Evaluating indicators of ecological health for estuaries in southwest Australia

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Abstract

A broad range of environmental indicators were evaluated to determine their suitability for describing the early onset of nutrient enrichment in south-west Australian estuaries. The southwest of Australia experiences a Mediterranean climate with hot dry summers and cool wet winters. Most of the south-west estuarine catchments have been extensively cleared for agricultural and urban development and have been losing unacceptably high loads of nutrients. Symptoms of nutrient enrichment have been observed in many south-west estuaries.

An evaluation of fifty years of historical water quality data defined the range of normal behaviour for these systems together with the nature of rarer extreme events. It was found that south-west Australian estuaries are highly variable in space and time and appear to be more susceptible to nutrient enrichment than those observed elsewhere in Australia.

While there may be significant fluctuations in physico-chemical conditions and the structure of biological communities in ecosystems subjected to natural variability and anthropogenic stressors, it is possible that the function of biological communities in these situations is less affected by these types of perturbations. Several indicators of biological function (rates and processes) were developed and evaluated to determine whether they offered a greater degree of diagnostic precision (early warning) than measures of stocks and status (inventory).

In evaluating various environmental indicators, it was found that no single indicator was able to unambiguously define the interactions between physico-chemical and biological processes and the response of these systems to anthropogenic and natural stressors. It has been concluded that a broad range of potential indicators must be evaluated simultaneously, in order to define baseline conditions, measurement endpoints and trends to inform catchment and estuarine management and restoration. Increased confidence in the selected indicator suite can flow from an evaluation of the monotonicity of correlated indicators, especially when assessments show consistent patterns for physico-chemical measures and measures of biotic community structure across several trophic groups.

Traditional physico-chemical indicators have provided reliable information in the past, but problems have arisen when relating these measures to biological endpoints, particularly for estuaries with significant seasonal and inter-annual variability. In the absence of biological data for estuarine ecosystems experiencing significant seasonal and inter-annual variability, socio-economic indicators of catchment land use practices may be the only option. Paleolimnological investigations may also provide additional insight into patterns of natural variability over the longer term, but the degree of taxonomic resolution required and requirements for supporting stable isotope analysis, may consume considerable resources.

Autotrophic protists (periphyton, phytoplankton), appear to be useful for describing nutrient enrichment, salinity and other physico-chemical conditions, but complicating factors such as the nature of coupling of secondary predation need to be identified. Autecology of local indicator species also needs to be defined. Zooplankton appear to be limited as environmental indicators, but because of their potential role in grazing and materials transfer, they may be useful as elements of biotic indices across several trophic groups. One of the major impediments to using planktonic organisms for inferring the condition of estuarine health is the considerable vertical, horizontal and temporal heterogeneity displayed by these organisms in both disturbed and undisturbed systems.

More recently, benthic macro-invertebrates have been successfully used to describe the nature and magnitude of organic enrichment of estuaries. Community structure, biomass and relative abundance of functional groups and indicator species have also been developed and used as environmental indicators. Problems may occur in the use of these organisms to infer health in south-west estuaries because of the presence of naturally immature communities.
and variable colonization dynamics where there is significant seasonal and inter-annual variability.

Inventory measures of community structure have problems because of a lack of information about exchange pathways connecting system components and unknown interactions between diversity, stability and resilience of the ecosystem. Species richness, diversity indices and measures of biomass have probably been the most widely used indicators in the majority of published works, but generally without appropriate critical analysis of their utility. Biomass appears to have less inter-annual variability than do other measures of community structure.

A myriad of biotic indices (ratios of functional groups) within and across trophic levels have been described in the international literature. There are problems in defining weightings and concordance methods for elements contributing to biotic indices and the loss of valuable information during these types of data reduction limit their potential. Detailed autecology of members of functional groups are required for biotic indices and this type of information is potentially available for some cosmopolitan species, but generally lacking for endemic species which may describe important nuances of the local environment.

As with biotic indices, there is a range of combined metrics described in the literature. Metrics generally combine physico-chemical elements, and may include some biological information. Many of the problems with biotic indices apply equally to metrics, but when calibrated for a particular local situation, they offer considerable discriminatory power.

Assessment of early colonisation dynamics and the responsiveness of periphyton communities to nutrient additions provided insights into some key processes in south-west estuaries. Periphyton communities in estuaries with a past history of nutrient enrichment responded well to nutrient additions while communities in less disturbed estuaries did not respond as readily. This infers that opportunistic species able to respond rapidly to nutrient additions may become established in estuaries having a nutrient enrichment history while they may be less able to maintain a viable presence in less enriched estuaries. While showing promise, additional testing and refinement of these process indicators would better define their potential as early warning indicators of nutrient enrichment for south-west estuaries.

