

Supplementary material

Integrating data, expert opinion and fuzzy logic in the development of an index of wetland condition

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The scoring system and field sheets on the following pages were extracted from Department of Environment, Land, Water and Planning (2019)¹ and were used in the Index of Wetland Condition.

¹ Department of Environment, Land, Water and Planning (2019). Index of Wetland Condition assessment procedure February 2019. DELWP, Melbourne, Vic., Australia.

Subindex: Wetland catchment																																	
Component: Wetland buffer		Wetland buffer width and continuity																															
<p>1. Mark the wetland buffer on base map 1. The buffer is the native vegetation adjacent to the wetland (from the maximum inundation level outwards). Consider the following:</p> <ul style="list-style-type: none"> For the purposes of the IWC buffer measure, native vegetation is defined as vegetation where the overstorey (if present) is predominantly native, and native species make up more than 25% of the total understorey cover Areas of revegetation are classed as native vegetation if they simulate the natural EVC and meet the above criteria—also mark these areas on base map 1 <p>2. Measure the buffer width around the wetland to calculate the average. Where the buffer width is greater than 50 m, consider this as 50 m when calculating the average. Circle the corresponding average buffer width score in column [A].</p> <p>3. Determine the percentage of the wetland perimeter with a buffer and circle the corresponding score in column [B].</p> <p>4. Multiply the average buffer width score [A] with the percentage of wetland perimeter score [B] and enter in [C].</p>		<table border="1"> <thead> <tr> <th>Average buffer width (m)</th> <th>Score [A]</th> </tr> </thead> <tbody> <tr><td>>0–5</td><td>0.5</td></tr> <tr><td>>5–20</td><td>1.0</td></tr> <tr><td>>20–50</td><td>1.5</td></tr> <tr><td>>50</td><td>2.0</td></tr> </tbody> </table> <table border="1"> <thead> <tr> <th>% of wetland perimeter with a buffer</th> <th>Score [B]</th> </tr> </thead> <tbody> <tr><td>0–5</td><td>0</td></tr> <tr><td>>5–25</td><td>1</td></tr> <tr><td>>25–50</td><td>2</td></tr> <tr><td>>50–75</td><td>3</td></tr> <tr><td>>75–95</td><td>4</td></tr> <tr><td>>95</td><td>5</td></tr> </tbody> </table>		Average buffer width (m)	Score [A]	>0–5	0.5	>5–20	1.0	>20–50	1.5	>50	2.0	% of wetland perimeter with a buffer	Score [B]	0–5	0	>5–25	1	>25–50	2	>50–75	3	>75–95	4	>95	5						
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Wetland buffer assessment score ([A] x [B])			[C]																														
Component: land use		Land-use intensity within 250 m of the wetland																															
<p>1. Observe the land use within 250 m of the wetland and determine whether it differs from that shown on the land-use map. Document 'Yes' or 'No' in box [D]. If yes, state the difference in box [E].</p> <p>2. Determine the percentage of land in each intensity class within 250 m of the wetland to the nearest 5% to total 100% and enter values in [F].</p> <p>3. Multiply the percentage [F] by the intensity factor [G] for each land-use class and enter the result in [H].</p> <p>4. Add the results for each category and enter total in box [I].</p> <p>5. Using [I], select the appropriate land-use score from [J] and circle.</p> <p>6. Add the buffer assessment score [C] to the land-use intensity score [J] to obtain the Wetland catchment sub-index score and enter it in [K].</p>		<table border="1"> <thead> <tr> <th>Is land use within 250 m of the wetland different from that on the land-use map?</th> <th>Yes No [D]</th> <th>If Yes, document the difference [E]</th> </tr> </thead> <tbody> <tr> <td></td> <td></td> <td></td> </tr> </tbody> </table> <table border="1"> <thead> <tr> <th>Land use intensity class</th> <th>% of adjacent land in each land-use intensity class (must total 100%) [F]</th> <th>Intensity factor [G]</th> <th>Result [H]</th> </tr> </thead> <tbody> <tr><td>Very high</td><td></td><td>0</td><td></td></tr> <tr><td>High</td><td></td><td>1</td><td></td></tr> <tr><td>Medium</td><td></td><td>2</td><td></td></tr> <tr><td>Low</td><td></td><td>3</td><td></td></tr> <tr><td>Very low</td><td></td><td>4</td><td></td></tr> </tbody> </table>		Is land use within 250 m of the wetland different from that on the land-use map?	Yes No [D]	If Yes, document the difference [E]				Land use intensity class	% of adjacent land in each land-use intensity class (must total 100%) [F]	Intensity factor [G]	Result [H]	Very high		0		High		1		Medium		2		Low		3		Very low		4	
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Wetland catchment sub-index score [C] + [J]			[K]																														

