

Aquatic ecosystems toolkit

MODULE 3:

Guidelines for identifying high ecological value
aquatic ecosystems (HEVAE)



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The Aquatic Ecosystems Toolkit is a series of documents to guide the identification of high ecological value aquatic ecosystems. The modules in the series are:

Module 1: Aquatic Ecosystems Toolkit Guidance Paper

Module 2: Interim Australian National Aquatic Ecosystem (ANAE) Classification Framework

Module 3: Guidelines for Identifying High Ecological Value Aquatic Ecosystems (HEVAE)

Module 4: Aquatic Ecosystem Delineation and Description Guidelines

Module 5: Integrated Ecological Condition Assessment (IECA) Framework

National Guidelines for the Mapping of Wetlands (Aquatic Ecosystems) in Australia

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Table of contents

List of figures.....	iv
List of tables.....	iv
Abbreviations.....	v
1 Introduction	1
1.1 Definitions	2
2 Identifying HEVAE	3
2.1 Groundwork	3
2.2 Identifying HEVAE	3
2.3 Expert knowledge input.....	3
2.4 International recognition	4
2.5 HEVAE criteria	4
3 Workflows.....	12
3.1 Groundwork before identifying HEVAE	12
3.2 Identifying HEVAE	14
4 Glossary.....	21
5 References.....	24
Appendix A Examples of attributes and metrics for HEVAE criteria.....	25
Appendix B Suggested methods for scoring and integrating attributes and metrics.....	30
Appendix C Checklist for completing the HEVAE identification workflow	34
Appendix D HEVAE identification record template	35

List of figures

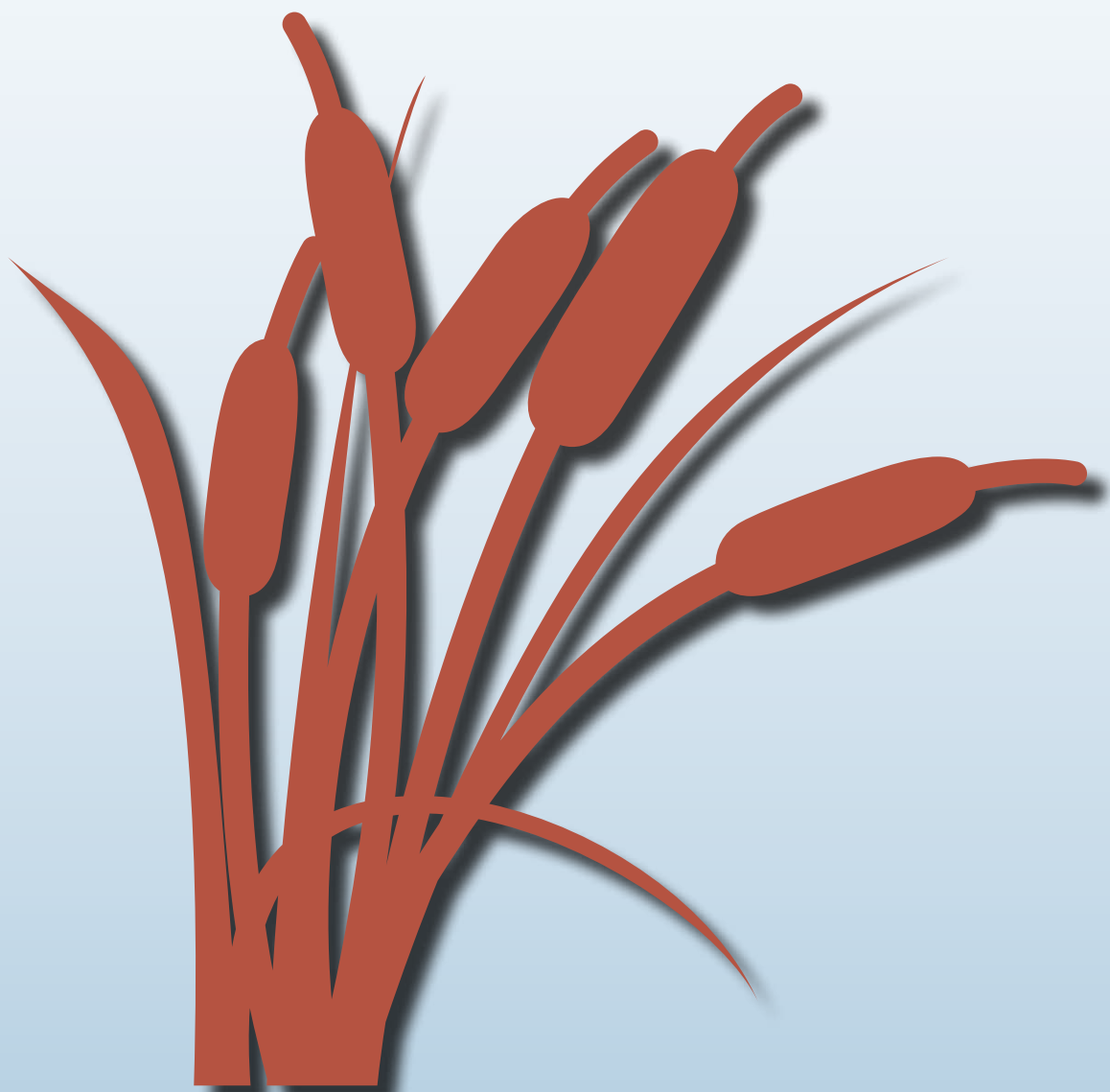
Figure 1	Potential process for implementing the Aquatic Ecosystems Toolkit within an adaptive management framework (outer and inner circles), highlighting Module 3	1
Figure 2	Groundwork steps to undertake before identifying HEVAE	12
Figure 3	Flow chart for the process of applying the criteria and attributes to identify HEVAE.....	15

List of tables

Table 1	Suggested methods of scoring and integrating attributes and/or metrics to obtain criterion scores	19
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Abbreviations

AETG	Aquatic Ecosystems Task Group
ANAE	(Interim) Australian National Aquatic Ecosystems (Classification Framework)
AquaBAMM	Aquatic Biodiversity Assessment Mapping Methodology
AUSRIVAS	Australian River Assessment System
CFEV	Conservation of Freshwater Ecosystem Values Framework
DSEWPac	Department of Sustainability, Environment, Water, Population and Communities
EHMP	Ecosystem Health Monitoring Program
EPBC	<i>Environment Protection and Biodiversity Conservation Act 1999</i>
Geofabric	Australian Hydrological Geospatial Fabric
HEVAE	High Ecological Value Aquatic Ecosystems
IBRA	Interim Biogeographic Regionalisation of Australia
IMCRA	Integrated Marine and Coastal Regionalisation of Australia
ISC	Index of Stream Condition
NRM	Natural Resource Management
NRPPC	Natural Resources Policies and Programs Committee
NWI	National Water Initiative
SRA	Sustainable Rivers Audit



1 Introduction

In response to commitments in the National Water Initiative (NWI), the Aquatic Ecosystems Task Group (AETG) has overseen the development of the Aquatic Ecosystems Toolkit. The toolkit provides practical tools to provide guidance in identifying high ecological value aquatic ecosystems (HEVAE), and mapping, classifying, delineating, describing and determining condition of aquatic ecosystems in a nationally consistent manner. The tools are also based on, and enhance, existing jurisdictional tools. Information on the toolkit including the drivers, its potential use, and history of the toolkit development are detailed in Module 1 (*Aquatic Ecosystems Toolkit Guidance Paper*) of this series.

This document is Module 3 *Guidelines for Identifying High Ecological Value Aquatic Ecosystems (HEVAE)* (Figure 1). It provides a set of non-prescriptive steps to guide proponents in the

groundwork required and process of identifying HEVAE. As many factors will determine the paths to be followed—including the purpose of the exercise, the amount of data readily available, and the resources (timeframe, money and skills) available—a selection of methods developed to cater for a spectrum of users and data availability are provided to guide the user to the same end i.e. a set of HEVAE.

This module has been developed concurrently with Module 4 (*Aquatic Ecosystem Delineation and Description Guidelines*) and can be applied in conjunction with that module or any other of the toolkit modules. Alternatively, it can be used independently, as a process on its own. In an adaptive management context, Module 3 may be applied as part of the 'vision' and 'planning' phases (Figure 1).

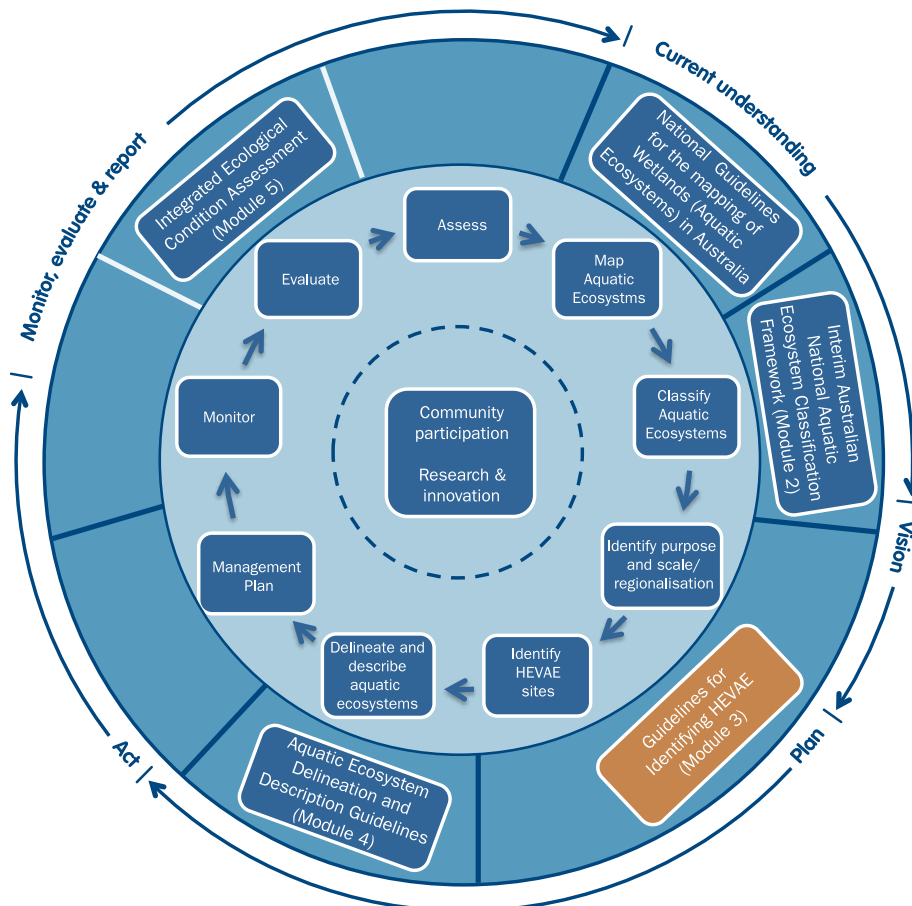


Figure 1 Potential process for implementing the Aquatic Ecosystems Toolkit within an adaptive management framework (outer and inner circles), highlighting Module 3



Cumbungi (Sarah Stuart-Smith & DSEWPaC)

1.1 Definitions

Aquatic ecosystems

No single definition of aquatic ecosystems exists, however, for the purposes of identifying high ecological value aquatic ecosystems, the AETG has defined 'aquatic ecosystems' as those that are:

dependent on flows, or periodic or sustained inundation/waterlogging for their ecological integrity e.g. wetlands, rivers, karst and other groundwater-dependent ecosystems, saltmarshes, estuaries and areas of marine water the depth of which at low tide does not exceed 6 metres.

