 2004).

- "Home to almost 20 per cent of the country's known plant species, the Great Western Woodlands . . . have been kept largely intact because of their remoteness and lack of value for agriculture and grazing. A report released today by the Wilderness Society has outlined the 'ecological significance' of the woodlands and recommended conservation strategies to protect their unique biodiversity" (WA Dept of Environment and Conservation 2008).

- Managed areas and 'ecologically significant sites' are lands set aside for a particular management objective or lands that are known to contain sensitive biological, cultural or scenic resources. (Tennessee Valley Authority 2004).

- Between 1993 and 1995, the Trust carried out a major project identifying ‘ecologically significant places’ throughout the province. . . The aim of the project was to bring together information on sites having a rich diversity of species or of sites with special features, e.g. rare plants or animals. (The Nature Trust of New Brunswick 2009).
- In Canada’s Natural Areas Conservation Program areas that are ‘nationally or provincially significant’ are those “that protect habitat for species at risk and migratory birds, or that enhance connectivity or corridors between existing protected areas such as National Wildlife Areas, National Parks and Migratory Bird Sanctuaries.” (Environment Canada 2005).

The Ramsar Convention (1971) and The Living Murray initiative are two key sources of natural resource management protocol in Australia and both use terms equivalent or connected to “sites with ecological significance” in reference to aquatic ecosystems. The Ramsar Convention aims to protect “wetlands of international importance” throughout the world. Under the *Environment Protection and Biodiversity Conservation Act 1999* “Ramsar wetlands are matters of national environmental significance”. The Living Murray initiative has a primary focus on six River Murray sites with “high ecological value and cultural significance” (MDBC 2005).

The Ramsar Convention (1971), Section 22 (Article 2.2) specifies Wetlands of International Importance based on of their ‘international significance in terms of ecology, botany, zoology, limnology or hydrology’ and qualifies this with 9 selection criteria (Ramsar 2009) (see Appendix 1).

The Living Murray icon sites are categorised as ‘significant ecological assets’ (SEA). These assets have been identified as possessing exceptionally high environmental, cultural, social and economic values. The six SEA embody the River Murray's distinctive character.” (MDBC 2005).

A further authority on ecologically significant wetland sites is the Directory of Important Wetlands in Australia (Environment Australia 2001). There are six criteria for determining nationally important wetlands. In an acknowledgement of the complexity and subjectivity involved in selection of sites with ecological significance, the Directory of Important Wetlands in Australia states “Many of the sites in the directory meet more than one of the criteria. Application of the criteria to individual wetland sites involves a degree of subjectivity. Not only may certain aspects of a site’s significance be interpreted differently by different investigators, but information gaps often exist that make it difficult to judge whether or not a site meets a particular criterion.” (DEWHA 2008).

The Department of Environment and Heritage recognised the importance of a national framework for the identification and management of Australia’s high conservation value aquatic ecosystems (HCVAE). In a review by SKM (2007) policies, processes and tools used to identify and ‘categorise’ HCVAE’ were identified. They included categories or criteria for asset values and condition, significance/importance, and protection and conservation status of HCVAE. One of the key findings of the review was that although all jurisdictions use different approaches, tools and terminology, there was some degree of similarity in the broad ecological criteria used. Elements of naturalness, representativeness, diversity, and importance for other systems or species were common to many of the approaches (SKM 2007).

The Tasmanian Conservation of Freshwater Ecosystems Values (CFEV) is an example of one of these assessment frameworks and is driven by three main components, Naturalness, Representativeness and Distinctiveness (described by up to seven separate classifications) (DPIW 2008).

WWF-Australia proposes a framework of prioritisation for protecting and managing HCVAE based on the spatial scale of significance:

> 'High national conservation value = international, national and state/territory scale.
>
> Medium national conservation value = regional scale (catchment or bioregion)
>
> Low national conservation value = local scale' (Blanch 2006).

Identification and subsequent valuing, or prioritisation, of "sites with ecological significance", while subjective to a degree, is well referenced with regard to aquatic ecosystems. The need to plan and prioritise conservation, management or restoration effort for environmental assets has led to the independent development of selection criteria within many organisations and initiatives. Assuming sound knowledge of ecology and of significant attributes of ecosystems is reasonable within the industry and the academic literature; a practice of cross referencing site characteristics with established criteria for significance (i.e. Ramsar wetlands, The Living Murray Icon Sites or the Directory of Important Wetlands in Australia) will deliver further identification of "sites with ecological significance". However, a site may have ecological value which is unrecognised due to limitations on valuing systems (metrics) or on the scientific understanding of the ecology of sites. So prioritisation processes need to be adaptively account for this.