For describing the ecological health of south-west Australian estuaries, physico-chemical indicators of catchment and estuarine water quality and socio-economic measures of catchment land use history may be of use. If assumptions about the linearity of interactions between the diversity of biotic communities and the stability and resilience of ecosystem function are valid, then conventional measures of community structure will also provide useful insights.

The ongoing selection, evaluation and refinement of environmental indicators for assessing the ecological health of south-west Australian estuaries, needs to proceed as a close partnership between land and waterway managers and scientific specialists.
Acknowledgements

This investigation evaluated physical, chemical and biological indicators of ecological health for estuaries in the southwest of Australia having catchments draining a geographical area of 140,000 km². During the course of the investigations, we covered more than 7,000 km in vehicles usually towing a boat with camping gear, food and water in addition to diving equipment and scientific sampling equipment. In addition to numerous investigations undertaken in daylight hours, nocturnal zooplankton trawls were undertaken, sometimes in remote estuaries lacking navigational charts or aids. These were achieved by plotting a course using GPS in daylight hours trying to avoid rocky outcrops and sandy shoals in the dark tannin stained waters, and then following the GPS in navigate mode with way-points at night. For remote estuaries on the south coast, this needed to be undertaken in complete darkness in very small boats (14 ft dingy) usually with 20 - 30 knot winds and up to 1 m chop.

A number of people assisted in various facets of this investigation.

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Declaration

This thesis is submitted for the degree of doctor of philosophy at Murdoch University. I certify that this investigation has not been previously published and it is original work.