Depending on the purpose of the assessment, the inclusion of artificial waterbodies (e.g. sewage-treatment ponds, canals, impoundments) may be appropriate if they are considered to provide significant ecological value (for example, through the criteria application process), although their importance may be weighted differently.

Ecological value

Ecological value is the perceived importance of an ecosystem, which is underpinned by the biotic and/or abiotic components and processes that characterise that ecosystem. In the Aquatic Ecosystems Toolkit, ecological values are those identified as important through application of the criteria and identification of critical components and processes in describing the ecological character of the ecosystem (or another comparable process).

2 Identifying HEVAE

2.1 Groundwork

Before undertaking an assessment to identify HEVAE, it is necessary to do some groundwork:

- Identify the purpose of the assessment and which modules of the toolkit are to be applied.
- Ensure the aquatic ecosystems in the area of interest have been mapped and classified, using the toolkit's *National Guidelines for the Mapping of Wetlands (Aquatic Ecosystems) in Australia*, and Module 2 (*Interim Australian National Aquatic Ecosystem (ANAE) Classification Framework*), or other appropriate mapping and classification methods.
- Determine the most appropriate approach to take for spatially assigning data:
 - Top-down—where the area of interest is arbitrarily separated into smaller units and each of those units is assigned with any relevant data. Regionalisation and assessment units with relevance to aquatic ecosystems in the area of interest (e.g. drainage division) should be adopted (refer to Levels 1 and 2 of the *Interim ANAE Classification Framework* (Module 2) for information on regionalisation).
 - Bottom-up—where, when sufficient data is available, the ecological values and relevant data (e.g. macroinvertebrate, fish, waterbird or flora community composition) are identified first, and then aggregated into appropriate geographical units.
- Identify and engage relevant experts (see section 2.3).

Further information and a workflow is provided in section 3.

2.2 Identifying HEVAE

The major tasks in identifying HEVAE are:

- Determining the criteria that will be used in the assessment, noting that it is recommended that the core criteria (Section 2.5) are used for any assessment for national purposes at the drainage division level.
- Identifying attributes and associated data for each criteria.
- Collating relevant data and applying the criteria.
- Developing and applying a scoring system to identify HEVAE.
- Determining the validity of identified HEVAE.

Section 2.5 of this document provides guidance on the HEVAE criteria, and section 3 provides further detail on the groundwork required and the methods for identifying HEVAE.

2.3 Expert knowledge input

Whilst an assessment may be undertaken by anyone with spatial/ecological skills, it is important that the process incorporates expert knowledge from relevant scientific disciplines with local knowledge and experience in the area of interest. This can take the form of expert reference panels that advise at particular stages of the assessment. During the identification of HEVAE, a panel of scientists with expertise in a range of relevant fields (e.g. hydrology, geomorphology, ecology, fish, plants, waterbirds) is advised.

Alternatively, experts can be engaged individually by the assessment team. This is less preferable as there is much to be gained by discussion within a group, but is sometimes the only option given competing schedules and workloads.

Expert information can also be drawn from the literature during the assessment process, to supplement data and expert engagement as appropriate. The experts should be able to provide:

- a broad contextual understanding of the area of interest and its aquatic ecosystems
- specific information and data for the selected attributes (e.g. waterbird abundance and breeding)
- the ability to review the high-ranking assessment units/aquatic ecosystems with respect to their probability of containing a known HEVAE and the potential reasons for why known significant aquatic ecosystems were not identified through the process.

Early engagement of experts is recommended, allowing time to ‘educate’ them on the intricacies of the HEVAE identification process. It is also important to remember to factor in additional costs related to the engagement of experts.

2.4 International recognition

Aquatic ecosystems already recognised as being of international significance under the Ramsar Convention and/or East Asian–Australasian Flyway Site Network may be recognised as HEVAE, while aquatic ecosystems in World Heritage Areas should be assessed on a case-by-case basis. However, to be considered a HEVAE, any internationally recognised aquatic ecosystem should be subject to the following provisos:

- The proposed ecosystem must be of an ecosystem type within the scope of the Aquatic Ecosystems Toolkit, therefore entirely marine systems greater than 6 metres in depth at low tide, and terrestrial ecosystems will be excluded.
- The ecosystem must align with the purpose of the assessment.
- The aquatic values of the ecosystem must meet international standards for those values and these components must be included in the relevant listing documentation.

- The values do not necessarily have to match the HEVAE criteria provided they are (a) aquatic values and (b) have been assessed according to the relevant international listing process e.g. Ramsar, World Heritage, East Asian–Australasian Flyway Site Network.

2.5 HEVAE criteria

This module identifies five core criteria that can be used at a range of scales to identify HEVAE: diversity, distinctiveness, vital habitat, naturalness, and representativeness. Although this guidance has been developed for identifying significant ecosystems at a national level (drainage division scale), they are equally applicable at the state/territory or regional level, provided they are used within the context of existing jurisdictional processes (see Module 1, Table 1). While the initial driver of the Aquatic Ecosystems Toolkit was to address Clause 25(x) of the National Water Initiative, it has a range of potential uses. As such, the criteria have been designed to be non-prescriptive and there is flexibility in their application.

2.5.1 Origin of the criteria

The criteria draw upon elements of the criteria for identifying wetlands of international importance under the Ramsar Convention and the thresholds for significance for the National Heritage List and *Environment Protection and Biodiversity Conservation Act 1999* (Cwlth) (EPBC) listing for threatened species and communities. This provides commonalities between these identification processes and standardisation of thresholds. The five criteria also capture core criteria used by jurisdictions in existing systems, enabling consistency in identifying HEVAE between and across jurisdictional boundaries (AquaBAMM, CFEV, Water-RAT, AVIRA).

2.5.2 Criteria

Diversity

The aquatic ecosystem exhibits exceptional diversity of species (native/migratory), habitats, and/or geomorphological features/processes.

Diversity includes diversity of ecosystem types (rivers, wetlands, subterranean systems etc.), biotic diversity (within and between species) and/or abiotic (e.g. geomorphic) features and processes.

Species

Places with a high diversity of native and migratory species are particularly important in maintaining biodiversity. The diversity of an individual aquatic ecosystem may be attributable to a diversity of habitats or its location in a centre of speciation.

Species diversity includes the full range of biota including microscopic taxa. Ecosystems identified through systematic and extensive survey for a particular taxonomic group may meet this criterion based on that group alone, rather than the entirety of the biota in that ecosystem.

Genetic diversity is the combination of different genes found within a population of species which is reflected in the patterns of variation between individuals and populations. Genetic diversity is also represented by the number of different species in an area. High genetic diversity within species (i.e. a high number of different gene combinations reflected as a variety of morphological, behavioural and/or physiological differences) should be considered under this criterion, as well as diversity among species. Genetic diversity within and between species are dependent on each other, and both contribute to biological diversity. Places of high genetic diversity are important for preventing the loss of species resulting from environmental change, and for allowing populations to adapt and survive.

Habitats and/or geomorphological features/processes

Diversity of geomorphic features and habitats within an ecosystem is significant in itself and may act as a surrogate for diversity of biota where data is limited.

Application of the criteria

Exceptional diversity should be assessed in respect to the observed/expected diversity. This will avoid naturally low diversity environments (e.g. arid environments) being assessed referentially to high-diversity environments (e.g. temperate floodplain river systems with highly diverse habitats). That is, in species-poor environments (e.g. alpine and arid regions) even if numbers are low relative to other areas, if everything that was expected is observed, then diversity should still be considered as high. If diversity significantly exceeded that which was expected, it could be considered exceptional on the proviso that further investigation did not indicate that the increase in the number of species was not the result of adverse conditions (e.g. eutrophication). The scope of the assessment should determine whether or not this limitation applies.

Where diversity may be generally low, or similar between catchments (for example fish diversity in river catchments, or species of marine vegetation in estuaries), diversity could be assessed relative to a region to account for natural variation in diversity across the landscape and ensure that naturally low diversity areas are represented in the identification of HEVAE.

The measures of diversity selected under this criterion will affect the results and use of the HEVAE assessment. For example, species richness (the number of species present in the ecosystem) is not the same as weighted diversity indices that account for the abundance of each species as well as the number of species present (e.g. Simpson's Diversity Index, Shannon's Diversity Index). Consequently, an assessment of diversity may be more robust if more than one measure is used in the HEVAE assessment. In the northern Australian HEVAE trial, diversity was measured using species

richness, the Shannon Diversity Index, an index of species richness weighted by individual species' frequencies of occurrence, and also a measure of phylogenetic variation (see Kennard 2010; Case Study 2: Northern Australia, in this toolkit).

Diversity should be assessed with reference to the classification of the type(s) of aquatic ecosystem under assessment, and in the context of regionalisation and aquatic ecosystem class (e.g. see Module 2 *Interim ANAE Classification Framework* for guidance on regionalisation and aquatic ecosystem classes). An area with several different types of aquatic ecosystems within its boundaries may be considered of particularly high value.

The use of expert opinion may help determine whether the diversity of species, habitat and/or geomorphological processes and features can be considered significant under the diversity criterion. Expert opinion may be particularly important in the absence of hard data, for example, related to geomorphic diversity. To be considered important at a national level, diversity must be regarded as exceptional, referential to the drainage division.

Distinctiveness

The aquatic ecosystem is rare/threatened or unusual; and/or

The aquatic ecosystem supports rare/threatened/endemic species/communities/genetically unique populations; and/or

The aquatic ecosystem exhibits rare or unusual geomorphological features/processes and/or environmental conditions, and is likely to support unusual assemblages of species adapted to these conditions, and/or are important in demonstrating key features of the evolution of Australia's landscape, riverscape or biota.

The distinctiveness criterion includes not only threatened species and communities but also rare, threatened or unusual aquatic ecosystem, habitats and geomorphological or hydrological features and processes. It also includes endemic species and key geomorphic features that represent Australia's physical and biological evolution.

Maintaining the biodiversity of species and communities is a familiar issue in the management of aquatic ecosystems and ecological values. The concept of rare geomorphic features and processes is less familiar. Such attributes are key components of aquatic ecosystems and, if lost, the possibility of regenerating such features within human time scales is unlikely. Where such features occur, there may be an unusual assemblage of species that is able to exploit the conditions, although the individual species may not be rare or threatened.

Ecosystems with typically low species diversity may score highly under this criterion where the species present are adapted to particular environmental conditions.

Rare and threatened species and communities are protected under legislation at both national and state levels. The *EPBC Act 1999* classes species and communities as 'vulnerable', 'endangered' or 'critically endangered' according to the extent of pressures upon that species or community, its geographic extent or population numbers and rates of decline. In the discussion that follows the term 'threatened' is used to include all of these risk categories.

'Rare' species and communities are considered as those which are not currently threatened, but may be at risk of becoming threatened in the future if circumstances change, while 'unusual' refers to those species or ecosystems whose presence is of particular interest, because of, for example, particular physical or chemical features, unusual interactions with other species, or it is unique to a particular biogeographic region.