Recommendation

It is recommended that the MDBA define sites with ecological significance as: A site which has recognised value associated with its ecological components (the processes, functions, attributes associated with a site).

2.5 Ecosystem Functions

Review of definitions

The term 'ecosystem function' is used in a variety of ways. At one end of the spectrum, the term has been applied very broadly, for example Hooper et al. (2005) tried to define the ecosystem function from the view point of both biologists and anthropologists and proposed the following definition:

> "ecosystem function encompasses a variety of phenomena including ecosystem properties, ecosystem goods and ecosystem services. Ecosystem properties include both size of compartments (e.g., pools of materials such as carbon or organic matter) and rates of process (e.g., fluxes of materials and energy among compartments). Ecosystem goods are those ecosystem properties that have direct market value they include food, construction materials, medicines, wild types for domestic plants and animal breeding gene for gene products in biotechnology, tourism and recreation."

This broad definition includes elements that are included in other definitions of Ecosystem Function. One common usage is to consider the terms Ecosystem Functions and Ecosystem Services to be synonymous. According to the United Nations Environment Program (UNEP) report (Nakamura 2000):

> "the ecosystem functions are generally categorised as functions for human benefits (flood control, water quality control, etc.), ability to produce products that are of economic value (agriculture, fishery, etc.) and ecosystem attributes (cultural heritage and biodiversity value, etc.). The ecosystem functions and their values depend on interacting elements within the ecosystem, such as water, soil, atmosphere and vegetation, through hydrological, geochemical and biophysical processes. Therefore it is crucial to consider various functions together within one system, so that its integrity can be maintained."

The terms ecosystem function and ecosystem process are also used interchangeably. Ecosystem Function should be the complement to Ecosystem Structure. With this approach, Ecosystem Structure includes biodiversity and physical components of the ecosystem while Ecosystem Function includes the processes that arise from the biota interacting with the physical system and each other. From a Basin Plan perspective it may be desirable to limit the use of Ecosystem Function to those processes that are deemed important to the maintenance of ecosystem integrity or health. Under this definition, many Ecosystem Services may also be Ecosystem Functions, but not all Ecosystem Functions may be regarded as Ecosystem Services.

Ecosystem processes occur as organisms utilise resources or transform material and include energy transformations and biogeochemical cycling and includes processes such as photosynthesis, decomposition, nutrient cycling and food web dynamics (Borman and Likens 1970). Many of these processes are also considered Ecosystem Services and are included in definitions of Ecosystem Function (see Section 2.3).

Two important ideas emerge from these definitions. The first is the idea that ecosystem functions are related to the maintenance of ecosystem integrity. For example, this element is included in the UNEP Glossary (Gilbert and Janssen 1998):

> "an intrinsic ecosystem characteristic related to the set of conditions and processes whereby an ecosystem maintains its integrity (such as primary productivity, food chain and biogeochemical cycles)."

And thus the Australian Heritage Commission (AHC) (2002) definition is useful in describing these aspects of ecosystem function as the processes that occur between organisms and within and between populations and communities, including interactions with the nonliving environment, which result in existing ecosystems and bring about changes in ecosystems over time.

Secondly, definitions of Ecosystem Function include some reference to interactions among ecosystem elements. This idea is included in both the UNEP report (Nakamura 2000) and in the Biology Online Dictionary (2005) definition:

> "the collective intraspecific and interspecific interactions of the biota, such as primary and secondary production and mutualistic relationships. The interactions between organisms and the physical environment, such as nutrient cycling, soil development, water budgeting, and flammability. "

The idea that Function emerges from the interaction of ecosystem elements underpins one of the major ecological issues; that of the relationship between biodiversity and ecosystem function. Some ecologists believe the functioning and sustainability of ecosystems depends on biological diversity and how it changes (Tilman et al. 1996) and any loss of biodiversity or species richness can have subsequent implications for ecosystem functioning (Cardinale et al. 2006). A corollary is that a larger number of species in an ecosystem will reduce variability in ecosystem function (Loreau et al. 2001). But again, it is DEWHA (2008) which brings the definition back to defining ecosystem functions as the processes, which are the dynamic forces at work within an ecosystem. The use of the word 'dynamic' is used to describe the adaptability within a functioning ecosystem, which was also used in the AHC (2002) definition.

