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A botanical importance rating system for estuaries

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Abstract. In many semi-arid areas, estuaries are threatened because of freshwater impoundment. Estuaries are important sites for ecological diversity and, increasingly, for recreation. A system has been developed which rates estuaries according to their botanical importance. A formula allows a single numerical importance score to be calculated. The area cover of each estuarine plant community type (i.e. intertidal salt marsh, submerged macrophytes, reed/sedge swamps and supratidal salt marsh) and its importance in the estuary forms the basis of the score. The 'ecological condition' of the plant community and the community richness within the estuary are incorporated into the formula. The formula is effective in determining the botanical importance of estuaries. Further methods to determine the zoological, physical and socio-economic importance of estuaries need to be developed to allow the overall importance of estuaries to be determined.

Keywords: Evaluation; Plant community type; South Africa.

Nomenclature: See Table 1.

Introduction

Estuaries in South Africa are threatened by encroaching industrial and residential development, recreational activities as well as an increasing demand for freshwater from a rapidly expanding population (Siegfried 1978; Begg 1985; Whitfield & Bruton 1989). The construction of impoundments and the resultant decrease in freshwater flowing into the estuaries will have far-reaching consequences for their biological and physical functioning (Allanson 1992; Adams et al. 1992; Reddering 1988). In place of a pristine system, a shallow, silted up estuary with degraded plant and animal communities will affect a number of common recreational activities such as swimming, boating, angling, canoeing and sailing (Ramm 1990; Begg 1975).

The construction of dams appears, at present, to be the only way to satisfy the freshwater demand of South Africa's population. This implies that not all estuaries will be able to be conserved with respect to their freshwater requirements. Estuaries with a high conservation priority need to be identified and their freshwater requirements met in order to ensure their continued functioning (Siegfried 1978). Any individual estuary can be identified as important for a number of different reasons. It may have a rare bird species present; another may have unique hydrological features and still another may have especially large salt marsh areas or it might be an important recreation area. These zoological, physical, socio-economic and botanical factors all contribute to the overall importance of an estuary. The Consortium for Estuarine Research and Management (CERM) is working towards incorporating all these attributes and developing an overall importance value for South African estuaries (N. Quinn pers. comm.). This paper, however, only deals with the botanical importance of estuaries.

Plant communities in estuaries have both ecological and economic importance within the estuary (Vernberg 1993). Ecologically, salt marshes are a source of primary production and they provide a habitat and food for a large variety of faunal species (Childers & Day 1990; Kokkin & Allanson 1985; Taylor & Allanson 1995). Reed beds are capable of removing large amounts of nutrients from the water column and act as nutrient sinks in the natural environment (Martin & Fernandez 1992; Brix 1993; Vernberg 1993). The economic importance of estuarine plant communities relates to the effectiveness of salt marshes in flood, erosion and storm-water surge control (Vernberg 1993). Their ability to improve water quality by retaining pollutants and excess nutrients can also have important economic implications. Any method which aims to determine the botanical importance of estuaries must take these properties into account.

A large salt marsh will be a more effective habitat than a small one and must, therefore, be considered more important for the estuary. Maintenance of habitat has long been recognized as the key issue in conservation and environmental management. In addition, the greater the number of different plant community types in an estuary the greater the variety of habitat but, according to Keddy (1991), we need indicators of biological health because in the absence of measurable criteria, we have little way to judge whether one environmental state is better than another.

A standard method of condensing biological community information for use by professionals not trained in biology is through the use of an index (Ramm 1988). Comparison of faunal or floral lists is difficult and therefore a variety of indices has been developed. The simplest of these provide information on community structure and examples include the Shannon-Weaver diversity index (Shannon & Weaver 1949), the index of species richness by Margalef (1958) and the evenness index by Pielou (1966). Many indices have been developed to assess water quality based on presence or absence of biota (Chutter 1972; van Dam et al. 1994) while others include an assessment of the habitat (Railsback et al. 1981; Harper et al. 1992; Campbell 1994).

Using indices, planners, developers, managers and conservationists are able to see at a glance which areas are sensitive and require more attention and which should have a high conservation priority. To this end, Raal & Burns (1996) have developed an index, which they call a '*Numerical Importance Value*', to assess the condition of the vegetation around the South African coast.