Spatial definitions of distribution used under *EPBC Act 1999* may need review for some aquatic ecosystems, such as rivers where linear connectivity confers particular constraints on species distributions. Where necessary, other thresholds using spatial or other measures more appropriate to aquatic ecosystems may be argued from ecological principles.

Depending on the purpose of assessment and/or the scale of application, both state

and Commonwealth listing processes can be considered in identifying rare or threatened species. The level of listing for threatened species identified under the distinctiveness criterion can then be scored from international to regional, with each species scoring once per assessment unit at the highest relevant level (see Case Study 1: Lake Eyre Basin, in this toolkit).

Both the National Heritage List and Australia's Biodiversity Conservation Strategy¹ acknowledge the significance of Australia's evolutionary history. This recognition applies to both physical and biological elements of aquatic ecosystems. Landforms, soils, geological history and palaeoclimates have shaped our landscapes and hence our aquatic ecosystems.

Rare/threatened or unusual aquatic ecosystem

Uncommon habitats or ecosystems demanding particular adaptations of biota are a feature of Australia's biodiversity. Defining what constitutes 'rare', 'unusual' or 'threatened' requires a clear understanding of the full range of habitats and classes or ecosystems.

Threatened habitats may be identified by articulating the processes that are threatening that particular aquatic ecosystem type, whether by human activity or climate change. The impact of threatening processes across a national scale, the rate at which change is progressing, and the scale of impacts should be considered. An estimate of the pre-1790 condition and extent of classes can be used as a reference point for comparative purposes. The identification of threatened ecosystems may act as a surrogate for biodiversity where detailed community and species data is lacking. An unusual aquatic ecosystem may also be one that is important for providing one of only a few known habitats of an organism of unknown but apparently limited distribution.

Supports rare/threatened/endemic species / communities/genetically unique populations

Other frameworks also provide indications of species and communities that are distinctive and of ecological value but do not necessarily fall under legislative provision e.g. some Regional Forest Agreements, some agreements supporting non-forest vegetation conservation. An expert reference panel approach may be one way to verify the claims for inclusion under the distinctiveness criterion, as it would be to all criteria. To avoid individual interests being promoted, decisions would not lie with a single expert.

The aquatic biota, like the biota of Australia's terrestrial environments, is often distinctive, demonstrating ancient and relict components of Pangaeian and Gondwanan origin and adaptations to special conditions including salinity, ephemeral water and variable hydrology. Many species and genera, even numerous families, are endemic. This endemism can be quite localised and reinforces the evolution of Australia's landscapes revealed in the geomorphology.

The scale of application of this criterion is important for identifying endemic species. Those that are endemic to a 'site' may be considered of greater ecological significance than those that are endemic at another chosen spatial level (e.g. drainage division). Thus the scale of application may be defined by the purpose of assessment, or different scales of endemism may be weighted as more or less significant.

Genetically unique populations are those that have become separated (e.g. physically isolated) and evolved to be genetically distinct from other populations of the same species. The genetic variation between individual populations may require consideration to ensure that the distinctiveness of each population type is adequately represented and may require input from genetic experts. It may cover those populations where there is evidence that the local population has physical or behavioural traits that are critical to survival in the local, unique environment.

¹ <http://www.environment.gov.au/biodiversity/strategy/index.html>

Rare or unusual geomorphological features/ processes/ environmental conditions

The geomorphological processes of aquatic ecosystems conspicuously defines character. The kinds of features and processes under this criterion include:

- geomorphic features of limited occurrence at continental scale
- geomorphic features that are vulnerable to threats
- geomorphic features/processes important for evolutionary history
- unusual hydrological features that are driven by geomorphology
- extreme or unusual environmental conditions that affect the biota inhabiting the ecosystem (e.g. water chemistry or temperature) and to which the biota have adapted.

Expert opinion may be used to assess whether such processes and features are rare or unusual, and if they can be considered important under the distinctiveness criterion. Because aquatic ecosystems demonstrating endemism and evolution may be more sparsely/randomly distributed, local expert knowledge could be important, particularly if data sets are lacking.

To be considered important at a national level, geomorphological features/processes or environmental conditions must be rare or unusual within the drainage division. Endemism may also be referential to smaller catchments/regions within the drainage division, and would be considered more significant the smaller the spatial scale.

Vital habitat

An aquatic ecosystem provides vital habitat for flora and fauna species if it supports:

- *unusually large numbers of a particular native or migratory species; and/or*
- *maintenance of populations of specific species at critical life cycle stages; and/or*

- *key/significant refugia for aquatic species that are dependent on the habitat, particularly at times of stress.*

The notion of vital habitat is particularly important in aquatic ecosystem ecology as flora and fauna are often highly dependent upon the patterns of watering, flow, or salinity at various stages of their life cycles. Many iconic aquatic ecosystem species, especially birds, are mobile and may be reliant upon more than one location or habitat type during their life cycle. Vital habitat may be characterised by particular salinity, tidal regimes, hydrology, productivity, seasonal patterns of drying and wetting, or extent and nature of vegetative cover or substrate.

While there may be a tendency to focus on waterbirds under this criterion, there is opportunity to consider any aquatic organisms, depending on the data/knowledge available. For example, diadromous fish require connectivity between systems for feeding and breeding. Rivers without barriers for the movement of aquatic fauna (e.g. fish, turtles etc.) could therefore be considered vital habitat.

Habitat for an unusual abundance of particular species

Large numbers of individual species will gather at some assets where the conditions are particularly favourable for feeding, breeding, nesting, or roosting e.g. Ramsar criteria set the threshold for this criterion at 20,000 waterbirds. This number is appropriate for assessment at a national scale, although lesser numbers may be appropriate at a regional scale. An alternative calculation may be a percentage of the total population, or highest numbers in a region or catchment. For example, in addition to the threshold abundance number above, the Ramsar criteria consider a wetland internationally important if it regularly supports 1 percent of the individuals in a population of a species of waterbird or other water-dependent non-avian species. This can only be used where population counts are reliable.

The Ramsar criteria include multi-species counts. To ensure consistency, multi-species counts will also be included under this criterion.

Supports species of interest in critical life cycle stages

Aquatic ecosystems provide resources required for particular fauna at certain seasons or at critical stages in their life cycle, e.g. breeding, moulting, migration and drought refuge for birds. Such habitats are particularly critical in arid zones. Less obviously, habitats that periodically dry out can be critical for other species, such as some invertebrate taxa and flora which depend on dry periods to develop resting stages or spores for recolonisation or dispersal.

Habitats with requisite characteristics, such as temperature, depth, chemistry, microhabitats, vegetation, will attract large numbers of species of interest. They may be key ecosystems in the wider region for species renewal and maintaining genetic diversity. Fish species may spawn under quite specific conditions in key locations and provide stock for areas beyond the immediate spawning grounds. Significant spawning grounds will apply where required conditions are uncommon or threatened, or fish species are of particular concern.

Characteristics such as those listed above are particularly important for prioritising ecosystems that might be considered to meet this criteria. For example, it could be that only those ecosystems that provide support for multiple critical life stages, e.g. breeding of a variety or abundance of species, moulting of waterbirds, drought refuge, migration stages, are considered. Aquatic ecosystems, notably riverine systems, can be critical to colonisation and extension of range. Under this criterion, importance for distribution and colonisation should only consider species that are directly dependent on the aquatic ecosystem, not incidental flora and fauna.

Aquatic biota, especially birds, must be opportunistic in accessing necessary resources in a variable landscape. Habitats may be critical in some years, but apparently not so in other years. Habitats may be identified as 'vital' on the basis that they provide links in a landscape chain of

habitats required to maintain populations under a variety of environmental conditions and over a number of seasons.

Stopover or seasonal ecosystems for migratory birds meet this criterion. Sites need to be visited on a regular basis by substantial numbers of birds to meet this criterion. In this context, 'regular' may be defined for example, as visits occurring in two thirds of no less than three seasons for which data are available. However, natural variability in use of an ecosystem should be considered; during drought there may be considerable time between visits, although the site will be significant upon re-wetting; therefore data should be interpreted over appropriate time frames. Substantial numbers may be considered, e.g. as a threshold abundance, as a percentage of the total population, or as the highest numbers in a region, but again should take into account natural variability.

Refuges for aquatic-dependent species particularly in times of stress

Drought and unpredictable weather patterns characterise Australia's natural environment. Aquatic ecosystems significant for biophysical features and hydrology will provide a refuge under these conditions. They can sometimes be identified by the increase in number and diversity of species located at the ecosystem during times of stress such as drought, as well as persistence of water and vegetation.

Loss of habitat through fire can also affect certain types of aquatic ecosystems. Ecosystems which as a consequence of topography tend to be less fire-prone are important refuges in the event of wildfire.

Expert opinion may be sought in assessing whether an ecosystem is important under the vital habitat criterion. For consideration at a national level an ecosystem must provide vital habitat for significant numbers of species, and/or critical life cycle stages, and/or refugia at times of stress that is regarded as significant referential to the drainage division.

Naturalness

The ecological character of the aquatic ecosystem is not adversely affected by modern human activity.

Naturalness is a widely accepted term in ecological assessments and can be broadly defined as a lack of human-induced disturbance. It includes ecological integrity, or the capacity of an ecosystem to sustain itself and remain resilient to natural forms of disturbance. Naturalness of aquatic ecosystems is generally inferred from the biota or the capacity of an ecosystem to maintain its natural chemical properties and functions (Dunn 2000).

Systems in natural condition are important for aquatic conservation. Not only are all aspects of ecosystems in natural condition assumed to be intact and functioning, but poorly known or unknown features or species would also be conserved. Naturalness can be determined relative to the pre-European condition, or by identifying those ecosystems where the components and processes are intact and considered outstanding for the region. In the absence of hard data, naturalness can be determined via the assessment of risk and pressures. This works best at a broad scale where detailed site-specific condition information is not available. The naturalness criterion can be aligned with risk and condition, where measured ecosystem components are compared to the levels expected in the absence of any threats/risks. There are entire assessment techniques devoted to this end. For example, the 'naturalness condition' is used for selecting reference sites in the referential approach to river condition assessment both nationally (e.g. in EHMP², AUSRIVAS³, SRA⁴, ISC⁵) and internationally (e.g. EU Water Framework Directive⁶, USEPA⁷).

In identifying systems in 'natural' condition, it is important to acknowledge the limitations of using indicators, such as risks and pressures, as

² <http://www.ehmp.org/EHMPHome.aspx>

³ <http://ausrivas.canberra.edu.au/>

⁴ <http://www.mdba.gov.au/programs/sustainable-rivers-audit>

⁵ <http://www.water.vic.gov.au/monitoring/river-health/isc>

⁶ http://ec.europa.eu/environment/water/water-framework/index_en.html

⁷ http://www.epa.gov/bioiweb1/html/reference_condition.html

surrogates of naturalness, e.g. the presence of barriers or land use. The use of such simplified indicators may not be sufficient to assume that all ecosystem components and processes are intact and functioning in a natural state. It should also be noted that condition does not always reflect the naturalness of an aquatic ecosystem. For instance, there may not be an immediate decline in condition following modification of an ecosystem; alternatively a system that is free of human modifications may appear to be in poor condition at a particular time because of natural disturbance cycles, but will recover rapidly in wetter phases. Therefore, if condition is used to measure naturalness under this criterion, consideration of spatial and temporal scales is required.