Recommendation

It is recommended that the MDBA regard a marrying of both DEWHA and AHC definitions of ecosystem function, as:

including all those processes that occur between organisms and within and between populations and communities, including interactions with the nonliving environment, that result in existing ecosystems and bring about dynamism through changes in ecosystems over time.

2.6 Productive Base

Review of definitions

Productive Base is a term not used before in scientific literature, and thus there is limited reference to it within the MDB, except for it being a new term used within the development of the Basin Plan. It is not defined in the *Water Act 2007*. Thus we must review where these words have been used before and how they relate to the MDB.

Production is the conversion of inputs into outputs. It is the process that uses resources to create a good or service that is suitable for exchange.

Production is a process, and as such it occurs through time and space. Because it is a flow concept, production is measured as a "rate of output per period of time". There are three aspects to production processes:

1. the quantity of the good or service produced,
2. the form of the good or service created,
3. the temporal and spatial distribution of the good or service produced.

A production process can be defined as any activity that increases the similarity between the pattern of demand for goods and services, and the quantity, form, and distribution of these goods and services available to the market place (Wikipedia 2009).

In ecological terms, production is among the most fundamental characteristics of ecosystems as it is a process by which energy moves through the food chain. In aquatic systems primary production is the rate of transformation of inorganic carbon (from carbon dioxide in the air or in the water) to organic carbon principally via photosynthesis (Hall et al. 2007; Wikipedia 2009).

Primary producers form the base of the food chain, with the various consumptive processes comprising secondary production. Since the productive base involves conversion of inputs to outputs, all stages of the productive cycle - primary and secondary production - must be considered as components of the productive base. However not all of the energy captured by primary producers is available as organic carbon for secondary production. Some of the energy is used to sustain essential metabolic respiration (Odum 1956). Multiple steps, within a complex foodchain, recycle a large proportion of carbon via different biotic groups. This means that total secondary production can appear to be greater than primary production (Strayer 1988).

In November 2003, the MDBC Ministerial Council in its announcement of the Living Murray First Step stated that "The River Murray is degraded and this degradation threatens the Basin's agricultural industries, communities' natural and cultural values, and national prosperity". One of the reasons that the fate of the Basin's communities is tied to that of its natural resources is that the agricultural production that sustains Basin communities is dependent on a similar suite of Ecosystem Functions/Services to the Ecosystems primary and secondary production. Thus, the productive base requirements can only be met once the ecosystem services requirements (i.e. ecosystem functions) are met. Therefore the processes underpinning them are the same.

Recommendation

It is recommended that the MDBA define the Productive Base as the support offered by ecosystems, ecosystem functions and ecosystem services of a water resource to provide for ecological and human (economic and social) production.

2.7 Environmental Outcomes

Review of definitions

In the *Water Act 2007* Section 4 definitions it states that:

Environmental outcomes include:
(a) ecosystem function; and
(b) biodiversity; and
(c) water quality; and
(d) water resource health.

Note 1: Paragraph (a) would cover, for example, maintaining ecosystem function by the periodic flooding of floodplain wetlands.
Note 2: Paragraph (d) would cover, for example, mitigating pollution and limiting noxious algal blooms.

The term outcome is used to identify something produced as an endpoint of an action (Wiktionary 2009) or a consequence (Oxford 2009).

Part of Object C of the *Water Act 2007* (Section 3) refers to management of the Basin water resources to optimise environmental outcomes:
“(i) to ensure the return to environmentally sustainable levels of extraction for water resources that are overallocated or overused; and (ii) to protect, restore and provide for the ecological values and ecosystem services of the Murray-Darling Basin (taking into account, in particular, the impact that the taking of water has on the watercourses, lakes, wetlands, ground water and water-dependent ecosystems that are part of the Basin water resources and on associated biodiversity”

In Section 4 of the *Water Act 2007* a number of key environmental outcomes for the water resource are specified, including; “ecosystem function, biodiversity; water quality and water resource health.” This definition appears to be based largely on the COAG (2004) definition.

The Council of Australian Governments (COAG) recognised the importance of a common language for water use and management and provided the following definitions:

> ***“environmental and other public benefit outcomes*** **–** environmental and other public benefit outcomes are defined as part of the water planning process, are specified in water plans and may include a number of aspects, including:
>
> \- *environmental outcomes*: maintaining ecosystem function (eg. through periodic inundation of floodplain wetlands); biodiversity, water quality; river health targets;
>
> \- *other public benefits*: mitigating pollution, public health (eg. limiting noxious algal blooms), indigenous and cultural values, recreation, fisheries, tourism, navigation and amenity values.” (COAG 2004).