The numerical value is calculated using a table of individual values for each component:

$$NIV = VRF \times END + SR + TS + DIS/2 + AV/2 \quad (1)$$

where VRF = Vegetation Rarity Factor, END = endemism, SR = Species richness; TS = Threatened species, DIS = Disturbance and AV = Alien Vegetation. Their results enabled them to classify the coastal vegetation into a number of importance categories, namely, High Conservation Importance, Intermediate Conservation Importance, Low Conservation Importance and Insignificant Conservation Importance.

The botanical importance index developed in this project is effective at summarising the most important estuarine botanical information into a single score. Using this index it is possible to identify estuaries which are botanically important and require careful consideration, management and conservation.

Development of a botanical importance score

The factors used in the botanical scoring of estuaries were:

- Plant community area covered;
- Plant community condition (degree of impact);
- Plant community importance within the estuary; and
- Plant community richness.

Species were not considered separately because, unlike in most terrestrial environments, most estuarine plant communities consist of either one or very few dominant species (O'Callaghan 1994). For example, monospecific stands of the reed *Phragmites australis* are common in brackish estuaries. Also, there are no South African estuarine plant species which are considered to be rare, endangered or threatened (Hilton-Taylor 1996) although this probably needs further investigation.

The principle behind the scoring was that the greater the area covered by a plant community, the fewer impacts associated with it, and the greater the number of communities – i.e. community richness – in an estuary, the higher

Table 1. Plant communities for the botanical scoring of estuaries.

Plant community	Main species (for South African estuaries)
Supratidal salt marsh	*Suaeda fruticosa* (L.) Forssk. *Sarcocornia pillansii* (Moss) A.J. Scott *Atriplex vestita* (Thunb.) Aell. var. *appendiculata* Aell. *Disphyma crassifolium* (L.) L. Bol
Intertidal salt marsh	*Sarcocornia perennis* (Mill.) A.J. Scott *S. decumbens* (Tölken) A.J. Scott *Triglochin bulbosa* L. *T. maritima* Ruiz & Pav. *Spartina maritima* (Curtis) Fernald *Chenolea diffusa* (Thunb.) *Cotula coronopifolia* L.
Submerged macrophyte beds	*Zostera capensis* Setch. *Ruppia cirrhosa* (Petag.) Grande
Reed and sedge community	*Phragmites australis* (Cav.) Steud. *Juncus kraussi* Hochst. *Schoenoplectus littoralis* (Schrad.) Palla

the final score. The four plant communities considered and their main species are listed in Table 1.

The formula developed for the calculation of the final botanical score for each estuary is as follows:

$$1\,(A_{supra} \times MF) + 1.75(A_{inter} \times MF) + 1.5(A_{reed} \times MF) + 2\,(A_{subm} \times MF) \quad (2)$$

Where 1, 1.75, 1.5 and 2 are community importance values; MF is a Multiplication Factor expressing plant community condition; and

A_{supra} = Area covered by supratidal salt marsh;
A_{inter} = Area covered by intertidal salt marsh;
A_{reed} = Area covered by the reed-sedge community;
A_{subm} = Area covered by submerged macrophytes.

Each of the components of the formula is discussed below. The scoring system has been applied to 33 South African estuaries. The Kowie estuary occurring along the eastern Cape coast (33° 36' S, 26° 53' E), with three plant communities, is used as an example. Results of this overall study are described in Coetzee et al. (in press).

Community area covered (A_x)

First the areas covered by the different plant communities and the water surface area in the estuary were summed. Then the percentage area covered by each plant community and the percentage water surface area were calculated from this total. To incorporate the area cover of the plant communities into the formula, cover scores were transformed as follows: first the percentage estimates were transformed into Braun-Blanquet cover scale values as used in phytosociology (Mueller-Dombois & Ellenberg 1974) and then these values were replaced by equally spaced figures between 20 and 100 (Table 2). This large range of values was chosen to enable a more distinct comparison between community types as to the area covered by them.

A major limitation to any project including a range of number of different areas is data availability and uniformity. Area data might be available for one estuary, but not for another; or for one estuary many historical data may be available, whereas for other estuaries only one recent description is known. This means that the same sort of data are not always available for all estuaries. Using percentage range classes means that estimations can be made of the area covered by different plant communities with some degree of accuracy. Each plant community in the estuary was allocated a cover score in this manner and is represented in the formula as A_x.