Given that many sites are already disturbed to some extent, a more practical approach of using 'least disturbed' is recommended (e.g. this was the basis of the National River Health Program, 1994–2000). Therefore, naturalness will also include aquatic ecosystems functioning in a near-natural way. This will allow the identification of aquatic ecosystems that are not pristine but retain values making them significant (drawn from Ramsar definition of 'near natural').

In some areas, most aquatic ecosystems will meet the naturalness criterion. In these circumstances, greater weighting may be given to other criteria in assessing an ecosystem's environmental values.

Expert knowledge may be used to assess whether an aquatic ecosystem is important under the naturalness criterion. This may be particularly important in regions where pre-European data that could be used as a baseline for assessing naturalness is absent or lacking.

Representativeness

The aquatic ecosystem is an outstanding example of an aquatic ecosystem class to which it has been assigned, within a drainage division.

The representativeness criterion is applied to an assessment region after the other criteria (diversity, distinctiveness, vital habitat, and naturalness) have been applied. Its purpose is to act as a filter to



Perched lake, Fraser Island Queensland (Allan Fox & DSEWPac)

ensure that the full range of (aquatic) ecosystems, and those with the highest ecological value, in a defined region are identified.

At the national level, HEVAE proposed under this criterion will, as far as possible, be among the ‘best’ or ‘outstanding’ examples of that aquatic ecosystem within the drainage division. That is, they should be typical of the class and retain the key ecosystem components and functions of that class, or be a rare example of the class. It is anticipated that this criterion would be applied at the end of the HEVAE identification process, and as a means of confirming that all classes that occur in the drainage division are captured.

In order to assess ‘representativeness’ of ecosystems there are two requirements:

- An agreed scale (that is fit for purpose).
At the national level, the Australian Drainage Divisions system for inland waters and the Integrated Marine and Coastal Regionalisation of Australia (IMCRA) for marine systems should be used as the scale of implementation of the HEVAE criteria.

At the state/territory or regional level, alternative systems may be selected e.g. catchments or sub-catchments.

- A classification for each ecosystem type. The *Interim Australian National Aquatic Ecosystem (ANAE) Classification Framework* has been developed, in part, to enable ubiquitous classification of aquatic ecosystems across Australia. Candidate HEVAE should be compared to all current HEVAE identified within the same region (e.g. drainage division). If the system is the best of its type in the drainage division or contains habitats that are under-represented, it will fulfil the representativeness criteria. Refer to the *Interim ANAE Classification Framework* (Module 2) for details of how to establish the ecosystem’s classification.

Under the representativeness criterion, expert knowledge may be used to drive the selection of HEVAE not identified in the initial assessment, and to decide whether particular aquatic ecosystem types need to be represented (i.e. there are sufficient ecological values to be identified as HEVAE).

3 Workflows

3.1 Groundwork before identifying HEVAE

In order to successfully apply the Guidelines for Identifying HEVAE, a number of preliminary tasks (Figure 2) need to be completed:

- identify the purpose of the assessment
- aquatic ecosystem classification and mapping
- identify an appropriate scale
- adopt a regionalisation with relevance to aquatic ecosystems in the area of interest
- identify and engage expert input.

Step 1 Identify purpose

Clearly identifying the purpose of the assessment should be the first step of any assessment process. This will underpin many of the subsequent decisions such as which modules should be applied, the selection of appropriate criteria and attributes, the scale at which the HEVAE criteria are applied, and thresholds for identifying HEVAE. For instance, is the assessment for planning, legislative or funding purposes and will other criteria be necessary in addition to the biophysical ones outlined in the HEVAE guidelines? In some instances the identification of HEVAE may only form part of the overall assessment process. It is essential that this step is clearly documented and clarified because if it is poorly scoped out it may result in assessment results that do not align with its intended use.

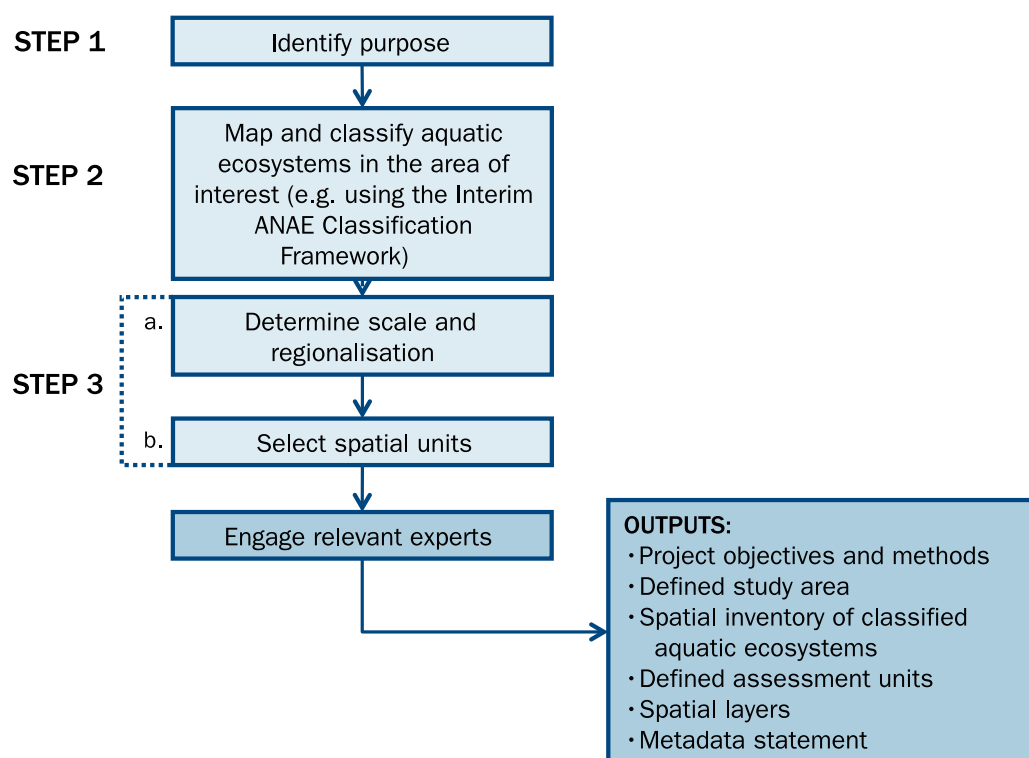


Figure 2 Groundwork steps to undertake before identifying HEVAE

Step 2 Map and classify aquatic ecosystems

Mapping and classification of aquatic ecosystems in the area of interest should be undertaken prior to the commencement of the HEVAE assessment. The importance of aquatic ecosystem mapping and a consistent, applied classification is paramount to the success of the implementation of the tools. National mapping guidelines and the *Interim Australian National Aquatic Ecosystem (ANAE) Classification Framework* (Module 2) are methods appropriate for this process. Notwithstanding, if consistent mapping and classification of the area of interest exists, or other appropriate methods are available, these can be used in place of the above methods.

Step 3 Determine scale, regionalisation, and spatial units

Scale is the level at which you decide to work e.g. national, catchment, reach. Regionalisation is the manner in which you break up the landscape into manageable pieces (artificial or related to the landscape) at the chosen scale e.g. drainage division, sub-catchment, habitat. Spatial units are the smaller landscape units against which data can be assigned e.g. assessment units, aquatic ecosystem boundary.

a. Determine scale and regionalisation

- At the national scale, the AETG and NRPPC have recommended that the application of a HEVAE assessment will be at the drainage division level for inland waters, and the Integrated Marine and Coastal Regionalisation of Australia (IMCRA)⁸ for marine ecosystems that are less than 6 metres in depth at low tide (see Module 2 *Interim ANAE Classification Framework* for further detail).
- The Australian Hydrological Geospatial Fabric (Geofabric)⁹ is a readily available system to determine the boundaries of drainage divisions. The Geofabric identifies the spatial relationships of important hydrological features such as rivers, lakes, reservoirs, dams, canals and catchments. Drainage divisions are defined by these major landscape features and climatic zones to form broad hydrological regions.

- Surface-water assessments undertaken at the state/territory or regional level may select alternative systems e.g. catchments or sub-catchments. Assessments of groundwater ecosystems may cross some of these boundaries.
- Attention should also be given to deciding if it is necessary to have sub-groups within the selected region against which assigned data can be compared referentially e.g. catchment, IBRA bioregion, Surface Water Management Areas (SWMAs).

b. Select spatial units

- Aquatic ecosystems occur on a variety of scales in terms of both spatial distribution within the landscape and in physical area or size. The HEVAE criteria are designed to be used at a variety of scales, with aquatic ecosystems ranging in size from small, discrete systems, such as rain-fed rock pools in arid landscapes, aggregations of ecosystems, to whole river systems, depending upon the purpose of the assessment.
- Where relevant data is poor and/or aquatic ecosystem mapping is limited, it is possible to 'break' the landscape up into manageable spatial units at a scale appropriate for the purposes of the assessment. These spatial (or assessment) units can be related to the landscape e.g. catchment-based such as nested catchments, Geofabric, Pfaffstetter, or artificial e.g. a grid.
- Where data is more plentiful and the area fully mapped, it may be possible to attribute that data directly to the aquatic ecosystems. The process of identifying HEVAE is then a matter of aggregation of the aquatic ecosystems into meaningful ecological units.

⁸ <http://www.environment.gov.au/coasts/mbp/publications/imcra/imcra-4.html>

⁹ <http://www.bom.gov.au/water/geofabric/index.shtml>

- A critical evaluation of the selected assessment units should be undertaken to consider whether any should be merged or the boundaries re-defined to ensure they are relevant and sensible (e.g. if they dissect large waterbodies, or ecological units). It should be noted that following the application of the criteria, assessment units may need to be re-evaluated again, to address any identified overlaps of adjoining assessment units.

3.2 Identifying HEVAE

This module of the Aquatic Ecosystems Toolkit provides guidance on the process of applying the criteria and identifying HEVAE (Figure 3). The major components of this process are to:

- select appropriate criteria and identify the attributes and metrics for each criteria
- identify and collate relevant data, and assign to assessment units/aquatic ecosystems
- apply the criteria
- develop and apply a scoring system to identify HEVAE
- validate identified HEVAE.

Reference is made in the following steps to a series of case studies that illustrate the process of identifying HEVAE. These case studies are part of the toolkit (Aquatic Ecosystems Task Group 2012a; 2012b; 2012c).

Step 4 Assign attributes to chosen spatial unit

The following principles should be considered when selecting criteria, attributes and metrics, and assigning data to spatial units. In addition, Appendix A provides examples of attributes and metrics to guide in the selection and application of criteria and attributes. Note that not all attributes will be applicable everywhere, and should be selected based on the ecological characteristics of the applicable region and the purpose of the assessment.

a. Selection of criteria

- In most instances the identification of HEVAE will mean that all the criteria should be applied, although decisions may be taken not to incorporate results from criteria that provide no value to the assessment (e.g. some areas might have blanket coverage for a particular criterion, rendering it non-discriminatory and therefore of limited use) (see Case Study 1: Lake Eyre Basin).
- The absence of detailed site-specific data does not mean that criteria cannot be applied. Where the data is absent or patchy, surrogacy or modelling may assist in ecosystem-by-ecosystem analysis, although confidence levels should be assigned. This approach was used in the trial of the draft HEVAE Framework (now Module 3) in northern Australia (see Case Study 2: Northern Australia).
- The scope of the HEVAE criteria is limited only to those of an ecological nature. While it is recommended that for consistency only the core criteria are used for assessments at a national scale, additional ecological criteria could be applied at local or regional scales in conjunction with the core criteria. Although it is beyond the scope of these guidelines to apply social, cultural or economic criteria as part of the assessment process, there is potential to incorporate them if desired. As such, it is up to those conducting the assessment to decide on how those criteria should be incorporated.

b. Selection of attributes

- Measurable attributes for each criterion should be identified. Attributes are a specific description of one component of a criterion that provides the basis for data collection and to score or characterise criteria. Attributes should be selected on the basis of available data and appropriateness to the purpose of assessment. They should not only be scientifically defensible, but also practical in terms of data, time and resource availability. Care should be taken to ensure attributes are not repeated within or across the criteria.