This definition was carried into Australian *Water Resources 2005* (NWC 2007a & b), baseline assessment of water resources to support the National Water Initiative (NWI), undertaken by the National Water Commission and incorporated into the NWI itself. However, in a progress report on the Initiative, the National Water Commission identified a lack of specificity in the environment outcomes an impediment to the Initiative and recommended establishing clear environmental outcomes as one way to improve the effectiveness of the NWI in protecting water dependent ecosystems (NWC 2008b).

In The Living Murray Foundation Report on the ecological assets targeted in the First Step Decision (MDBC 2005), environmental outcomes were simply defined as project outcomes that benefit the ecological health of the river system.

In 2008 the Productivity Commission convened a roundtable on Promoting Better Environmental Outcomes. One of its primary aims was to identify how governments could improve environmental outcomes and to determine feasible objectives for environmental policy (Productivity Commission 2008). There is much discussion in the proceedings about environmental outcomes and although there is no actual definition of the term. Craik and Cleaver (2008) and Pannel (2008) highlight the importance of establishing clear strong links between actions/decision and environmental outcomes (a key component of adaptive management) to improve the environmental outcomes of policies and actions. One way to establish clear links is the between actions and outcomes is to have clear objectives and appropriate monitoring programs.

Craik and Cleaver (2008) use the specific ecological objectives of TLM for birds and vegetation at icon sites as an example:

- “successful breeding of thousands of colonial water birds in at least three years in ten (at the Barmah–Millewa Forest)
- thirty per cent of River Red Gum forest in healthy condition (at the Gunbower and Koondrook-Perricoota Forests)
- increasing the population size and breeding events of the endangered Murray Hardyhead, Australian Smelt, Gudgeons and other wetland fish (at the Hattah Lakes).” (Craik and Cleaver 2008; MDBC 2005)

In summary, ‘Environmental outcomes’ is not a term that appears to be widely used outside Australia or in the scientific literature and appears mostly in management documents as an umbrella term for a range of environmental indicators or objectives. In theory an outcome could be either beneficial or detrimental but its use when associated with the environment infers the former.

Specifying environmental outcomes based on ecological objectives is critical to the success of environmental policy / management and putting in place appropriate monitoring and reporting is a key factor for determining its effectiveness.

Recommendation

Future review of the *Water Act 2007*, may consider environmental outcomes as the environmental responses and results of a management action. Specifically, this would include ecological responses relating to ecosystem function, biodiversity, water quality; river health targets. In addition to the definition for key environmental outcomes as provided in the *Water Act 2007,* clarification and interpretation of what is an outcome should include other improvements or maintenance of the environment.

When developing environmental policy, it is recommended that the MDBA include ecological objectives for each of the environmental outcomes, and allow for future knowledge and understanding of outcomes and their measurement to be included in management considerations.

2.8 Biodiversity

Review of definitions

The *Water Act 2007* defines biodiversity as:

the variability among living organisms from all sources (including terrestrial, marine and aquatic ecosystems and the ecological complexes of which they are a part) and includes:

(a) diversity within species and between species; and

(b) diversity of ecosystems.

Biodiversity is often used as a measure for ecological condition or to measure outcomes from management actions. In doing so, it should be considered that biodiversity should be measured as those species which are native, or endemic or desired.

In other literature, the terms ‘biodiversity’ and ‘biological diversity’ are used interchangeably in the literature. As a rule, biologists tend to default to the more ‘all-inclusive’ definitions of biodiversity such as that given by Sarkar and Margules (2002):

> “The concept of biodiversity includes the entire biological hierarchy from molecules to ecosystems, or the entire taxonomic hierarchy from alleles to kingdoms, all the logical classes in between (individuals, genotypes, populations, species, etc.), and all of the different members of all those classes. It also includes the diversity of living interactions and processes at all these levels of organization”.

Similarly, the 1992 United Nations Earth Summit in Rio de Janeiro defined "biological diversity" as:

> "the variability among living organisms from all sources, including, 'inter alia', terrestrial, marine, and other aquatic ecosystems, and the ecological complexes of which they are part: this includes diversity within species, between species and of ecosystems".