Table 2. Braun-Blanquet (Br-Bl) percentage cover classes and associated scores allocated.

Cover interval	Customary Br-Bl score	Score allocated for use in the formula
0.01 - 5 %	1	20
5.01-25%	2	40
25.01-50%	3	60
50.01-75 %	4	80
> 75 %	5	100

Results for the Kowie estuary

This estuary has a supratidal marsh covering 2 % of the area, an intertidal marsh with 42 % cover and a submerged macrophyte community with 3 %. This gives a total plant community cover of 47 %, the balance of 53 % being water. The scores for each of these communities are:

	Cover	Br-Bl class	Score
Supratidal marsh	2 %	< 5%	**20**
Intertidal marsh	42 %	25 - 50 %	**60**
Submerged macrophyte community	3 %	<5 %	**20**

These values are then used as the cover score in the formula, i.e.

A_{supra} = 20
A_{inter} = 60
A_{subm} = 20.

Plant community condition (MF)

The ecological condition of the plant communities was incorporated into the formula using a multiplication step. Multiplication was used instead of addition as an addition step would always result in an increase in the score, even if the condition of the plant community was poor. A high score indicates a plant community in good condition.

The condition of the community was assessed by looking at the number of impacts affecting it. The impacts (Table 3) included were chosen after reviewing the literature and from local experience of estuarine systems and the factors affecting them. The impacts were grouped into five categories, namely, hard engineering structures, anthropogenic impacts, alien plant invasion status, water quality and sedimentation. Examples of impacts within each of these categories are indicated in Table 3. Each estuarine community needs to be checked and the number of impacts affecting the community noted. In this way the total number of impacts for each community type can be determined.

Four different condition classes (Class 1 - 4) were subjectively determined, based on the number of impacts (Table 4) and multiplication factors were assigned to these classes. Class 1, ‘pristine’, indicates an estuary

Table 3. Impact checklist against which each plant community type in the estuary is checked.

Hard engineering structures

Bridge, weir through habitat, rubble obstructing flow
Retaining walls, canalisation of estuary course, canalisation of the mouth
Jetties through the vegetation
Major dam or numerous farm dams in catchment affecting freshwater inflow

Anthropogenic impacts

Littering
Trampling and foot paths
Bait digging
Overgrazing
Boats mooring in the vegetation

Alien plant invasion status

Presence of invasive plants

Water quality

Effluent discharge upstream negatively affecting plant community
Storm water discharge into estuary negatively affecting plant communities

Sedimentation

Erosion from catchment increasing siltation in plant community
Marine sediment intrusion into the vegetation

in a natural condition with no major impacts. Class 2, 'under impact', indicates an estuary under some impact, but no rehabilitation is required; it includes estuaries where, for example, the salt marsh communities undergo some impacts, but the marsh as a whole is not in an ecologically poor condition. Class 3,'degraded', refers to those estuaries which have been changed to the extent that the plant communities involved are in a degraded state. Rehabilitation measures are necessary to restore significant botanical importance potentially attached to them. These measures may include the removal of a weir, managing the water quality or removal of invasive plant species. Class 4, 'disturbed', indicates estuaries which are under severe anthropogenic impact and have little remaining botanical significance.

The multiplication factors assigned to the community condition classes were used to modify the cover score to give a final number which incorporated the community area cover and community condition (see below). If the plant community has a large area and is in a pristine condition (Class 1) then the score is doubled. If, however, the marsh is impacted and in poor condition (Class 3), the score is divided by a factor of 2. If the community is disturbed and of little botanical significance, the cover score is multiplied by 0.1, which decreases the score considerably. Such a reduction in importance score may appear if a large salt marsh area has been degraded.

Results for the Kowie estuary

The impacts affecting each of the plant communities were determined using the impact table shown in Table 3. The supratidal marsh had two impacts affecting it, the intertidal marsh six impacts and the submerged macrophytes community five impacts. Multiplication factors MF could then be assigned using Table 4. The condition scores then change the cover scores A_x in the following manner:

	Score	A_x	MF	$A_x \times$ MF
Supratidal marsh	2%	20	2	**40**
Intertidal marsh	42%	60	1	**60**
Submerged macrophytes	3%	20	1	**20**

With 40, 60 and 20 being the adjusted scores for each community type.