David M Deeley
19th March, 2001
# Table of contents

1. Introduction .................................................................................................................. 1
   1.1 The concept of ecological health ............................................................................. 2
   1.2 Health, the human condition: An appropriate analogy? ........................................... 4
   1.3 Australian estuaries ................................................................................................. 6
   1.4 Rationale, aims and structure of the report .............................................................. 8
      1.4.1 Rationale ........................................................................................................... 8
      1.4.2 The aim of the thesis ......................................................................................... 9
      1.4.3 The structure of the thesis ............................................................................... 11
2. Factors influencing the distribution of estuarine biota .................................................. 18
   2.1 Estuarine geomorphology ....................................................................................... 19
      2.1.1 Geology and climate ......................................................................................... 19
      2.1.2 Estuarine morphology ...................................................................................... 20
   2.2 Temperature and light ............................................................................................ 21
      2.2.1 Water temperatures ......................................................................................... 21
      2.2.2 Light .................................................................................................................. 22
   2.3 Water balance ......................................................................................................... 24
      2.3.1 Run-off and tides ............................................................................................. 24
   2.4 Dissolved constituents in estuaries ......................................................................... 26
      2.4.1 Salinity ............................................................................................................. 26
      2.4.2 Nutrients .......................................................................................................... 27
      2.4.3 Trace elements .................................................................................................. 30
      2.4.4 Dissolved gases in estuarine waters and sediments .......................................... 32
      2.4.5 Spatial and temporal heterogeneity of estuarine constituents and biota ............ 33
   2.5 Sediments .............................................................................................................. 35
3. Distribution of biota in estuaries .................................................................................... 42
   3.1 Natural stressors and biotic communities ............................................................... 43
      3.1.1 Theoretical ecology and estuarine biota ............................................................ 43
      3.1.2 Dispersal and migration .................................................................................... 46
      3.1.3 Settlement and establishment .......................................................................... 47
      3.1.4 Selection pressure ............................................................................................ 49
      3.1.5 Habitat complexity ......................................................................................... 51
      3.1.6 Salinity and seasonal cycles in abundance ........................................................ 52
   3.2 Primary production ................................................................................................. 53
      3.2.1 Phytoplankton .................................................................................................. 53
      3.2.2 Periphyton and benthic microalgae ................................................................... 55
   3.3 Secondary production ............................................................................................. 58
      3.3.1 Zooplankton ..................................................................................................... 58
      3.3.2 Zoobenthos ...................................................................................................... 60
   3.4 Feedback effects of biota on habitats ...................................................................... 62
4. The impact of urban and rural development on the distribution of estuarine biota ........ 64
   4.1 The nature of anthropogenic disturbance ............................................................... 65
   4.2 Non-point-source pollution .................................................................................... 66
4.2.1 Impact of development on run-off ........................................ 67
4.2.2 Impact of development on sediment delivery and pollutant inputs ........................................ 68
4.3 Point-source pollution .............................................................. 69
  4.3.1 Sewage inputs ..................................................................... 70
  4.3.2 Industrial discharges ........................................................... 71
4.4 Impact of pollutants on biota .......................................................... 74
  4.4.1 Impact of suspended solids on biota ........................................ 75
  4.4.2 Impact of organic loadings and nutrient inputs ...................... 76
  4.4.3 Impact of thermal pollution and acid-sulphate run-off on biota .... 83
  4.4.4 Impact of toxicants on biota ................................................. 85
4.5 Introduced organisms, fishing and recreational pressure ................. 92
4.6 Assessing disturbance in biotic communities .................................. 93
  4.6.1 Sources of uncertainty in observations ..................................... 95
  4.6.2 Taxonomic resolution ............................................................ 97
5. Ecological health assessment in Australian estuaries ................................ 101
  5.1 Biological processes and ecological health .................................... 104
  5.2 Ecosystem function ................................................................. 106
  5.3 Community structure .................................................................. 108
    5.3.1 Species richness ............................................................... 108
    5.3.2 Relative abundance ........................................................... 109
    5.3.3 Species diversity ............................................................... 110
    5.3.4 Size strata ........................................................................... 112
  5.4 Biotic indices ............................................................................. 113
  5.5 Indicator species ........................................................................ 114
  5.6 Biomarkers and developmental stability analysis .............................. 115