Guidance for determining land-use intensity

Land-use intensity class	Examples of land use	Intensity factor
Very high	Built urban (including alpine resort development), industrial, intensive animal production, multiple-lane roads, multiple-track railway, aqueduct, water storage	0
High	Cleared land for urban development, irrigated agriculture (cropping, horticulture and pasture), broad-acre cropping, medium- or high-density grazing, golf course, playing field, major roads (not multiple-lane), vehicle tracks in peatland wetlands	1
Medium	Non-indigenous plantation forestry, low-density grazing, minor roads/tracks and railways	2
Low	Forestry in native forests, nature conservation with moderate to high recreational use, vehicle tracks (non-peatland wetlands). If vehicle tracks are present in peatland wetlands, assign class as medium.	3
Very low	Nature conservation with low recreational use	4

Subindex: Physical form

<p>Component: wetland area</p> <p>Note: An enlargement of the wetland is considered an aspect of altered hydrology and is not part of the wetland area assessment.</p> <ol style="list-style-type: none"> Identify the original and current wetland boundary on the ground, and using base map 1, estimate the percentage reduction in area. Circle the corresponding score in column [A]. If there is a reduction in wetland area, document the reason(s) by marking an x in column [C] against the appropriate option(s). If there is a reduction in wetland area, document the time when the reduction took place by marking an x in column [D] against the appropriate option(s). 	Reduction in wetland area		<table border="1"> <thead> <tr> <th>% reduction in wetland area</th> <th>Score [A]</th> </tr> </thead> <tbody> <tr> <td>>95</td> <td>0</td> </tr> <tr> <td>>75–95</td> <td>2</td> </tr> <tr> <td>>50–75</td> <td>4</td> </tr> <tr> <td>>25–50</td> <td>6</td> </tr> <tr> <td>>5–25</td> <td>8</td> </tr> <tr> <td>0–5</td> <td>10</td> </tr> </tbody> </table>		% reduction in wetland area	Score [A]	>95	0	>75–95	2	>50–75	4	>25–50	6	>5–25	8	0–5	10
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	0–5	10																
	What is the reason for a reduction in wetland area?		[C]															
	Not applicable (no reduction)																	
	Infilling																	
	Barriers to filling (such as levees or roads without culverts)																	
	Fire (for peat-dominated wetlands only)																	
	Channelisation/drains within the wetland																	
	Other (please state)																	
When did the reduction in wetland area take place?		[D]																
Not applicable (no reduction)																		
unknown																		
< 1994																		
1994–2003																		
2004–2013																		
After 2013																		
Enter year if known:																		
<p>Component: wetland bathymetry</p> <ol style="list-style-type: none"> Mark with an x in column [E] the activities present that change the bathymetry of the wetland. Do not include activities captured in the soils component. Show the location of these activities on base map 1. Determine the severity and extent of the change and enter it in [F]. Severity guidance is provided in the table below. For each severity class, multiply the percentage at [F] by the severity factor [G] and enter the result in the score column. Sum the reduction in wetland area score in [A] and the change in bathymetry score in [H] and enter total at [I]. 	Activities that change the bathymetry of the wetland		[E]															
	Excavation of the wetland bed (e.g. channels, dams, dredging)																	
	Landforming (e.g. raised-bed cropping, laser-levelling, building mounds, levees, aqueducts, tracks)																	
	Other (please state)																	
	No activities that change bathymetry																	
	Severity of change in the bathymetry of the wetland																	
	Severity	% of wetland area (must total 100%) [F]	Severity factor [G]	Score ([F] x [G])														
	High		0															
	Medium		0.05															
	Low		0.075															
	None		0.1															
	Change in bathymetry score (sum of severity scores above)			[H]														
	Physical form sub-index score [A] + [H]			[I]														