According to Wikipedia, this latter definition is, in fact, the closest thing to a single legally accepted definition of biodiversity, since it is the definition adopted by the United Nations Convention on Biological Diversity (CBD).

Ramsar’s definition of biological diversity is an extension of the CBD definition

> ‘biological diversity means the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species (genetic diversity), between species (species diversity), of ecosystems (ecosystem diversity), and of ecological processes’ Ramsar (2009).

Locally, the *Environment Protection and Biodiversity Conservation Act 1999* defines Biodiversity as a function of its components, specifically:

> ***components of biodiversity*** includes species, habitats, ecological communities, genes, ecosystems and ecological processes.

whereas DEWHA define biodiversity as:

> “the variety of life: the different plants, animals and micro-organisms, their genes and the ecosystems of which they are a part”.

Notably, neither the UN or DEWHA definitions include explicit reference to interactions and processes that occur between the organisms described whereas the other three definitions do. This is an important point to resolve in the Basin Plan context (see below).

All of these definitions are very broad, and some biologists argue that they are too broad - even to the point of being ‘capricious’ (Ricotta 2005). This highlights an important distinction between the <u>definition</u> and <u>measurement</u> of biodiversity that needs to be considered explicitly when defining biodiversity.

In such a complex and opinion based field, it is somewhat surprising that there appears to be uniform agreement that any measurement of biodiversity relates only to the purpose for which that data is collected, that is, there is no uniformly appropriate measurement of biodiversity. As a result, 'biodiversity' is commonly measured under several categorisations. In its (arguably) simplest form, biodiversity is measured as the number of species (i.e. species richness) and/or the (relative) abundance of species within a given boundary/location (species abundance, which equates to 'evenness' in multi-species analysis). This definition forms the basis of many diversity indices that are widely used and reported on (e.g. Simpson's Diversity Index, Shannon's Diversity index).

However, some researchers argued that the 'numbers' or 'abundances' of species within a system represented a poor measure of biodiversity because in many cases this data is largely unknowable, scale dependent, and not useful for (in particular) conservation purposes (Ricotta 2005). In response, Vane-Wright et al. (1991) suggested that biodiversity be measured by quantifying the phylogenetic relationships amongst species, and not their abundances. Common criticisms of this approach, however, focus on the lack of understanding and/or changing resolution of taxonomic relationships between species (and this is particularly true of Australian freshwater biota – e.g. Bertozzi et al. 2000).

Critics of both of these measures point to their lack of a relationship with the ecosystem processes and function that form a key component of many definitions of biodiversity (see Naeem and Wright 2003). As a result, indices measuring 'functional diversity' (see Walker et al. 2008, Rao 1982) have been developed and correlated with a range of measures of system stability, production and resilience (e.g. Wiegelt et al. 2008; Naeem and Wright 2003; Nystron and Folk 2001).

There is considerable ongoing research in this field (i.e. the relationship between measurements of Functional Diversity and system function), with new context-dependent indices being regularly developed and applied (again, see Walker et al. 2008). Importantly, the 'applied' nature of these functional diversity measures underpins their likely importance to the development and execution of the Basin plan. It follows that the broader definition of biodiversity, as incorporated into Basin Plan legislation, should include explicit reference to the processes underlying system function. As a result, the definition of either Sarkar and Margules (2002 – re-stated below) or the 'biodiversity components' definition outlined in the *Environment Protection and Biodiversity Conservation Act 1999* appear to be the most appropriate.

To summarise: in the area of biodiversity, there is a distinction between the definition of the broader term (or concept), and the means by which it should be measured. From the discussion above, it appears that the <u>definitions</u> most appropriate for the Basin are that of either Sarkar and Margules (2002):

> "The concept of biodiversity includes the entire biological hierarchy from molecules to ecosystems, or the entire taxonomic hierarchy from alleles to kingdoms, all the logical classes in between (individuals, genotypes, populations, species, etc.), and all of the different members of all those classes. It also includes the diversity of living interactions and processes at all these levels of organization".

or, if there is a willingness to accept a component-based, less prescriptive definition (does not, for example, include specific reference to taxonomic measures biodiversity), the *Environment Protection and Biodiversity Conservation Act 1999* definition:

> ***components of biodiversity*** includes species, habitats, ecological communities, genes, ecosystems and ecological processes.

might also represent an acceptable alternative.