    5.6.1 Biomarkers ......................................................................... 116
    5.6.2 Developmental stability analysis ............................................... 116
    5.6.3 Metrics (combination indicators) .............................................. 117
6. Utility of biota for indicating the ecological health of estuaries ............... 121
  6.1 Phytoplankton as ecological indicators .......................................... 122
  6.2 Benthic microalgae and periphyton as ecological indicators .............. 125
  6.3 Zooplankton as ecological indicators ............................................. 126
  6.4 Benthic macro-invertebrates as ecological indicators ....................... 128
7. Historical data for south-western Australian estuaries .......................... 131
  7.1 Rainfall .................................................................................... 131
  7.2 Stream flow ............................................................................... 132
  7.3 Stream-water quality .................................................................... 133
  7.4 Stream nutrient loads .................................................................... 135
  7.5 Swan estuary ............................................................................. 136
  7.6 Peel Inlet ................................................................................... 139
  7.7 Leschenault Inlet ....................................................................... 142
  7.8 Summary of historical information .................................................. 143
<table>
<thead>
<tr>
<th>Section</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>8.</td>
<td>Inventory of south-western Australian estuaries</td>
<td>167</td>
</tr>
<tr>
<td>8.1</td>
<td>Materials and methods</td>
<td>168</td>
</tr>
<tr>
<td>8.1.1</td>
<td>Estuarine sampling sites</td>
<td>168</td>
</tr>
<tr>
<td>8.1.2</td>
<td>Sampling strategy</td>
<td>170</td>
</tr>
<tr>
<td>8.1.3</td>
<td>Biological monitoring</td>
<td>170</td>
</tr>
<tr>
<td>8.1.4</td>
<td>Data analysis</td>
<td>173</td>
</tr>
<tr>
<td>8.2</td>
<td>Results and discussion</td>
<td>173</td>
</tr>
<tr>
<td>8.2.1</td>
<td>Physical and chemical water quality</td>
<td>173</td>
</tr>
<tr>
<td>8.2.2</td>
<td>Phytoplankton</td>
<td>177</td>
</tr>
<tr>
<td>8.2.3</td>
<td>Zooplankton</td>
<td>185</td>
</tr>
<tr>
<td>8.2.4</td>
<td>Benthic macro-invertebrates</td>
<td>189</td>
</tr>
<tr>
<td>8.3</td>
<td>Linking biological and physico-chemical information</td>
<td>194</td>
</tr>
<tr>
<td>8.4</td>
<td>Summary of biological inventories</td>
<td>197</td>
</tr>
<tr>
<td>9.</td>
<td>Periphyton colonisation and responsiveness</td>
<td>256</td>
</tr>
<tr>
<td>9.1</td>
<td>Factors influencing periphyton communities</td>
<td>257</td>
</tr>
<tr>
<td>9.1.1</td>
<td>Light and temperature</td>
<td>257</td>
</tr>
<tr>
<td>9.1.2</td>
<td>Seasonal influences</td>
<td>258</td>
</tr>
<tr>
<td>9.1.3</td>
<td>Nutrient availability</td>
<td>258</td>
</tr>
<tr>
<td>9.1.4</td>
<td>Substratum effects on colonisation dynamics</td>
<td>259</td>
</tr>
<tr>
<td>9.1.5</td>
<td>Grazing and disturbance of communities</td>
<td>261</td>
</tr>
<tr>
<td>9.2</td>
<td>The aim of evaluating periphyton as environmental indicators</td>
<td>262</td>
</tr>
<tr>
<td>9.3</td>
<td>Materials and methods</td>
<td>263</td>
</tr>
<tr>
<td>9.3.1</td>
<td>Development of the periphyton collector</td>
<td>263</td>
</tr>
<tr>
<td>9.3.2</td>
<td>Periphyton accumulation in estuaries</td>
<td>264</td>
</tr>
<tr>
<td>9.3.3</td>
<td>Development and calibration of the zone-enrichment apparatus</td>
<td>264</td>
</tr>
<tr>
<td>9.4</td>
<td>Results of the periphyton investigations</td>
<td>266</td>
</tr>
<tr>
<td>9.4.1</td>
<td>Periphyton sampler</td>
<td>266</td>
</tr>
<tr>
<td>9.4.2</td>
<td>Periphyton accumulation in estuaries</td>
<td>266</td>
</tr>
<tr>
<td>9.4.3</td>
<td>Nutrient enrichment at one site</td>
<td>267</td>
</tr>
<tr>
<td>9.4.4</td>
<td>Nutrient enrichment in the south-west estuaries</td>
<td>268</td>
</tr>
<tr>
<td>9.5</td>
<td>Discussion</td>
<td>269</td>
</tr>
<tr>
<td>9.5.1</td>
<td>Success of the periphyton-sampling apparatus</td>
<td>269</td>
</tr>
<tr>
<td>9.5.2</td>
<td>The effect of water movement</td>
<td>271</td>
</tr>
<tr>
<td>9.5.3</td>
<td>The effect of nutrient availability</td>
<td>272</td>
</tr>
<tr>
<td>9.5.4</td>
<td>Salinity effects</td>
<td>272</td>
</tr>
<tr>
<td>9.5.5</td>
<td>Other factors</td>
<td>273</td>
</tr>
<tr>
<td>9.6</td>
<td>Conclusions</td>
<td>274</td>
</tr>
<tr>
<td>10.</td>
<td>Health indicators for Western Australian Estuaries</td>
<td>294</td>
</tr>
<tr>
<td>10.1</td>
<td>Why south-west Western Australian estuaries are highly susceptible to nutrient enrichment</td>
<td>294</td>
</tr>
<tr>
<td>10.1.1</td>
<td>Patterns of rainfall</td>
<td>295</td>
</tr>
<tr>
<td>10.1.2</td>
<td>Leaching soils</td>
<td>295</td>
</tr>
<tr>
<td>10.1.3</td>
<td>Heterogeneous run-off</td>
<td>296</td>
</tr>
<tr>
<td>10.1.4</td>
<td>Lack of in-stream assimilation</td>
<td>297</td>
</tr>
<tr>
<td>10.1.5</td>
<td>Small diurnal tidal ranges</td>
<td>297</td>
</tr>
<tr>
<td>10.1.6</td>
<td>Shallow estuarine basins and restricted entrance conditions</td>
<td>298</td>
</tr>
<tr>
<td>10.1.7</td>
<td>Catchment clearing</td>
<td>299</td>
</tr>
<tr>
<td>Section</td>
<td>Title</td>
<td>Page</td>
</tr>
<tr>
<td>---------</td>
<td>---------------------------------------------------------</td>
<td>------</td>
</tr>
<tr>
<td>10.1.8</td>
<td>Annual pastures and fertiliser applications</td>
<td>299</td>
</tr>
<tr>
<td>10.1.9</td>
<td>Nutrient export</td>
<td>300</td>
</tr>
<tr>
<td>10.1.10</td>
<td>Estuarine processes</td>
<td>300</td>
</tr>
<tr>
<td>10.2</td>
<td>Health and risk assessment for south-west estuaries</td>
<td>302</td>
</tr>
<tr>
<td>10.2.1</td>
<td>Defining ecosystem health</td>
<td>302</td>
</tr>
<tr>
<td>10.2.2</td>
<td>South-west estuaries at risk from nutrient enrichment</td>
<td>303</td>
</tr>
<tr>
<td>10.3</td>
<td>Validation of indicators</td>
<td>305</td>
</tr>
<tr>
<td>10.4</td>
<td>Physico-chemical indicators</td>
<td>307</td>
</tr>
<tr>
<td>10.4.1</td>
<td>Catchment run-off quality</td>
<td>307</td>
</tr>
<tr>
<td>10.4.2</td>
<td>Estuarine processes and flushing</td>
<td>310</td>
</tr>
<tr>
<td>10.4.3</td>
<td>Dissolved oxygen</td>
<td>310</td>
</tr>
<tr>
<td>10.4.4</td>
<td>Nutrients</td>
<td>312</td>
</tr>
<tr>
<td>10.4.5</td>
<td>Chlorophyll a</td>
<td>313</td>
</tr>
<tr>
<td>10.5</td>
<td>Biological indicators</td>
<td>315</td>
</tr>
<tr>
<td>10.5.1</td>
<td>Phytoplankton</td>
<td>317</td>
</tr>
<tr>
<td>10.5.2</td>
<td>Zooplankton</td>
<td>318</td>
</tr>
<tr>
<td>10.5.3</td>
<td>Benthic macro-invertebrates</td>
<td>319</td>
</tr>
<tr>
<td>10.5.4</td>
<td>Indicator species</td>
<td>321</td>
</tr>
<tr>
<td>10.6</td>
<td>The Dawesville Channel: a restoration success?</td>
<td>322</td>
</tr>
<tr>
<td>10.7</td>
<td>Suitability of biological health indicators for south-western Australian estuaries</td>
<td>324</td>
</tr>
<tr>
<td>10.7.1</td>
<td>South-west phytoplankton communities</td>
<td>324</td>
</tr>
<tr>
<td>10.7.2</td>
<td>South-west zooplankton communities</td>
<td>324</td>
</tr>
<tr>
<td>10.7.3</td>
<td>South-west benthic macro-invertebrate communities</td>
<td>325</td>
</tr>
<tr>
<td>10.7.4</td>
<td>South-west periphyton communities</td>
<td>326</td>
</tr>
<tr>
<td>10.7.5</td>
<td>Conclusions</td>
<td>326</td>
</tr>
<tr>
<td>11.</td>
<td>References</td>
<td>348</td>
</tr>
</tbody>
</table>