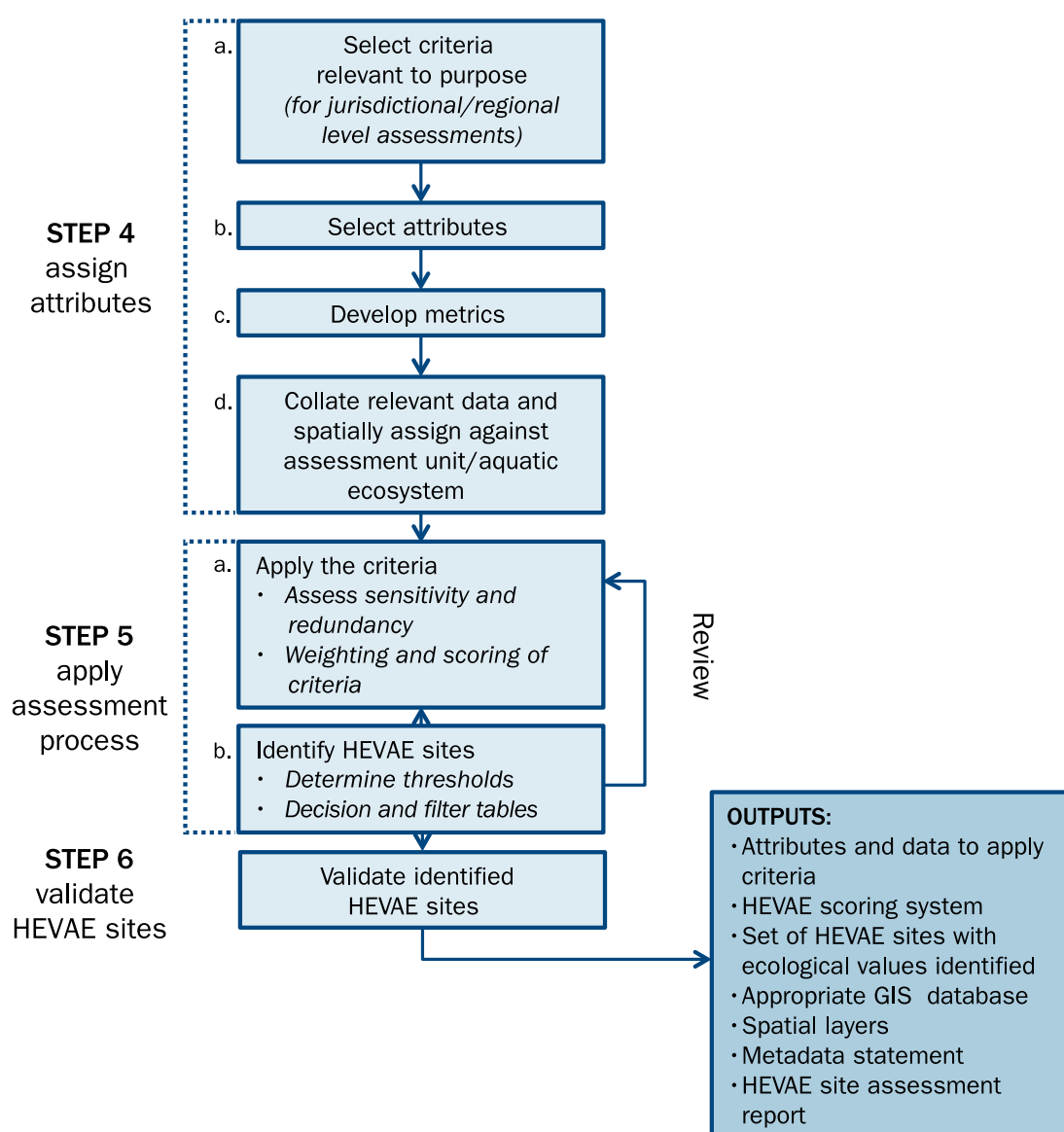
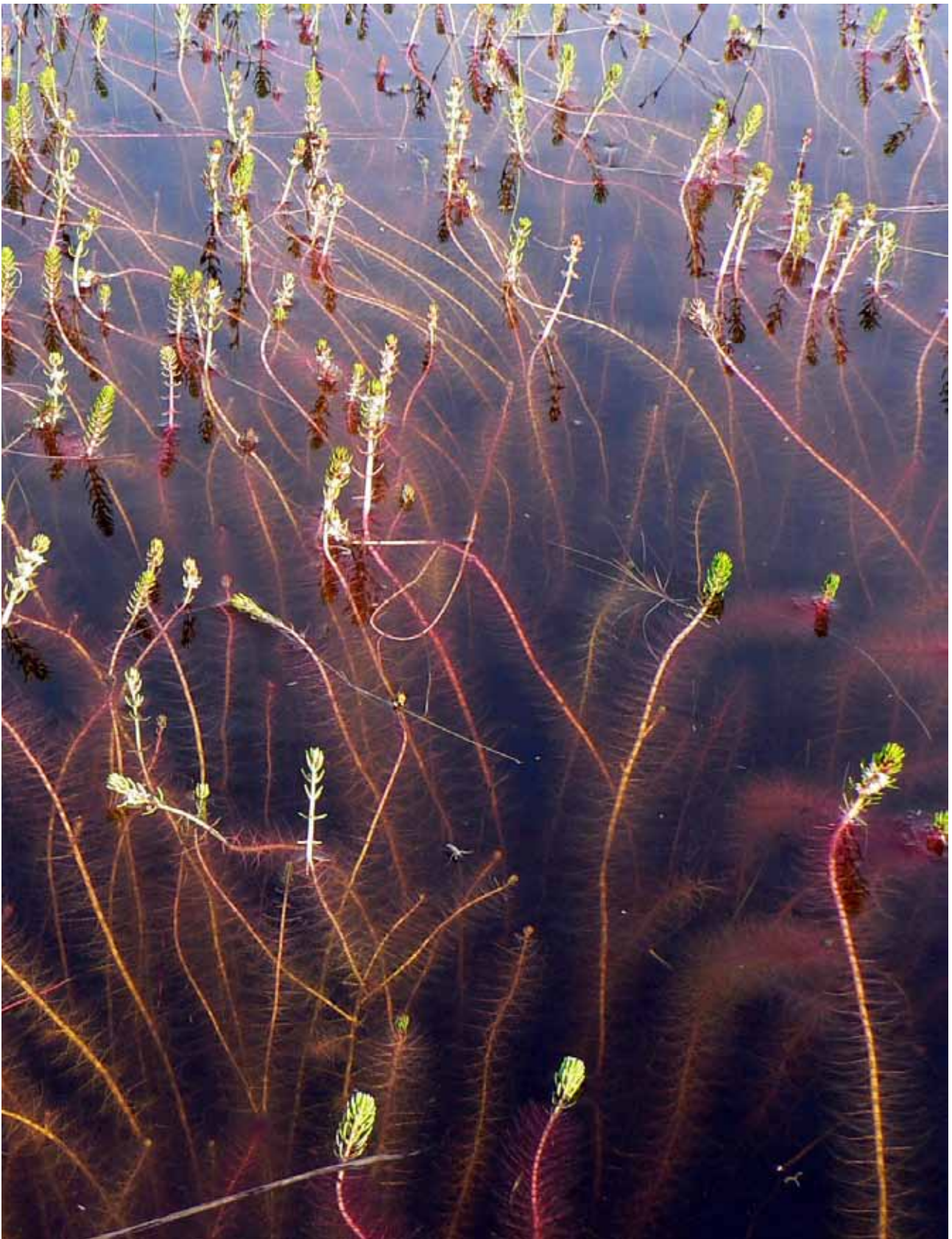


Figure 3 Flow chart for the process of applying the criteria and attributes to identify HEVAE

- Attributes selected should reflect data that is of sufficient quality and spatial extent, thus improving confidence in the appropriateness of identified HEVAE. Modelling and surrogacy may be used to improve the quality and extent of data as appropriate. However, the selection of attributes should be justified through the use of ecological knowledge/theory, and not only driven by available data.
- The data should also be examined to ensure that those species used in the systematic analysis are appropriately dependent on the aquatic environment for part or all of their life cycle.
- The approach taken in the assessment (e.g. direct assignment of data, surrogacy, or modelling) will guide the number and type of attributes applied. However, it is advised that attributes are selected carefully, so that only those considered most important are applied, rather than applying as many attributes as possible for each criterion.
- Attribute characteristics should also:
 - be considered particularly significant in the region undergoing assessment
 - allow comparisons to be made across ecosystems



Water milfoil (Diane Conrick)

- be drawn from other similar projects/ processes where they exist
- be relevant to the associated criteria.
- Attributes should be critically assessed each time the HEVAE guidelines (Module 3) are applied, considering the purpose of the exercise, methods for applying criteria, and the ecological characteristics of the area of interest. Many of the attributes are common to most purposes and/or areas of interest e.g. species richness, threatened species, but there will be some that are specific to regions and purposes e.g. importance of permanent water.

c. Development of metrics

- One or more metrics or measures may be required for each attribute, depending on the characteristics of the assessment area (e.g. drainage division), the types of ecosystems being assessed, the spatial unit of assessment (e.g. river reaches, catchments) and the availability of suitable data. For instance, metrics to apply an attribute, such as species richness, under the diversity criterion might include empirical measures such as the number of fish species, number of waterbird species, and number of amphibian species etc., or be a derived measure e.g. Shannon's Diversity Index. Under the vital habitat criterion, an attribute may be waterbird abundance, which could be measured by the presence of significant waterbird populations (e.g. greater than 20,000) (see Appendix A for further examples).
- Metrics should be assessed by comparison to the range of expected values within the selected referential area (see step 3a, Case Study 1: Lake Eyre Basin).
- Metrics may be referential to one or more regions e.g. drainage division, an Interim Biogeographic Regionalisation of Australia (IBRA) region, catchment; this is determined using ecological knowledge. For instance, in order to fairly assess naturally species-poor environments, with species-rich environments, it may be necessary to make species richness referential to a catchment or bioregion, rather than the entire drainage division.

d. Compile and assign data

- The robustness of any HEVAE assessment lies with the data that underpins it, and data limitations may impact on the ability to apply the criteria. Therefore it is essential that before any data is assigned or analysis is attempted the data is compiled, preferably into one dataset. Data can be gathered from many sources e.g. national, jurisdictional, research and academic databases, museum collections, and ad hoc sources.
- The manner in which this collated dataset is used is dependent on the proposed methodology, and to some degree the purpose of the assessment. Data can be used in several ways:
 - Empirical data—raw or 'massaged' data is used. This method enables the user to drill down to the original data post analysis to provide supporting evidence, although it is more difficult to be referential. There can be issues associated with the use of raw data, particularly with respect to the cultural and ecological sensitivity of some attributes e.g. location information for threatened species, significant indigenous sites.
 - Modelled data—where data distribution is patchy in coverage, but relatively comprehensive from the viewpoint of aquatic ecosystem types, gathered data can be used to create models of specific attributes or metrics to provide universal coverage across the area of interest, albeit still assigning against assessment units or aquatic ecosystems. The development of predictive models goes some way in overcoming sample biases, which often exist where data is inconsistent. As only modelled data is used, there is no ability to query the original dataset (Case Study 2: Northern Australia).