Guidance for determining the severity of change to the bathymetry of the wetland

Severity rating	Examples of wetland bathymetry change
High	Change in bathymetry, in which bed of wetland has been raised or lowered by >50 cm due to excavation and/or the landforming activities listed above
Medium	Change in bathymetry, in which bed of wetland has been raised or lowered by >10–50 cm due to excavation and/or the landforming activities listed above
Low	Change in bathymetry, in which bed of wetland has been raised or lowered by <10 cm due to excavation and/or the landforming activities listed above

Subindex: Hydrology					
<p>1. Mark the water sources of the wetland with an x in column [A].</p> <p>2. In column [B], enter the level of confidence you have in determining the wetland water source(s).</p> <p>3. In column [C], enter the source of information used to determine the water source from using one of the following categories:</p> <ul style="list-style-type: none"> • Current wetland inventory • Field data or observation • Local knowledge (landholder or land manager) • Wetland management plan or report • Other (please describe). <p>4. Mark, using an x, activities that change the wetland's water regime in column [D].</p> <p>5. Determine the severity of change on the timing of inundation and frequency/duration of inundation category by circling one option in each column of Table [E]. Total and enter in [F] (frequency/duration categories are described in the table at the bottom of the page).</p> <p>6. Enter the level of confidence you have in your assessment at [G].</p> <p>7. At [H], enter the source of information used to make your assessment using one of the following categories:</p> <ul style="list-style-type: none"> • Field data or observation • Local knowledge (landholder or land manager) • Wetland management plan or report • Other (please describe). 	Water source(s) for the wetland	[A]	[B] Confidence (Options: High, Medium, Low)	[C] Source of information (see Step 3)	
	River/stream (water delivered via in-channel or over-bank flows)				
	Local surface run-off				
	Groundwater				
	Artificial (discharge from agriculture/industry/urban or environmental water delivered through channels and regulating structures)				
	Activity that changes the wetland's water regime				[D]
	River regulation				
	Activities that change the local surface drainage patterns				
	Artificially manipulated water inflow or drawdown that is not associated with maintaining or enhancing the condition of the wetland				
	Obstruction, regulation or alteration of the connection between the wetland and its water source				
	Obstruction or regulation of natural water outlets				
	Drainage of water from the wetland through a pipe or channel				
	Disposal of waste or drainage water into the wetland that is not associated with maintaining or enhancing the condition of the wetland				
	Extraction of water directly from the wetland				
	Activities that permanently raise the water level when full (e.g. damming the wetland or constructing levees to restrict the spread of water)				
	Activities leading to an increase in groundwater height				
	Activities leading to a decrease in groundwater height				
	Other (please state)				
	No activities present that change the water regime				
	[E] Determining the severity of change to the water regime (select one option in each column)				
	Timing and duration		Water regime category (see table at bottom of page)		
	Changed to another season [0]		Change in category [0]		
	Changed but still within same season [5]		Some change but not sufficient to change category [5]		
Little or no change [10]		Little or no change [10]			
Severity of change in water regime score (total from each column above) (Note: this is the Hydrology sub-index score.)				[F]	
How confident are you about your assessment? (Options: High, Medium, Low)				[G]	
What main source of information did you use to make your assessment? (Select from a category in Step 7.)				[H]	

Water regime categories used to assess severity of change to the water regime

Category	Frequency of inundation	Duration of inundation
Permanent	Constant, annual or less frequently	Never dries or dries rarely (i.e. holds water at least 8 years in every 10)
Periodically inundated – Seasonal	Annual or near-annual inundation (i.e. fills 8–10 years in every 10)	1–8 months
Periodically inundated – Intermittent	Infrequent – holds water, on average 3–7 years in every 10	>1 month to more than 1 year, then dries
Periodically inundated – Episodic	Infrequent – holds water, on average <3 years in every 10	>1 month to more than 1 year, then dries