The <u>measurement</u> of biodiversity in the Basin Plan will necessarily be context dependent, and as such a uniform approach cannot be mandated. It does appear, however, that there is likely to be significant value in the broader application of functional diversity measures and the establishment of their relationship to system level response. As such, it can be argued that where sensible, the measurement of 'functional biodiversity' (e.g. Rao's question) should be encouraged in preference to more traditional 'richness and evenness' measures of biodiversity (e.g. Simpson's or Shannon's diversity indices).

Recommendation

It is recommended that the MDBA use the *Water Act 2007* definition of biodiversity:

the variability among living organisms from all sources (including terrestrial, marine and aquatic ecosystems and the ecological complexes of which they are a part) and includes:

(a) diversity within species and between species; and

(b) diversity of ecosystems.

However, biodiversity should be interpreted in terms of 'native' or 'endemic' biodiversity. It is hoped that in a future review of the Water Act this is clarified, because pest species can be a threat to local and /or regional biodiversity, and these species should not be used as a measure of biodiversity.

2.9 Water Quality

Review of definitions

The term 'water quality' refers to the condition of a water body and its related suitability for different purposes (EPA SA 2009). Water quality can be assessed using a combination of physical, chemical and/or biological indicators. Many references, both nationally and internationally use similar definitions (see Karr & Dudley 1981; OECD 2007; Park 2007; Department Environmental Affairs and Tourism South Africa 1999; Wikipedia 2009).

The appropriate suite of indicators for assessing water quality is chosen with reference to the local environmental conditions and the environmental value for which the water body is being assessed. The National Water Quality Management Strategy (NWQMS), through the *Water Quality Guidelines* (Australian and New Zealand Guidelines for Fresh and Marine Water Quality) recognises the following environmental values for water:

- Aquatic ecosystems
- Primary industry
- Recreation and aesthetics
- Drinking water
- Industrial water
- Cultural and spiritual values

The *Water Quality Guidelines* address the first four of these values. Water quality guidelines "provide an authoritative guide for setting water quality objectives required to sustain current or likely future, environmental values [uses] for natural and semi-natural water resources in Australia." For Aquatic ecosystems the *Water Quality Guidelines* identify biological indicators, physical and chemical stressors, toxicants in water and toxicants in sediments as the indicator types appropriate for assessing water quality. For Aquatic ecosystems there is an emphasis on site-specific guidelines developed within the context of:

- water quality objectives
- different ecosystem types
- different levels of protection recommendation
- using a risk-based approach, and
- utilisation of reference sites

to establish benchmarks for assessing and maintaining water quality at a site (ANZECC & ARMCANZ 2000).

Within Australia and New Zealand many sources of water quality information now utilise the Australian and New Zealand Guidelines for Fresh and Marine Water Quality for direction (see NWQMS 2009; EPA SA 2009; Liston & Maher 1997). As described in Bennet (2008) "The National Water Quality Management Strategy (NWQMS) is the main mechanism for water quality management in Australia."

According to the *Water Act 2007* water quality is a key environmental outcome (along with ecosystem function, biodiversity and water resource health). Whittington et al. (2001) acknowledge that water quality can be considered as an outcome; "…a resulting sum total of water inputs, flow and in stream ecological processes, and as a habitat medium for many organisms" but is "…more commonly regarded as a driver of river health. Physicochemical indicators of water quality characteristics can be seen as 'drivers' influencing important ecological processes".

In summary, water quality refers to a combination of physical, chemical and/or biological characteristics of a water body in the context of the value, or use for which the water body is being recognised. Water quality can be expressed as an outcome; the result of the combination of the designated characteristics of the water body, or as a driver; a characteristic of a water body which influences the ecology of an aquatic ecosystem. In Australia, the Australian and New Zealand Guidelines for Fresh and Marine Water Quality have been widely recognised and adopted.

Recommendation

The term 'water quality' refers to the condition of water and its related suitability for different purposes. Water quality refers to a combination of physical, chemical and/or biological characteristics of a water body in the context of the value, or use for which the water body is being recognised. Water quality maybe a key environmental outcome or a driver of ecosystem function.

2.10 Water Resource Health

Review of definitions

The *Water Act 2007* definition for water resource is:

(a) surface water or ground water; or

(b) a watercourse, lake or wetland or aquifer (whether or not it currently has water in it);

and includes all aspects of the water resource (including water, organisms and other components and ecosystems that contribute to the physical state and environmental value of the water resource).