Existing datasets—specific datasets developed for other prioritisation purposes are used. In this situation the selection of attributes and associated data is a more prescriptive, and somewhat easier task (Case Study 3: Tasmania, in this toolkit).

- Empirical and modelled data can be further manipulated by categorising the data. By compiling the data into categories it is easier to handle, consistent and referential, but the ability to drill down to the original information is lost (Case Study 1: Lake Eyre Basin).
- Once the data has been compiled it is spatially assigned to the assessment unit or aquatic ecosystem and stored in an appropriate geographic information system database.
- The source of the data should be recorded in the dataset.

Step 5 Apply the assessment process and identify units of high ecological value

a. Apply the criteria

- Once the data has been compiled and assigned, the attributes and metrics should be scrutinised to ensure there is no redundancy (discarding those attributes/metrics that are not providing any additional meaning to the analysis), or ‘double dipping’ (a repeat of an attribute/metric used under another criterion/attribute). This may be achieved through correlation analysis (e.g. using Spearman’s rank correlations), and ecological knowledge and reasoning. Attributes that are found to be highly correlated and for which the functional relationship is well understood can be identified as potentially redundant and removed from the analysis (Chadderton, Brown & Stephens 2004, cited in Hale 2010). In other instances, although the statistical test may indicate that some attributes are correlated, there may be value in retaining all the attributes. This is where ecological knowledge is valuable.
- Once a score has been developed for each attribute and/or metric, it is necessary to integrate them to obtain a score for each

criterion. Several methods of scoring and integration have been identified as being of potential use in applying the HEVAE criteria including categorical scales, averaging, and percentiles (Table 1). For advantages, disadvantages and examples of using each potential method, refer to Appendix B.

- Weighting may be undertaken using a sound statistical and/or expert knowledge approach, although the method used to integrate attributes will influence how they are weighted.
- A degree of uncertainty in the data used to apply the attributes is likely and so data assurance should also be considered. This can be accounted for during the weighting process (i.e. higher weightings are associated with greater certainty). Alternatively, data assurance can be flagged when populating the database.
- Sensitivity is the overall contribution or effect a metric or attribute has on the criteria. Sensitivity analyses may be undertaken for attributes and metrics, weightings, and/or aggregation of assessment units as appropriate. This can be achieved by re-running the complete analysis with, for example, one metric omitted for each re-analysis, and the average percent change in the criteria recorded. Undertaking such an analysis will indicate how robust the assessment has been and the level of confidence that can be assigned to the outcomes. Similarly, sensitivity can be analysed in the applied weightings by repeating the scoring of assessment units both with and without weightings. Such analysis can provide information on the strength of the weighting arguments.
- Once a set of HEVAE have been identified, if time and resources permit, it may be appropriate to review them to identify any that overlap with adjacent assessment units. If it is found that this situation exists, those relevant assessment units should be combined and the assessment re-run (i.e. steps 4a and b are repeated).

Table 1 Suggested methods of scoring and integrating attributes and/or metrics to obtain criterion scores

METHOD	DESCRIPTION
1. Simple averaging (mean)	Take the mean of the attributes/metrics (these may be weighted).
2. Simple averaging (median)	Take the median of the attributes/metrics (these may be weighted).
3. Precautionary principle	Applying a weight to the most conservative attributes/metrics.
4. Priority principle	Only consider the attributes/metrics that are above average (say in the top 10% of values for that attribute/metric across all spatial units). All non-significant values are removed from the analysis.
5. Quartile/threshold	The quartiles of the data are used to set thresholds and each unit receives an ordinal score for each attribute/metric, e.g. 1 = poor, 2 = acceptable, 3 = good, 4 = very good.
6. Quartered/threshold (AquaBAMM)	Mean of the highest three scores divided by four, e.g. mean = 10, then the categories are: very high = >7.5; high = >5 to 7.5; medium = 2.5 to 5; low = < 2.5.
7. Standardised Euclidean distance	Pythagoras's theorem extended across multiple dimensions. The standardised Euclidean distance tends to return values lower than the mean of the two scores and higher than the precautionary principle method.
8. Expert Rules/Fuzzy Logic	Intelligent decision making involved before including all attributes/metrics.
9. Jenks natural breaks	Classification determined by comparing sums of squared difference and assigning categories based on the minimum differences in squared difference.
10. Percentiles	Based on percentiles of the data (e.g. low = 1% to 10%, medium = >10% to 50%, high = > 50% to 90%, very high = >90%).

b. Identify HEVAE

- The number (or threshold) of criteria to be met to achieve HEVAE status should be determined on a case-by-case basis, and will be guided by the purpose of the assessment.
- Once the criteria have been scored, decision rules should be applied to categorise the scores into a set of prioritised HEVAE. There are a number of potential approaches that can be used in this process. For example, a decision may be that the threshold for inclusion as a HEVAE is that it meets one criterion, or alternatively, a minimum number of criteria.
- Depending on the purpose of the assessment, some criteria may be considered more important than others for identifying HEVAE. Consequently, those assessment units that scored higher for those particular criteria may be identified as being a higher priority HEVAE. Alternatively, it may be appropriate to simply assume that the greater number of criteria met, the greater the ecological value and those assessment units that meet the most criteria are identified as HEVAE. However, a decision is required on the threshold or 'cut-off' for determining which assessment units are considered the priority HEVAE.

- The use of filter tables is the recommended method for prioritising HEVAE, such as those used in Queensland's AquaBAMM toolkit (Clayton et al. 2006). Filter tables involve systematic comparisons of each criterion score against pre-defined 'if-then' statements that serve as decision rules. These ecologically meaningful statements are ordered into a filter table and the criterion scores sequentially compared to the statements to establish the HEVAE status of each assessment unit. The statements contained within the filter table will be determined on a case by case basis.
- Overall, decision rules applied to the filter table should be prioritised, based on the purpose of the assessment, and not developed generically. The relative importance of each criterion score will also be sensibly driven by the purpose of the assessment. For instance, if a categorical scoring approach has been used, it may be appropriate that an aquatic ecosystem that has criterion scores of 'high' in three criteria, is given greater priority than an aquatic ecosystem with a single criterion score of 'very high' and the remainder scoring 'low' (see Case Study 1: Lake Eyre Basin).
- Whether or not the final criteria scores are merged into one overall score for the assessment unit/ecosystem will depend upon the purpose of the assessment. Whilst it could be useful for a broad-scale prioritisation purpose to integrate criteria scores, retention of individual criteria scores will provide a degree of transparency in the scoring and enable easier drilling back into the data for the delineation phase.
- The use of additional sources of information such as expert opinion and local knowledge to augment the analysis in situations where data is patchy or limited should be considered. Expert opinion, ecological theory and the literature should also be considered when determining thresholds. This will help to ensure that all aquatic ecosystems of the highest ecological value are identified through the assessment process (e.g. see Case Study 1: Lake Eyre Basin).

- In all cases, the method used to determine the thresholds for identifying HEVAE should be ecologically relevant, justifiable and relevant to the purpose of the assessment.

Step 6 Validate identified HEVAE

As much of this assessment process depends on spatial analysis it is important to make an assessment of whether those HEVAE identified align with what is known about those aquatic ecosystems of highest ecological value in the assessment area, thus validating their status as HEVAE.

- In the first instance, this step may be undertaken through expert opinion (e.g. see Case Study 1: Lake Eyre Basin). Ideally, however, identified HEVAE should be validated through a 'ground-truthing' process in the field, to confirm that those ecosystems identified as HEVAE in the assessment process are a true reflection of the values that currently exist on-ground (e.g. see Case Study 3: Tasmania).
- This step provides a link with Module 4 *Aquatic Ecosystem Delineation and Description*. Consequently, this step can be undertaken as either part of the HEVAE assessment, or as part of the delineation and description process, if this is to be undertaken.
- The validation process should also include a review of the assessment process and identified HEVAE to ensure errors in the application of the methodology have not occurred, and that HEVAE have not been incorrectly identified as a consequence.

Outputs

It is essential that a full record of the approach used to identify HEVAE be maintained through both a report and a metadata statement. Examples of reporting the HEVAE identification process are provided in the case studies, and checklist and record sheet templates are provided in Appendices C and D respectively. Additionally, any spatial output should be maintained along with supporting documentation.

4 Glossary

The following terms and their definitions are specifically for the purposes of the Aquatic Ecosystems Toolkit.

Abiotic features	Non-living chemical and physical factors in the environment.
Aggregation	Statistical: the grouping of data combined from several measurements that provide information on a broader level than the level at which the detailed data was collected.
AquaBAMM	Aquatic Biodiversity Assessment and Mapping Method (AquaBAMM) is a comprehensive method that identifies relative wetland conservation values within a specified study area (usually a catchment). < http://wetlandinfo.derm.qld.gov.au/wetlands/SupportTools/AssessmentMethods/AquaBAMM/Method.html >
Aquatic ecosystem-dependent species	Those species that depend on aquatic ecosystems for a significant portion or critical stage of their lives (fauna) or are dependent on inundation or waterlogging for maintenance or regeneration (flora).
Aquatic ecosystems	Ecosystems that depend on flows, or periodic or sustained inundation/waterlogging for their ecological integrity (e.g. wetlands, rivers, karst and other groundwater-dependent ecosystems, saltmarshes and estuaries) but do not generally include marine waters (defined as areas of marine water the depth of which at low tide exceeds 6 metres, but to be interpreted by jurisdictions). For the purpose of the Aquatic Ecosystems Toolkit, aquatic ecosystems may also include artificial waterbodies such as sewage treatment ponds, canals and impoundments.
Assessment unit	The spatial unit at which the attributes and criteria for identifying HEVAE are applied in a 'top-down' assessment.
Attribute	An attribute is a mathematical or statistical indicator, or characteristic of a HEVAE criterion that provides the basis for scoring. An attribute may contain several metrics that are aggregated to provide an attribute score.
Biodiversity	Biodiversity (or biological diversity) is 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 a part; this includes diversity within species (genetic diversity), between species (species diversity), of ecosystems (ecosystem diversity), and of ecological processes.
Biodiversity surrogate	Commonly used to optimally represent multiple components of unmeasured biodiversity. Biodiversity surrogates include taxa (e.g. species), the characters they represent (e.g. phylogenetic relationships), assemblages or environmental habitats (different types of environments are assumed to support different combinations of species).
CFEV	The Conservation of Freshwater Ecosystem Values Framework in Tasmania < www.dpiw.tas.gov.au/inter.nsf/ThemeNodes/CGRM-7JH6CM?open >
Community	An assemblage of organisms characterised by a distinctive combination of species occupying a common environment and interacting with one another.
Components	The physical, chemical and biological parts of an aquatic ecosystem e.g. habitat, species, genes etc.