Subindex: Water properties		
<p>Component: nutrients</p> <ol style="list-style-type: none"> 1. Mark with an x in column [A] activities leading to nutrient enrichment. 2. Document the severity of nutrient enrichment using the scores provided and mark at [E]. 3. Enter the level of confidence you have in your assessment at [C]. 4. At [D] enter the source of information used to make your assessment using one of the following categories: <ul style="list-style-type: none"> • Field data or observation • Local knowledge (landholder or land manager) • Wetland management plan or report • Other (please describe). 5. Document evidence of nutrient enrichment if available (e.g. algal blooms, field data) and enter at [E]. 	<p>Nutrient enrichment</p>	[A]
	Discharge of nutrient-rich water to the wetland (e.g. from sewage, industrial effluent or irrigation water)	
	Drainage of nutrient-rich water into the wetland from an urban area (via a drain)	
	Run-off of nutrients to wetland (e.g. from fertiliser application or grazing)	
	Grazing by livestock in the wetland	
	Grazing by feral animals in the wetland (e.g. pigs, goats, deer, rabbits, horses – please state the animal/s in box to the right)	
	Application of fertiliser in the wetland	
	Aquaculture	
	Other (please state)	
	No activities leading to nutrient enrichment	
	What is the severity of nutrient enrichment? No enrichment [10], Low [7], Medium [5], High [0]	[B]
	How confident are you about your assessment? (Options: High, Medium, Low)	[C]
	What main source of information did you use to make your assessment? (See categories in Step 4.)	[D]
	Document evidence of nutrient enrichment if available (e.g. algal blooms, nutrient data).	[E]
<p>Component: salinity</p> <ol style="list-style-type: none"> 1. Mark with an x in column [E] the reason for a change in salinity from its reference (i.e. pre-European) state. 2. Document the severity of the change in salinity and mark in [F] using the scores provided. 3. Enter the level of confidence you have in your assessment at [G]. 4. At [H], enter the source of information you used to make your assessment using one of the following categories: <ul style="list-style-type: none"> • Current Wetlands / Pre European Wetlands spatial inventories • Field data or observation • Local knowledge (landholder or land manager) • Wetland management plan or report • Other (please describe) 5. Add the scores for both measures [B] and [F] to obtain the sub-index score and enter at [I]. 6. Document evidence of a change in salinity if available (e.g. change in salinity classification, change in vegetation, change in wetland fauna, salinity data) and enter at [J]. 	<p>Change in salinity</p>	[E]
	Saline groundwater intrusion resulting in an increase in salinity from its natural state	
	Saline water intrusion from the marine environment, resulting in an increase in salinity from its natural state	
	Saline water is unnaturally delivered to a fresh or brackish wetland.	
	Fresh water is unnaturally delivered to a saline wetland.	
	Other (please state)	
	No change in salinity	
	What is the severity of change in salinity? Little or no change [10], Low [7], Medium [5], High [0]	[F]
	How confident are you about your assessment? (Options: High, Medium, Low)	[G]
	What main source of information did you use to make your assessment? (See source of information categories on left.)	[H]
	Water properties score ([B] + [F])	[I]
Document evidence of a change in salinity if available (e.g. change in salinity classification, change in vegetation, change in wetland fauna, salinity data).	[J]	

Subindex: Soils				
<p>Component: Physical soil disturbance</p> <p>1. Mark with an x in column [A] the presence of activities that cause soil disturbance.</p> <p>2. Show location of soil disturbance on base map 1.</p> <p>3. Estimate the percentage of wetland soils in each soil disturbance severity class and enter in [B] (guidance is provided in the table at the bottom of the page).</p> <p>4. For each class, multiply the % of wetland soils affected by the severity factor [C] and enter in [D].</p> <p>5. Sum the results in [D] and mark result in [E] – this is the soils sub-index score.</p>	Activity that causes soil disturbance		[A]	
	Pugging by livestock			
	Disturbance or pugging by feral animals (e.g. pigs, goats, deer, rabbits, horses—please state the animal/s in box to the right).			
	Carp mumbling			
	Trampling by humans			
	Cultivation			
	Driving of vehicles in the wetland			
	Other (please state)			
	No activities that cause soil disturbance			
	Soil disturbance severity			
	Severity of disturbance	% of wetland soils (must add to 100%) [B]	Severity factor [C]	[D]
	High		0	
	Medium		0.1	
	Low		0.15	
No disturbance		0.2		
Soils sub-index score			[E]	