Appendix 1: Examples of environmental indicators used globally to assess aspects of estuarine conditions. 398

Appendix 2: Examples of biological indicators used to assess aspects of the ecological health of Australian estuaries. 410
Table of figures

Figure 1.1: Distribution of tides around Australia (After Radock, 1976) ... 13

Figure 1.2: Average monthly rainfall (mm) for Australian capital cities ... 14

Figure 2.1: A three-stage conceptual model of a typical annual cycle of transport, retention and transformation of material for permanently open estuaries in the south-west of Australia that are under the influence of a Mediterranean climate ... 38

Figure 2.2: A four-stage conceptual model of a typical annual cycle of transport, retention and transformation of material for seasonally closed estuaries in the south-west of Australia that are under the influence of a Mediterranean climate ... 39

Figure 2.3: Nutrient behavior during post flood recovery of the Richmond River Estuary Northern NSW, Australia (after Eyre and Twigg, 1977). Also shown are zones of potential nutrient limitation from Figure 2.4 ... 40

Figure 2.4: Potential nutrient limitation during post flood recovery of the Richmond River Estuary Northern NSW, Australia (data reworked from Eyre and Twigg, 1977) ... 41

Figure 7.1: Estuarine and marine locations monitored. Estuarine catchments are also shown ... 147

Figure 7.2: Long term rainfall for Boyanup Post Office from 1908 to 1991 ... 148

Figure 7.3: Probability of non-exceedance for daily rainfall by month at Boyanup from 1908 to 1991 ... 149

Figure 7.4: Average annual flow with one standard deviation and NO3-N, NH4-N and total N for south-west rivers showing median and 90th-percentile concentrations ... 150

Figure 7.5: Concentrations of TN and TP from rivers draining south-western Australian catchments ... 152

Figure 7.6: Water quality in the Swan River estuary from 1945 to 1995. Salinity, dissolved oxygen, total N and total P ... 153

Figure 7.7: Water quality in the Swan River estuary from 1945 to 1995. NO3-N, NH4-N, FRP and chlorophyll a ... 154

Figure 7.8: Relationships between forms of N and P and chlorophyll a in the Swan River estuary from 1945 to 1995 ... 155

Figure 7.9: Water quality in the Peel-Harvey estuary from 1977 to 1995. Salinity dissolved oxygen, total nitrogen and total phosphorus ... 156

Figure 7.10: Water quality in the Peel-Harvey estuary from 1977 to 1995. NO3-N, NH4-N, FRP and chlorophyll a ... 157
Figure 7.11: Relationships between forms of nitrogen and phosphorus and chlorophyll a in the Peel-Harvey estuary from 1977 to 1995. ............................................. 158

Figure 7.12: Surface water quality (Salinity, dissolved oxygen and total phosphorus) in Leschenault Inlet from 1976 to 1985. ................................................................. 159

Figure 7.13: Surface water quality (NH4-N, FRP and turbidity) in Leschenault Inlet from 1976 to 1985. .................................................................................. 160

Figure 8.1: Location of the Swan estuary, its catchment, and historical and recent sampling sites. ................................................................................. 197

Figure 8.2: Location of the Peel–Harvey estuary, its catchment, and historical and recent sampling sites. ................................................................. 201

Figure 8.3: Location of Leschenault, its catchment, and historical and recent sampling sites. .................................................................................. 199