Condition	The state or health of individual animals or plants, communities or ecosystems. Condition indicators can be physical-chemical or biological and represent the condition of the ecosystem. They may also be surrogates for pressures and stressors acting within the ecosystem.
Connectivity	Environmental connectivity consists of links between water-dependent ecosystems that allow migration, colonisation and reproduction of species. These connections also enable nutrients and carbon to be transported throughout the system to support the healthy functioning and biodiversity of rivers, floodplains and wetlands. Hydrologic and ecological links are between upstream and downstream sections of river (longitudinal connectivity) and between rivers and their floodplains (lateral connectivity).
Delineation	Delineation is the spatial identification, mapping and recording of an identified ecosystem, including its core elements and ecological focal zones.
Diadromous	Migrating between freshwater and marine environments.
Ecological Value	Ecological value is the perceived importance of an ecosystem, which is underpinned by the biotic and/or abiotic components and processes that characterise that ecosystem. In the Aquatic Ecosystems Toolkit, ecological values are those identified as important through application of the criteria and identification of critical components and processes in describing the ecological character of the ecosystem (or another comparable process).
Ecosystem	An ecosystem is a dynamic combination of plant, animal and micro-organism communities and their non-living environment (e.g. soil, water and the climatic regime) interacting as a functional unit. Examples of types of ecosystems include forests, wetlands, grasslands and tundra (Natural Resource Management Ministerial Council 2010).
Ecosystem function	Activities or actions which occur naturally in ecosystems as a product of the interactions between the ecosystem structure and processes e.g. floodwater control, nutrient, sediment and contaminant retention, food web support, shoreline stabilisation and erosion controls, storm protection, and stabilisation of local climatic conditions, particularly rainfall and temperature.
Endemic species	A species or higher taxonomic unit found only within a specific area.
Floodplain	Those aquatic systems that are either seasonally or intermittently flooded flat areas that are outside the riverine channels or palustrine/lacustrine systems but that display characteristics of hydric soils or vegetation that are characteristically adapted to the seasonal or intermittent presence of water.
Groundwater-dependent ecosystem (GDE)	Natural ecosystems that require access to groundwater to meet all or some of their water requirements on a permanent or intermittent basis so as to maintain their communities of plants and animals, ecological processes and ecosystem services.
Habitat	The environment where an organism or ecological community exists and grows for all or part of its life.
High Ecological Value Aquatic Ecosystems (HEVAE)	For the purposes of the toolkit, HEVAE are aquatic ecosystems that are considered to be of high ecological value as determined by a consistent and objective process such as that provided by Module 3 <i>Guidelines for Identifying High Ecological Value Aquatic Ecosystems (HEVAE)</i> .

HEVAE criteria	The HEVAE criteria are the five core biophysical characteristics that have been agreed by the Aquatic Ecosystems Task Group as appropriate for the identification of HEVAE: diversity, distinctiveness, vital habitat, naturalness and representativeness.
Metric	A metric is a specification for how an attribute will be measured. It may be binary ('yes' or 'no', 'present' or 'absent'), a ranking (high, medium, low), or a number.
Precautionary principle	States that a lack of full scientific certainty should not be used as a reason for postponing a measure to prevent degradation of the environment where there are threats of serious or irreversible environmental damage.
Pressure	Activities and processes, which act on the environment and bring about environmental change.
Processes	Are the dynamic forces within an ecosystem. They include all processes that occur between organisms and within and between populations and communities, including interactions with the non-living environment that result in existing ecosystems and that bring about changes in ecosystems over time.
Ramsar Convention	<p>Convention on Wetlands of International Importance especially as Waterfowl Habitat. Ramsar (Iran), 2 February 1971. UN Treaty Series No. 14583. As amended by the Paris Protocol, 3 December 1982, and Regina Amendments, 28 May 1987. The abbreviated names 'Convention on Wetlands (Ramsar, Iran, 1981)' or 'Ramsar Convention' are used more commonly.</p> <p>The 'Ramsar Convention' is an intergovernmental treaty that embodies the commitments of its member countries to maintain the ecological character of their 'Wetlands of International Importance' and to plan for the 'wise use' or sustainable use of all of the wetlands in their territories.</p> <p>Based on information found at http://www.ramsar.org.</p>
Refugia	A place where organisms can survive during periods of stress.
Riverine	Those systems that are contained within a channel and its associated streamside vegetation. This definition refers to both single channel and multi-channel systems e.g. braided channel networks. The beds of channels are not typically dominated by emergent vegetation, may be naturally or artificially created, periodically or continuously contain moving water, and may form a connecting link between two bodies of standing water. See Module 2 for more information.
Subterranean	Subterranean aquatic systems comprise all underground areas containing water.
Surface water	Includes water in a watercourse, lake or wetland, and any water flowing over or lying on the land after having precipitated naturally or after having risen to the surface naturally from underground.

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Appendix A

Examples of attributes and metrics for HEVAE criteria

1. DIVERSITY
The aquatic ecosystem exhibits exceptional diversity of species (native/migratory), habitats, and/or geomorphological features/processes.
PILOT TRIALS
<ul style="list-style-type: none"> • Three or more aquatic ecosystem types (hydrologically connected and interdependent) • Three or more aquatic ecosystem classes (hydrologically connected and interdependent) • All or most of the communities typical of that ecosystem class • Species diversity exceeds expected • Species diversity more than two standard deviations from mean • High diversity of taxa at higher taxonomic levels (e.g. genus, family)
LEB TRIAL
<p>Diversity of aquatic ecosystem type:</p> <ul style="list-style-type: none"> • Number of aquatic ecosystem types within an assessment unit. <p>Diversity of native aquatic ecosystem-dependent species:</p> <ul style="list-style-type: none"> • number of fish species. • number of waterbird species. • number of reptile species. • number of amphibian species. • number of mammal species. • number of woody perennial plant species. • number of non-woody plant species. <p>Diversity of aquatic ecosystem vegetation types:</p> <ul style="list-style-type: none"> • number of aquatic ecosystem vegetation types within an assessment unit.
NA TRIAL
<p>Richness:</p> <ul style="list-style-type: none"> • number of taxa in a planning unit. <p>Diversity:</p> <ul style="list-style-type: none"> • Shannon Diversity—index that incorporates the number of species and the evenness of distribution of individuals across species (Shannon 1948). <p>Richness Index:</p> <ul style="list-style-type: none"> • an index of species richness which is weighted by individual species' frequencies of occurrence (Minns 1987; Chu, Minns & Mandrak 2003). <p>Phylogenetic Diversity:</p> <ul style="list-style-type: none"> • a measure of diversity based on units of phylogenetic variation (instead of species) (Faith 1992; Faith, Reid & Hunter 2004).
TASMANIA TRIAL
Sites of fauna species richness.

2. DISTINCTIVENESS
<p><i>The aquatic ecosystem is a rare/threatened or unusual aquatic ecosystem; and/or supports rare/threatened/endemic species/communities/genetically unique populations; and/or exhibits rare or unusual geomorphological features/ processes and/or environmental conditions, and is likely to support unusual assemblages of species adapted to these conditions; and/or are important in demonstrating key features of the evolution of Australia's landscape, riverscape or biota.</i></p>
PILOT TRIALS
<ul style="list-style-type: none"> • Rare and aquatic ecosystems or habitats • Threatened aquatic ecosystems or habitats • Supports EPBC-listed species, i.e. species listed under the <i>Environment Protection and Biodiversity Conservation Act 1999</i> (Cwlth) • Supports EPBC-listed communities • Exhibits rare or unusual geomorphological features, processes or environmental conditions at a continental scale • Provision of habitat for an unusually high diversity of endemic taxa • Provision of habitat for a diversity of taxa endemic at higher taxonomic levels • Provision of habitat for a group of endemic species suggesting a centre of speciation • Provision of habitat for a sequence of related taxa indicative of evolutionary processes • Provision of habitat for iconic species recognised as 'living fossils'
LEB TRIAL
<p>Threatened species:</p> <ul style="list-style-type: none"> • accumulated scores based on the presence of aquatic ecosystem-dependent threatened species (scores based on level of listing). <p>Priority species:</p> <ul style="list-style-type: none"> • number of priority aquatic ecosystem-dependent species in each assessment unit. <p>Migratory bird species (East Asian–Australasian Flyway):</p> <ul style="list-style-type: none"> • number of migratory bird species in each assessment unit. <p>Distinctive, rare or threatened geomorphic, hydrological or ecological features.</p> <p>Threatened ecological community:</p> <ul style="list-style-type: none"> • number of EPBC-listed threatened aquatic ecological communities. <p>Conservation status of aquatic regional ecosystems:</p> <ul style="list-style-type: none"> • scored as: <ul style="list-style-type: none"> – endangered; – of concern; – not of concern; – none present. <p>Endemic species:</p> <ul style="list-style-type: none"> • accumulated scores based on the presence of endemic species in the assessment unit: <ul style="list-style-type: none"> – endemic to assessment unit; – endemic to the SWMA; – endemic to the drainage division • species only scored once per assessment unit at the highest relevant level.

NA TRIAL
<p>Rarity Index:</p> <ul style="list-style-type: none"> • an index of species' rarity based on the mean frequent of occurrences of individual species/ecotopes. <p>Rare and threatened species score:</p> <ul style="list-style-type: none"> • the number of aquatic ecosystem-dependent species listed on the International Union for Conservation of Nature Red List and/or the EPBC Act as endangered, vulnerable or conservation-dependent multiplied by an arbitrary ranking. <p>Number of monospecific genera:</p> <ul style="list-style-type: none"> • calculated simply as the number of monospecific genera (genera or families of taxa that contain only a single species) recorded from a planning unit. <p>Number of species endemic to a region:</p> <ul style="list-style-type: none"> • a simple index of endemism calculated as the number of species present in a single region. <p>Taxonomic endemism index:</p> <ul style="list-style-type: none"> • an index of endemism identifying areas where species with restricted ranges are concentrated, based on the number of species within a planning unit weighted by the inverse of each species' distribution range (also known as weighted endemism). <p>Phylogenetic Endemism Index:</p> <ul style="list-style-type: none"> • a measure of the degree to which elements of evolutionary history are spatially restricted in space. To estimate the degree of Phylogenetic Endemism represented by the taxa in a given area, the range size of each branch of the phylogenetic tree (rather than the range of each taxon) is quantified. The index is the sum of the branch length/clade range for each branch on the tree (where a clade is a single branch on the tree consisting of an organism and all its descendants).
TASMANIA TRIAL
<ul style="list-style-type: none"> • Priority freshwater taxa/communities • Threatened native vegetation communities • Nationally important features • Threatened species • Phylogenetically distinct flora/fauna • Distinctive ('primitive') taxa