Guidance for determining severity of soil disturbance

Severity rating	Soil disturbance examples
High	<ul style="list-style-type: none"> • High density of pug marks (page 31, Plate 4) • Severe soil disturbance by livestock (aside from pugging, e.g. erosion or uprooted vegetation) • High density of deer or feral pig wallow (page 31, Plate 5) • High density of carp mumbling (page 31, Plate 6) • High density of rabbit diggings • Rabbit warrens present • High density of human trampling • High density of vehicle tracks • Cultivation
Medium	<ul style="list-style-type: none"> • Medium density of pug marks (page 31, Plates 2 and 3) • Medium level of soil disturbance by livestock (aside from pugging, e.g. erosion or uprooted vegetation) • Medium density of deer or feral pig wallow • Medium density of carp mumbling • Medium density of rabbit diggings • Medium density of human trampling • Medium density of vehicle tracks
Low	<ul style="list-style-type: none"> • Low density of pug marks • Slight soil disturbance by livestock (aside from pugging, e.g. erosion or uprooted vegetation) • Low density of deer or feral pig wallow • Low density of carp mumbling • Low density of rabbit diggings • Low density of human trampling • Low density of vehicle tracks (page 31, Plate 1)

Subindex: Bbiota

1. Determine the wetland EVCs present at the wetland (use the wetland landscape profile diagrams commencing on page 44 to assist). In the case of an aggregate where the components are difficult to resolve, use the aggregate and assess as usual.
2. Determine whether any EVC should be split into units for assessment and identify these as Unit 1, Unit 2, etc. in brackets after the EVC name. Where there is a significant difference in quality between two or more distinct parts of an EVC, the EVC should be divided into separate units for assessment, and each unit assessed separately. This may occur, for example, where a fence prevents livestock grazing part of the EVC.
3. Mark distribution of wetland EVCs (and units, if relevant) within the wetland on the EVC base map.
4. Areas of the wetland that are not vegetated (or nearly so) are classified as EVC 990 (open water/bare soil/mud). EVC 990 is not included in the vegetation scores and should not be listed on the assessment summary below. These areas should however be mapped and assessed for weeds and indicators of altered processes, as described in the benchmark.
5. Determine the percentage of the wetland covered by vegetation (i.e. all EVCs excluding EVC 990); enter value in box [A].
6. Record EVC name [B] and EVC number [C] for each EVC or EVC unit (excluding EVC 990).
7. Estimate the percentage of the vegetated area of the wetland covered by each EVC and/or EVC units and enter at [D]. (The sum of these should equal 100%.)
8. Assess each EVC or EVC unit separately and transfer score to [E]. If it was not possible to assess the EVC, write 'NA' instead of the EVC score at [E]. In this instance, no overall biota score can be obtained.
9. Multiply the individual EVC scores [E] by the proportion (%) of the vegetated wetland area that is covered by the EVC [D] and enter the result in [F].
10. Add the results [F] divided by 100 and enter the total in box [G] to obtain the biota sub-index score.

What percentage of the wetland area is covered by vegetation? (Do not include EVC 990 as this is unvegetated.)

[A] (%)

EVC name (and unit number, if relevant) [B]	EVC No. [C]	Percentage of vegetated area covered by EVCs ^{1,2} [D]	EVC score [E]	Result [F]
Biota sub-index score (sum of [F] divided by 100)				[G]

¹ Excluding EVC 990

² Must total 100%

Size ranges used for critical life forms in the IWC

Life form	Size classes				
	Tiny	Prostrate	Small	Medium	Tall
Shrubs	NA	<20 cm	20 cm – <1 m	1 – 3 m	>3 m
Herbs	<5 cm	<5 cm and carpet or mat-forming	5 cm – <15 cm	15 cm – <50 cm	>50 cm
Graminoid	<10 cm	<10 cm and mat-forming	10 cm – <30 cm	30 cm – <1m	>1 m

Notes on size ranges:

- The range of a given size class can differ from the most similar Vegetation Quality Assessment category (Habitat Hectares).
- The term semi-shrubs applies to robust herbs that are to some extent woody—where this term is used in the benchmarks, the relevant size range for herbs applies.
- Graminoids can variously include grasses, sedges, rushes, restiads, mat-rushes and grass trees. Where the term 'monocot' is used in a generalised way in the benchmarks, the relevant size range as for graminoids applies.
- 'Cane-grass' is sometimes used in the benchmarks as a life form (rather than more generalised 'medium-to-tall grasses')—this term applies to hard-stemmed grasses, notably of the genus *Eragrostis*—these species can appear either tufted or non-tufted, according to growing conditions and grazing pressure.
- The term 'tiny floating aquatics' is self-explanatory—these species comprising detached individual plants up to a few cm in size, but frequently much smaller, that are not rhizomatous.