Figure 8.4: Location of Hardy Inlet, its catchment and recent sampling sites. .................................................................................. 200

Figure 8.5: Location of Broke Inlet, its catchment and recent sampling sites. .................................................................................. 201

Figure 8.6: Location of Walpole-Nornalup Inlet, its catchment and recent sampling sites. .................................................................................. 202

Figure 8.7: Location of Wilson Inlet, its catchment and recent sampling sites. .................................................................................. 203

Figure 8.8: Location of Oyster Harbour, its catchment and recent sampling sites. .................................................................................. 204

Figure 8.9: Location of Stokes Inlet, its catchment and recent sampling sites. .................................................................................. 205

Figure 8.10: Water quality in south-west estuaries during trip 1, summer 1995. .................................................................................. 206

Figure 8.11: Water quality in south-west estuaries during trip 2, winter 1995. .................................................................................. 207

Figure 8.12: Water quality in south-west estuaries during trip 3, summer 1996. .................................................................................. 208

Figure 8.13: Nutrient limitation in surface and bottom waters of all estuarine sites for trip 1 and trip 3 (summer 1995, summer 1996). Points falling in the area marked N, P or Si show stoichiometric (potential) nutrient limitation. ................................................. 209

Figure 8.14: Nutrient limitation in surface and bottom waters of all estuarine sites for Trip 2 (winter 1995). Points falling in the area marked N, P or Si show stoichiometric (potential) nutrient limitation. ................................................. 210

Figure 8.15: Dendrogram of log transformed phytoplankton community data for 1995 using group averaged linking. ......................................................... 211

Figure 8.16: Dendrogram of log transformed phytoplankton community data for 1996 using group averaged linking. ......................................................... 212

Figure 8.17: Percent similarity versus sampling area for 1996 phytoplankton community at all sites. ................................................................. 213
Figure 8.18: Ordination bi-plot from multidimensional scaling of phytoplankton community data at each site in 1995. ................................. 214

Figure 8.19: Ordination bi-plot from multidimensional scaling of phytoplankton community data at each site in 1996. ........................................ 215

Figure 8.20: Ordination bi-plot from principal components analysis of physicochemical variables influencing the 1995 phytoplankton community at each site. ................................................................................................. 216

Figure 8.21: Ordination bi-plot from principal components analysis of physicochemical variables influencing the 1996 phytoplankton community at each site. ................................................................................................. 217

Figure 8.22: Percent similarity plots of 1995–96 zooplankton community for sites with six replicates. .................................................. 218

Figure 8.23: Dendrogram of fourth-root transformed zooplankton community data for 1995 using group averaged linking. .................. 219

Figure 8.24: Ordination bi-plot from multidimensional scaling of zooplankton community data for 1995–96. .................................................. 220

Figure 8.25: Ordination bi-plot from principal components analysis of physicochemical variables influencing the 1995–96 zooplankton community at each site. ................................................................................................. 221

Figure 8.26: Percent similarity plots of 1996 benthic macro-invertebrate community. .................................................. 222

Figure 8.27: Dendrogram of fourth-root transformed benthic macro-invertebrate community data for 1995 using group average linking. .......... 223

Figure 8.28: Dendrogram of fourth-root transformed benthic macro-invertebrate community data for 1996 using group average linking. .......... 224

Figure 8.29: Ordination bi-plot from multidimensional scaling of benthic macro-invertebrate data in 1995. .................................................. 225

Figure 8.30: Ordination bi-plot from multidimensional scaling of benthic macro-invertebrate data in 1996. .................................................. 226

Figure 8.31: Ordination bi-plot from principal components analysis of physicochemical variables influencing the 1995 benthic macro-invertebrate community at each site. .................................................. 227

Figure 8.32: Ordination bi-plot from principal components analysis of physicochemical variables influencing the 1996 benthic macro-invertebrate community at each site. .................................................. 228

Figure 8.33: Ordination bi-plot from detrended canonical correspondence analysis of the phytoplankton community for 1995 with the eigenvectors for the environmental variables influencing the community at each site. ................................. 229
Figure 9.15: Results of periphyton accumulation in south-west estuaries.......................... 284

Figure 9.16: Accumulation of AFDW as periphyton in each estuary in response to nutrient additions................................................................................................................. 285

Figure 9.17: Relationship between TP in each estuary and BAP measured from the periphyton collectors................................................................................................................ 286

Figure 9.18: Bioavailable phosphorus and periphyton accumulation in response to nutrient additions................................................................................................................ 287

Figure 10.1: Location of the main soil types in the south-west of Western Australia (Redrawn from WA Govt, 1979). ........................................................................................................ 326