The term resource refers to something that is useful for satisfying human needs or wants. The term health is most often used to describe the state of a living organism, most commonly humans. Human health is often defined in terms of the absence of disease and the presence of high levels of function. An example would be: "A state characterized by anatomic, physiologic and psychologic integrity; ability to perform personally valued family, work and community roles; ability to deal with physical, biologic, psychologic and social stress..."(Stokes et al. 1982). If this is applied to a population level then a healthy population as one in which its members were all healthy and in the broader context, a healthy society is one in which the various systems (economic, legal, governmental, etc.) function smoothly. Related definitions include some that view health in terms of resiliency (e.g., "the capability of individuals, families, groups and communities to cope successfully in the face of significant adversity or risk." (Vingilis & Sarkella 1997). Applied to population health, the definition might include elements such as the success with which the population adapts to change such as shifting economic realities or natural disasters. An epidemiological ecological definition used by Last et al. (1995) is: "a state in which humans and other living creatures with which they interact can coexist indefinitely."

It is logical therefore, that the introduction of the use of the term health in connection with the environment was conceived as way to encompass a range of aspects of condition with respect to the dynamic nature of living ecosystems. Therefore when we refer to the health of water resources, we are referring to the biological health i.e. the health of the biological organisms and systems associated with the water resource.

The Convention on Biological Diversity defined biological resources as ‘includes genetic resources, organisms or parts thereof, populations, or any other biotic component of ecosystems with actual or potential use or value for humanity’ (UNEP 1992).

Many terms have been used to infer health of the environment in management and scientific literature including; sustainability, integrity, condition and quality. Variations on these terms include:

> Biological health, biological quality, biological integrity, biological condition, ecosystem health, ecological quality, ecological integrity, ecological condition, ecological status, ecological sustainability, ecological character, river health, wetland health

In the Australian Water Resources 2005 report (NWC 2007b) river and wetland health is synonymous with the term ‘ecological condition’.

The Ramsar Convention developed the concept of “ecological character” for wetlands which is defined as: “Ecological character is the combination of the ecosystem components, processes and benefits/services that characterise the wetland at a given point in time.” (Resolution IX.1 Annex A, 2005) where ‘ecosystem benefits’ were defined in accordance with the Millennium Ecosystem Assessment definition of ecosystem services as “the benefits that people receive from ecosystems” (Ramsar 2009). Ramsar justify the use of ecological character as an indication of wetland ‘health’ as to maintain ecological character of a site, retains those essential ecological and hydrological functions which ultimately provide its “benefits/services” (Ramsar 2009).

Clarke et al. (2003) identify the use of the terms ‘biological quality’ ‘ecological quality’ and ‘ecological status’ in the European Water Framework Directive which are essentially describing health or quality of sites and they adopted ‘ecological quality’ as their preferred term.

In the United States, ‘biological integrity’ is the term widely used to indicate ecosystem health (USEPA….). The stated objective of The Federal *Clean Water Act 1972* is ‘… to restore and maintain the chemical, physical, and biological integrity of the nation's waters’.

In 1981 Karr and Dudley defined biological integrity as- the ability of an aquatic ecosystem to support and maintain a balanced, adaptive community of organisms having a species composition, diversity, and functional organization comparable to that of natural habitats within a region. This definition has widespread use in the US and the definition has also been adopted in Australia as a definition for river health.

In the National River Health Program the definition of health in urban waterways is essentially that of Karr and Dudley 1981 (although not attributed to them) ‘the ability to support and maintain a balanced, integrative, adaptive community of organisms having a species composition, diversity and functional organisation as comparable as practicable to that of natural habitats of the region’ (NHRP 2009).

When we are defining 'water resource health' it is assumed that we really mean 'aquatic ecosystem health' which takes into account the physical, chemical and biological components associated with water. As in this example from the Indiana Department of Environmental Management which defines 'aquatic ecosystem' as 'complex of biotic and abiotic components of natural waters. The aquatic ecosystem is an ecological unit that includes the physical characteristics (such as flow or velocity and depth), the biological community of the water column and benthos, and the chemical characteristics such as dissolved solids, dissolved oxygen, and nutrients. Both living and nonliving components of the aquatic ecosystem interact and influence the properties and status of each component'.