3. VITAL HABITAT
<p>An aquatic ecosystem provides vital habitat for flora and fauna species if it supports unusually large numbers of a particular native or migratory species; and/or maintenance of populations of specific species at critical life cycle stages; and/or key/significant refugia for aquatic species that are dependent on the habitat, particularly at times of stress.</p>
PILOT TRIALS
<ul style="list-style-type: none"> • Location for very large number of individuals (e.g. >20 000 waterbirds) <ul style="list-style-type: none"> – or identifying the 'largest' number rather than meeting a specific threshold (NSW trial) • Location for intensive-breeding activity • Maintains natural wetting/drying regime critical to some species • Sustains species under conditions of stress (e.g. drought refuges) • Location most utilised by migratory birds • Supports at least 10% of dependent species
LEB TRIAL
<p>Waterbird abundance:</p> <ul style="list-style-type: none"> • presence of significant waterbird populations (nominally >20 000). <p>Significance of site for waterbird breeding (large colonial events):</p> <ul style="list-style-type: none"> • breeding efforts scored as follows: <ul style="list-style-type: none"> – $\geq 10\ 000$ pairs; – 1000–10 000 pairs; – 100–1000 pairs; – < 100 pairs. <p>Refugia:</p> <ul style="list-style-type: none"> • presence of permanent and near-permanent waterbodies: <ul style="list-style-type: none"> – permanent refuge—not known to ever dry out – near-permanent refuge—only dries out in moderate to severe droughts.
NA TRIAL
<p>Number/area permanent/perennial dry season refuge:</p> <ul style="list-style-type: none"> • calculated as the length of perennial streams/rivers (riverine) or area of permanent lacustrine or palustrine areas in each planning unit. <p>Degree of natural longitudinal connectivity:</p> <ul style="list-style-type: none"> • calculated as the proportional stream length within each planning unit that was unaffected by artificial barriers (dams, reservoirs and large weirs) downstream, within or upstream of each planning unit. <p>Number of migratory bird species:</p> <ul style="list-style-type: none"> • calculated simply as the number of migratory waterbird species recorded from a planning unit.
TASMANIA TRIAL
<ul style="list-style-type: none"> • Important bird sites • 'Expert opinion'

4. NATURALNESS
The ecological character of the aquatic ecosystem is not adversely affected by modern human activity
PILOT TRIALS
<ul style="list-style-type: none"> • Degree of naturalness relative to remoteness • Naturalness—aquatic • Naturalness—catchment • Total area of land reserved for conservation purposes • Use definition of ecologically healthy rivers to identify those where some change from natural may have occurred, but major natural features, biodiversity, and/or functions are still present and will continue into the future
LEB AND NA TRIALS
<p>River Disturbance Index:</p> <ul style="list-style-type: none"> • Mean Catchment Disturbance Index • Mean Flow Regime Disturbance Index.
TASMANIA TRIAL:
<ul style="list-style-type: none"> • Unimpacted/impacted ecosystems • Ozestuary list of ‘pristine estuaries’
5. REPRESENTATIVENESS
The aquatic ecosystem is an outstanding example of an aquatic ecosystem class to which it has been assigned, within a drainage division
PILOT TRIALS
<ul style="list-style-type: none"> • Regionalisation • Classification • Integrity assessment—where no condition assessment is available, the following may be used as surrogates for identifying sites in natural or near-natural condition: <ul style="list-style-type: none"> – percentage of uncleared land (remote sensing) – percentage of land reserved for conservation purposes
LEB TRIAL
<ul style="list-style-type: none"> • Filter to ensure that all aquatic ecosystem types are captured in the HEVAE process.
NA TRIAL
<ul style="list-style-type: none"> • Bray-Curtis similarity of each planning unit to the group centroid, where group is defined for the entire study region, each drainage division, and each aggregated region. Planning units with higher Bray-Curtis similarity to group centroid are more representative of the group (Belbin 1993).
TASMANIA TRIAL
<ul style="list-style-type: none"> • Representative Conservation Value (RCV)

Appendix B

Suggested methods for scoring and integrating attributes and metrics

METHOD	DESCRIPTION	EXAMPLE OF WHERE IT IS USED	ADVANTAGES	DISADVANTAGES
1. Simple averaging (mean)	Take the mean of the attributes/metrics (these may be weighted).	Victorian Index of Stream Condition (ISC) (e.g. hydrology theme) South-east Queensland Ecosystem Health Monitoring program (EHMP) Stewart (2011)	Simple and intuitive	Assumes attributes/metrics are correlated Will return muddy results (values tend to the middle of the distribution) especially with more attributes/metrics Requires sound conceptual framework to establish appropriate weightings Weightings subject to expert opinion Which experts? Cost of meetings, etc. Weightings are susceptible to missing data
2. Simple averaging (median)	Take the median of the attributes/metrics (these may be weighted).	Sustainable Rivers Audit	Simple and Intuitive Less constrained by statistical assumptions of shape of distributions	As per method 1.

METHOD	DESCRIPTION	EXAMPLE OF WHERE IT IS USED	ADVANTAGES	DISADVANTAGES
3. Precautionary principle	Applying a weight to the most conservative attributes/metrics.	Across the themes of the Victorian Index of Stream Condition (ISC)	Simple and intuitive Systematically returns more conservative scores than any other method	Susceptible to missing data
4. Priority principle	Only considering the attributes/metrics that are above average (say in the top 10% of values for that attribute/metric across all spatial units). All non-significant values are removed from the analysis.	Not currently used	Generally removes the greater majority of attributes/metrics which then reduces the amount of muddying going on Handles missing data	Needs development
5. Quartile/threshold	The quartiles of the data are used to set thresholds and each unit receives an ordinal score for each index, e.g. 1 = poor, 2 = acceptable, 3 = good, 4 = very good.	More commonly used in social type research	25% of the spatial units are in every category Outputs are simple categories that are easily interpreted	More muddier results than simple averaging as it adds further error by converting ratio to ordinal scale data Some attributes/metrics can't be quartered
6. Quartered/threshold (AquaBAMM)	Mean of the highest three scores divided by four, e.g. mean = 10, then the categories are: very high = >7.5; high = >5 to 7.5; medium = 2.5 to 5; low = < 2.5.	AquaBAMM Some HEVAE identification regional trials	Outputs are simple categories that are easily interpreted No <i>a priori</i> decision about size of class	More muddier results than simple averaging as it adds further error by converting ratio to ordinal scale data Can't be applied to small data sets (i.e. with less than three records) Doesn't take into account the distribution of the data

METHOD	DESCRIPTION	EXAMPLE OF WHERE IT IS USED	ADVANTAGES	DISADVANTAGES
7. Standardised Euclidean distance	Pythagoras's theorem extended across multiple dimensions. The standardised Euclidean distance tends to return values lower than the mean of the two scores and higher than the precautionary principle method.	The Framework for the Assessment of River and Wetland Health (FARWH)	Returns the Euclidean distance from a reference (e.g. a perfect or a desirable) condition	Susceptible to missing data
8. Expert Rules/ Fuzzy Logic	Intelligent decision making involved before including all attributes/metrics.	Sustainable Rivers Audit CFEV	Intuitive Can make very complex integrations simple	Results can be considerably more variable than other methods Requires sound conceptual framework to establish weightings Weightings subject to expert opinion Which experts? Cost of meetings, etc. Weightings are susceptible to missing data
9. Jenks natural breaks	Classification determined by comparing sums of squared difference and assigning categories based on the minimum differences in squared difference.		No <i>a priori</i> decision about size of class Takes into account the distribution of the data	Assignment of classes seems arbitrary Intuitively difficult to understand

METHOD	DESCRIPTION	EXAMPLE OF WHERE IT IS USED	ADVANTAGES	DISADVANTAGES
10. Percentiles	Based on percentiles of the data (e.g. low = 1% to 10%, medium = >10% to 50%, high = >50% to 90%, very high = >90%).		Takes into account the distribution of the data Standard statistical technique	Makes an <i>a priori</i> decision about the size of the groups Difficult to apply to small datasets

Adapted from Hale 2010; Kennard 2010



Steam Engine Swamp rookery, North Redbank Wetlands, Yanga National Park (Paul Doyle & DSEWPac)

Appendix C

Checklist for completing the HEVAE identification workflow

HEVAE name:

Preliminary activities

- ☐ Purpose for HEVAE identification defined
- ☐ Aquatic ecosystems classified and mapped (e.g. using Interim ANAE Classification Framework)
- ☐ Scale and spatial units identified (e.g. drainage division, assessment unit, aquatic ecosystem)
- ☐ Relevant data and information sources compiled (maps, imagery, reports)
- ☐ Expert reference panel identified and engaged*

HEVAE identification process

- ☐ Selection of additional or alternative criteria (for jurisdictional/regional level assessments only)
- ☐ Attributes and metrics identified
- ☐ Data identified and confidence levels applied
- ☐ Data assigned to spatial units
- ☐ Attributes/metrics scored and integrated into criterion scores
- ☐ Thresholds and decisions rules set
- ☐ HEVAE identified
- ☐ Documentation and metadata completed

HEVAE documentation process

- ☐ Knowledge gaps identified
- ☐ Stakeholder consultation undertaken
- ☐ Metadata completed
- ☐ Spatial layers completed
- ☐ HEVAE assessment report completed

* Expert panels should be used to contribute to the selection of attributes/metrics and data, and verify results of output assessment process.

Appendix D

HEVAE identification record template

IDENTIFICATION OF HEVAE RECORD SHEET	
Name of HEVAE	
Date of identification	
Purpose for identification	<i>e.g. water planning, NRS</i>
Ecosystem description	<i>Provide information on the big picture scale including overall system description, locality, major systems (rivers, lakes etc.), area</i>
Ecosystem types	<i>List dominant types and identify classification used e.g. ANAE</i>
Land use	
Land tenure	
Scale	<i>Provide description about scale at which you are working</i>
Experts involved	<i>Name—Contact Details—Discipline</i>
Criteria applied	<input type="checkbox"/> Criteria 1 Diversity <input type="checkbox"/> Criteria 2 Distinctiveness <input type="checkbox"/> Criteria 3 Vital Habitat <input type="checkbox"/> Criteria 4 Naturalness <input type="checkbox"/> Criteria 5 Representativeness Other criteria:
Attributes/metrics used	
Datasets used	<i>Listing of datasets used—include information on scale, currency, quality / confidence rating and any custodianship information</i>
Gaps/limitations	<i>Summary of data and information gaps or limitations encountered during the HEVAE identification process.</i>
Scoring/integration	<i>Method for scoring and integrating attributes and metrics, including weighting and sensitivity analyses</i>
Thresholds	<i>Method used to determine thresholds for identifying HEVAE</i>
HEVAE criteria met	<input type="checkbox"/> Criteria 1 Diversity <input type="checkbox"/> Criteria 2 Distinctiveness <input type="checkbox"/> Criteria 3 Vital Habitat <input type="checkbox"/> Criteria 4 Naturalness <input type="checkbox"/> Criteria 5 Representativeness Other criteria:

Summary of values	<p>Criteria related:</p> <p>Identified by experts:</p> <p><i>A summary of what values made the area score highly.</i></p>
Presence in other listing	<p><input type="checkbox"/> Ramsar</p> <p><input type="checkbox"/> World Heritage Areas</p> <p><input type="checkbox"/> National Heritage Places</p> <p><input type="checkbox"/> Flyways</p> <p><input type="checkbox"/> EPBC threatened species</p> <p><input type="checkbox"/> EPBC ecological communities etc.</p>
References	<p><i>References (and links if available) and other related processes and documents e.g. water resource plan, wild rivers etc), conceptual models etc</i></p>



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