Figure 10.2: Daily flow for the Frankland River at Mount Frankland from 1956 to 1997. Grey area represents normal flow patterns. Red points represent higher than normal summer and autumn flows, blue points are higher than normal winter flows and green points are higher than normal spring flows. ........................................................................................................... 327

Figure 10.3: The relationship between indicators, end points and system values (after Costanza et al., 1998). ........................................................................................................ 328

Figure 10.4: The relationship between the cell width of fixed interval sampling and the reliability of load estimates (After Weaver, 1993). .................................................................................. 329

Figure 10.5: Auditing water quality targets for the Peel-Harvey catchment................................................................................................................................. 330

Figure 10.6: A profile plot of bottom dissolved-oxygen percentage saturation in the Peel–Harvey estuary from 1982 to 1994. ........................................................................................................ 331

Figure 10.7: A probability plot of dissolved oxygen in the Swan River estuary from 1945 to 1995........................................................................................................................................ 332

Figure 10.8: Total phosphorus concentrations in surface estuarine waters from 1945 to 1995 with LOWESS smooth fitted........................................................................................................ 333

Figure 10.9: Probability plots of Chlorophyll a for different TN and TP concentration ranges for surface estuarine waters from October to May: ........................................................................ 334

Figure 10.10: Interaction plot by year for phytoplankton communities in 1995 and 1996 from analysis of variance for a) log of biomass, b) species richness, c) Shannon-Weiner diversity ($H'$) and d) Pielou's evenness (Ep) for each estuary................................................................................................................ 335

Figure 10.11: Zooplankton communities in 1995–96 from analysis of variance for a) log of biomass, b) species richness, c) Shannon-Weiner diversity ($H'$) and d) Pielou's evenness (Ep) for each estuary................................................................................................................ 336

Figure 10.12: Interaction plot by year for benthic macro-invertebrate communities in 1995 and 1996 from analysis of variance for a) log of biomass, b) species richness, c) Shannon-Weiner diversity ($H'$) and d) Pielou's evenness (Ep) for each estuary................................................................................................................ 337
Figure 10.13: Ratios of potentially harmful phytoplankton species in south-west estuaries for summer 1995 (Trip 1) and summer 1996 (Trip 3). ............................................ 338

Figure 10.14: Seasonal and annual water quality for bottom waters of Harvey estuary. Salinity and dissolved oxygen concentrations.......................................................... 339

Figure 10.15: Seasonal and annual water quality for bottom waters of Harvey estuary. \( \text{NH}_4\text{-N} \) and FRP concentrations. ................................................................. 340

Figure 10.16: Seasonal and annual water quality for bottom waters of Harvey estuary. Secchi disk depth and chlorophyll \( a \) concentrations.................................................. 341

Figure 10.17: Probability plots for various water quality variables for the Peel-Harvey estuary before and after completion of the Dawesville Channel. Dissolved oxygen, DIN, FRP and chlorophyll \( a \) concentrations. ................. 342
Table of tables

Table 1.1: Distribution of estuaries, marine embayments and tidal creeks in Australia (after Ferguson, 1996) ....................................................... 15

Table 1.2 Environmental indicators used to define ecosystem health of estuaries. (After Rochford, 1951; NOAA, 1988; NOAA, 1989; Alve, 1991; Riding, 1992; Ahl, 1993; Cairns Jr. et al., 1993; NOAA, 1993; Harris, 1994; Harris, 1995; Holdway et al., 1995; Strobel et al., 1995; ANZECC, 1998; Fairweather and Napier, 1998; Ward et al., 1998a; Ward et al., 1998b) .......................... 16

Table 1.3 Symptoms of ecosystem distress syndrome described in the literature. (After Odum 1985; Havens 1994, Birkett and Rapport 1996, Nielsen and Jernakoff 1996) ....................................................... 17

Table 4.1: Potential impacts and threats to coastal ecosystems in Australia (after Fairweather, 1990). ............................................................................ 97

Table 4.2: Mobilisation and toxicity of heavy metals in marine waters in decreasing order of toxicity (After Ketchum, 1980). ....................................................... 98

Table 4.3: Typical concentrations of nutrients reported in the literature for severe phytoplankton blooms ............................................................................ 98

Table 4.4: Characteristics of some petroleum products (After Connell, 1995). ............................................................................ 99

Table 7.1: Description of gauging stations recording flow for streams discharging to west-coast estuaries ............................................................................ 158

Table 7.2: Description of gauging stations recording flow for streams discharging to south coast estuaries ............................................................................ 159

Table 7.3: Description of ungauged areas for each estuary ............................................................................ 159

Table 7.4: Average annual flow volume (Mm³/yr) and coefficient of variation for gauged streams discharging to estuaries for 1985-1995 ............................................................................ 160

Table 7.5: Description of run-off sampling sites for the West Coast ............................................................................ 161