The complex nature of ecosystems is discussed at length by many authors, but there is a common theme whereby a healthy ecosystem is self sustaining; i.e. able to maintain its function, structure and identity (Walker et al. 2004). Key attributes that ensure the maintenance or health of an ecosystem include resistance to disturbance, resilience to maintain or recover from stressors (Holling 1986)

Costanza and Mageau (1999) describe ecosystem health as a 'comprehensive, multi-scale, dynamic, hierarchical measure of system resilience, organization, and vigour. These concepts are embodied in the term 'sustainability' which implies the system's ability to maintain its structure (organization) and function (vigour) over time in the face of external stress (resilience)'. Costanza and Mageau (1999) also highlight the importance of assessing ecosystem health at relevant scales. They define a healthy ecosystem 'in light of both its context (the larger system of which it is part) and its components (the smaller systems that make it up). In its simplest terms, then, health is a measure of the overall performance of a complex system that is built up from the behaviour of its parts' (Costanza & Mageau 1999).

The National Water Commission (2007) addressed this issue of scale in the development of a national Framework for the Assessment of River and Wetland Health (FARWH) which incorporated related elements of river and wetland condition. Specifically, physical form, water quality, aquatic biota, hydrological disturbance, fringing zone and catchment disturbance.

In many programs assessing the health of rivers and wetlands the key focus is on biological indicators. Under the AusRivAS (**Aus**tralian **Riv**er **A**ssessment **S**ystem (developed under the National River Health Program)) rapid assessments of biological health of Australian rivers are based primarily on the macroinvertebrate communities observed or collected at a site compared with those expected at a site based on a ideal 'healthy' community from a reference stream/condition (pristine or relatively unpolluted / unimpacted by human influences) i.e. generating observed versus predicted scores for communities.

Under the European Union Water Framework Directive (Council of the European Communities 2000) ecological quality objectives are required (Pollard and Huxham 1998). RIVPACS was developed and is widely used in the United Kingdom and uses a similar modelling approach to AusRivAS.

In North America the Index of Biological Integrity is a similar system that uses a range of metrics to describe the biological community at sites compared with reference conditions (Karr 1991 USEPA).

Recommendation

It is recommended that the MDBA define water resource health as: the ability of a water resource (as defined by the *Water Act 2007*) to maintain ecological character, which includes retaining those essential ecological and hydrological functions which ultimately provide its benefits and services within itself or to the wider ecosystem.

3.0 Conclusion

It is imperative that with the development of scientific knowledge, which comes from greater understanding and methods for evaluation, and as management actions improve with adaptive management cycles, and as law (legislation and policy work) also is developed, that reviews of the interpretation and application of the terms detailed in this document, should be undertaken. The use of 'includes' or 'including' within the Water Act, when detailing what a term encompasses, implies that some of the terms are not to be limited in their interpretation. Future reviews of the Water Act should see these terms reviewed and changes made (e.g. as this document has suggested for 'biodiversity'), and where other terms have been coined by the MDBA and become common terms of reference, the Act will need to define and review these also.

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Appendix 1

Ramsar listed wetlands of international importance are selected on the basis of nine criteria

- "Group A of the criteria: Sites containing representative, rare or unique wetland types
- Criterion 1: A wetland should be considered internationally important if it contains a representative, rare, or unique example of a natural or near-natural wetland type found within the appropriate biogeographic region.
- Criterion 2: A wetland should be considered internationally important if it supports vulnerable, endangered, or critically endangered species or threatened ecological communities.
- Criterion 3: A wetland should be considered internationally important if it supports populations of plant and/or animal species important for maintaining the biological diversity of a particular biogeographic region. Criteria based on species and ecological communities.
- Criterion 4: A wetland should be considered internationally important if it supports plant and/or animal species at a critical stage in their life cycles, or provides refuge during adverse conditions.
- Criterion 5: A wetland should be considered internationally important if it regularly supports 20,000 or more waterbirds. Specific criteria based on waterbirds.
- Criterion 6: A wetland should be considered internationally important if it regularly supports 1% of the individuals in a population of one species or subspecies of waterbird.
- Criterion 7: A wetland should be considered internationally important if it supports a significant proportion of indigenous fish subspecies, species or families, life-history stages, species interactions and/or populations that are representative of wetland benefits and/or values and thereby contributes to global biological diversity. Specific criteria based on fish.
- Criterion 8: A wetland should be considered internationally important if it is an important source of food for fishes, spawning ground, nursery and/or migration path on which fish stocks, either within the wetland or elsewhere, depend.
- Group B of the criteria: Sites of international importance for conserving biodiversity Specific criteria based on other taxa.
- Criterion 9: A wetland should be considered internationally important if it regularly supports 1% of the individuals in a population of one species or subspecies of wetland-dependent non-avian animal species." (Ramsar 2009).