Subindex: Biota							
<p>Individual EVC assessment</p> <p>1. From EVC summary sheet, record EVC name [A] and number [B].</p> <p>2. Refer to the EVC benchmark description.</p> <p>3. Check the benchmark description for any conditions when the EVC should not be assessed. If not assessed, record 'NA' on <u>EVC assessment summary</u> at [D].</p> <p>4. Document the number of the critical life-form group (not the number of species in the group) identified in the benchmark at [C].</p> <p>5. List all critical life forms present in table [D].</p> <p>Note: Only wetland species should be used to assess critical life forms. Species should only be allocated to one critical life-form group, and allocation should be based on the mature life stage. Opportunistic dryland species should not be included.</p> <p>6. For each critical life form present, indicate whether it is unmodified (UM), or modified by a reduction in species (S), percentage cover (C) or both (B).</p> <p>7. Count the number of critical life forms listed that are unmodified (UM) and record at [E].</p> <p>8. Count the number of critical life forms listed that are modified (i.e. scored as (S), (C) or (B) and record at [F].</p> <p>9. Record the number of critical life forms absent at [G].</p> <p>10. Determine the critical life-form groups score $[25 \times E/C + 25/2 \times F/C]$ and enter at [H].</p> <p>11. Determine and circle weeds score and enter value at [I].</p> <p>12. List high-threat weeds on the reverse of this sheet.</p> <p>Note: high-threat weeds include those listed in the benchmark and other weeds that have the ability to displace native vegetation.</p> <p>13. Determine indicators of altered processes score and enter at [J]. Refer to the critical life-form groups listed in benchmark Section 1 to determine whether or not 50% of these are present.</p> <p>Note: This can include invasions of indigenous or introduced species occurring outside their normal range of habitat or performance. It could also include declines in indigenous species where this is indicating hydrological change.</p> <p>14. Determine vegetation structure and health score and enter at [K].</p> <p>15. Add the scores for each benchmark attribute to get the EVC score, divide by 5 and transfer to the EVC assessment summary.</p> <p>16. Optional: list any other species of interest/ or a full species list on the EVC base map.</p>	EVC name (and unit number, if relevant) [A]		EVC No. [B]				
	Critical life-form groups (EVC benchmark Section 1)						
	Number of critical life forms identified in the benchmark			[C]			
	Critical life forms present [D]			Is the critical life form unmodified (UM) or modified by a reduction in species (S), % cover (C), or both (B)			
	Number of life forms present that are unmodified			[E]			
	Number of life forms present that are modified			[F]			
Number of life forms absent			[G]				
Critical life-form groups score $[(25 \times (E/C)) + ((25/2) \times (F/C))]$ (round to two decimal places)					[H]		
Weeds (EVC benchmark Section 2)							
Total cover of weeds in EVC			Total cover of high-threat weeds				
	nil	>0-<1%	1-<5%	5-<25%	25-<50%	≥50%	
≥50%	7	6	5	3	1	0	
25-<50%	12	10	8	6	3	-	
5-<25%	17	15	13	10	-	-	
1-<5%	23	21	18	-	-	-	
<1%	25	23	-	-	-	-	
Weeds score						[I]	
Indicators of altered processes (EVC benchmark Section 3)						Score	
EVC completely displaced and site substantially modified (e.g. cropped or completely drained)						0	
<50% of critical life-form groups still represented						5	
≥50% of critical life-form groups present (or exempted as per benchmark) and altered process as:							
(a) severe						10	
(b) moderate						15	
(c) minor						20	
No evidence of altered process						25	
Indicators of altered processes score						[J]	
What is the evidence for the altered process?							
Vegetation structure and health (EVC benchmark Section 4)							
% of benchmark cover		% of cover of structural dominants that are healthy					
		>70	30-70	<30			
<10		5	2	0			
10-50		15	10	5			
>50		25	20	15			
Vegetation structure and health score						[K]	
Wetland EVC score $([H] + [I] + [J] + [K])/5$						[L]	