Table 7.6: Description of run-off sampling sites for the South Coast ............................................................................ 162

Table 7.7: Observed and estimated average annual run-off and nutrient loads for gauged and ungauged portions of south-west estuarine catchments ............................................................................ 163

Table 8.1: Description of each estuary where five sampling sites were established (n=50) ............................................................................ 234

Table 8.2: Description of sites within west-coast estuaries ............................................................................ 235

Table 8.3: Description of sites within south-coast estuaries ............................................................................ 236

Table 8.4: Variable list, units, sampling position, sampling times and sites for run-off and estuarine waters ............................................................................ 237
Table 8.5: Variable list, replicates, units, sampling position, sampling times and sites for sediments .......................................................... 238

Table 8.6: Biological variables, replicates, units, sampling position, sampling times and sites .......................................................... 239

Table 8.7: Gilvin concentrations in selected south-west estuaries .......................................................... 240

Table 8.8: Overall percentage similarity for each estuary for two summer index periods of 1995 and 1996, calculated using the five sites at each estuary and both the entire phytoplankton community, and with five percent of the rare species removed .......................................................... 241

Table 8.9: Total number of species observed, total number of individuals, species richness, Shannon-Weiner diversity, Pielou’s evenness, and biomass (mg/m$^3$) for phytoplankton at all estuarine sites in 1995 .......................................................... 242

Table 8.10: Total number of species observed, total number of individuals, species richness, Shannon-Weiner diversity, Pielou’s evenness, and biomass (mg/m$^3$) for phytoplankton at all estuarine sites in 1996 .......................................................... 243

Table 8.11: Results of analysis of variance for phytoplankton community data showing level of significance for log biomass, species richness, Shannon-Weiner diversity (H') and Pielou’s evenness (E$_p$) .......................................................... 244

Table 8.12: Results of post-hoc investigations of significance of phytoplankton communities using Duncan’s new multiple-range test for log biomass, species richness, Shannon-Weiner diversity (H') and Pielou’s evenness (E$_p$) .......................................................... 245

Table 8.13: Overall percentage similarity for each estuary for the summer index period of 1995, and 1996 in Stokes Inlet, calculated using the five sites at each estuary and both the entire zooplankton community, and with five percent of the rare species removed .......................................................... 246

Table 8.14: Total number of species observed, total number of individuals, species richness, Shannon-Weiner diversity, Pielou’s evenness, and biomass (mg/m$^3$) for zooplankton at all estuarine sites .......................................................... 247

Table 8.15: Results of post-hoc investigations of significance of the 1995–96 zooplankton community using Duncan’s new multiple-range test for log biomass, species richness, Shannon-Weiner diversity (H') and Pielou’s evenness (E$_p$) .......................................................... 248

Table 8.16: Overall percentage similarity for each estuary for the two summer index periods 1995 and 1996, calculated using the five sites at each estuary with the entire benthic macro-invertebrate community and with five percent of the rare species removed .......................................................... 249

Table 8.17: Total number of species observed, total number of individuals, species richness, Shannon–Weiner diversity, Pielou’s evenness, and biomass (mg/m$^2$) for benthic macro-invertebrates at all estuarine sites in 1995 .......................................................... 250
Table 8.18: Total number of species observed, total number of individuals, species richness, Shannon–Weiner diversity, Pielou’s evenness, and biomass (mg/m²) for benthic macro-invertebrates at all estuarine sites in 1996.

Table 8.19: Results of analysis of variance for benthic macroinvertebrate communities showing level of significance for log biomass, species richness, Shannon–Weiner diversity (H'), and Pielou's evenness (Ep).

Table 8.20: Results of post-hoc investigation of significance of benthic macroinvertebrate communities using Duncan's new multiple range test for log biomass, species richness, Shannon–Weiner diversity (H'), and Pielou's evenness (Ep).

Table 2.21: Highest correlations obtained between biological and physico-chemical variables for each year and trophic group.

Table 9.1: Nutrient content of slow release fertiliser Scott’s Osmacote Plus (N, P, K, Mg ratio of 15:4.8:10:8:1.2).

Table 9.2: Results of ANOVA for various experiments using periphyton collectors.

Table 9.3: Periphyton accumulation and responsiveness observed from the zone enrichment experiments in south-western estuaries.

Table 9.4: Plant pigments monitored in periphyton groups collected in estuaries (Wright et al., 1991).

Table 10.1: Macro-invertebrate taxa in south-western and south-eastern Australian streams (after Bunn and Davies, 1990).

Table 10.2: Catchment and basin characteristics, and average annual nutrient and water loads to south-western Australian estuaries.

Table 10.3: The area of south-west catchments consisting of siliceous sands and leached podzol soils and the proportion of sandy soils cleared.