Plant community importance

Each plant community was assigned an importance value according to its association with the estuary, particularly the water column. Because of their close association with the water, submerged macrophytes

Table 4. Impact classes and multiplication factors assigned to them.

Class	No. of impacts	Community quality indication	Multiplication factor
1	<2	Pristine: largely natural conditions	×2
2	3-6	Under impact: some forms of impact operating, but no rehabilitation required	×1
3	7-10	Degraded: under heavy impact: rehabilitatory measures are required	×0.5
4	>10	Disturbed: severely degraded and of little botanical significance	×0.1

(e.g. *Zostera* and *Ruppia* beds) were regarded as the most important plant community (importance value = 2). They support more diverse and abundant invertebrate and juvenile fish communities than soft-bottomed habitats and marshes (Whitfield 1984; Whitfield 1989; Fredette et al. 1990; Connolly 1994). Submerged macrophytes are an important source of net organic carbon production (Allanson 1982). Although they can be grazed directly for food, it is more common that the consumption of plant material is centred around filamentous algae and diatoms growing on the consumer organisms (Harlin 1973; Blaber 1974; Zimmerman et al. 1979). The primary productivity from an average-size seagrass bed and its associated algae and the secondary production from the large variety of resident faunal species is high, similar to some highly productive marine and terrestrial ecosystems (Fredette et al. 1990; Day 1981). Intertidal salt marshes were seen as the second most important plant community (importance value = 1.75). Although they also perform most of the functions associated with submerged macrophytes, they do not support as wide a variety of faunal species (Fredette et al. 1990). Both the submerged macrophyte and intertidal salt marsh communities are important with respect to water column processes and produce considerable amounts of plant detrital matter (Allanson 1982; Whitfield 1988).

Salt marshes are important inorganic and organic nutrient sources for estuaries but the degree of tidal flushing is important in determining how much of the nutrient is released into the water column (Childers & Day 1990). A supratidal marsh with little tidal flooding would be less important with respect to nutrient exchange with the water column than an intertidal marsh or submerged macrophyte bed (Taylor & Allanson 1995). For this reason supratidal salt marshes were given the lowest importance value (importance value = 1) as they are rarely flooded and in contact with the water column. Reed swamps and sedge communities were assigned an importance value of 1.5. These wetlands act as natural biological filters (Weisser & Parsons 1981; Brix 1993); they are important for bank stabilization and contribute to the diversity of aquatic life (particularly avifauna) (Haslam 1971).

Results for the Kowie estuary

The scores determined according to the cover and condition components are 40, 60 and 20 for the supratidal marsh, the intertidal marsh and the submerged macrophyte bed respectively. After incorporating the Importance values for each community the scores are adjusted in the following way:

	Cover × condition $A_x \times \text{MF}$	Importance value	Importance score $n(A_x \times \text{MF})$
Supratidal marsh	40	1	40
Intertidal marsh	60	1.75	105
Submerged macrophytes	20	2	40

The values used in the following step would be 40, 105 and 40.

Plant community richness

The scores calculated for each individual community, i.e. the product of the cover, condition and Importance values are added together to obtain an overall score for the estuary. The addition step incorporates the community richness aspect of the importance rating i.e. the greater number of plant communities in the estuary the higher the score.

Results for the Kowie estuary

Using the same example, the three final scores for each community are summed:

40 + 105 + 40= 185.

The score of 185 is the final botanical importance score for the estuary which includes the area covered by the three plant communities present in the estuary, condition, importance and richness of all the different plant communities . In multiple estuary comparisons the estuary which obtained the highest score after this step would be regarded as the most important estuary botanically. The estuaries would then be rated from highest to lowest to achieve a botanical importance rating.

Discussion

The botanical scoring system was successful in condensing the botanical significance data for the estuaries to a single number. Because the formula is made up of a number of different components –i.e. area, condition, importance and richness– an estuary can achieve a high or low score for different reasons. The presentation of tables showing the allocation of points is therefore essential.

Although the area covered by the plant communities has been included in the formula, the total area has been excluded. While we acknowledge that a large estuary will be more important than a small one, the problem is that most South African estuaries are small when compared with estuaries, for example, in the USA. If we had added a scoring factor based on overall size, a situation might arise where a large estuary, for example Olifants (area 650 ha) is rated against a small one, for example Buffels Oos (area 0.92ha). In our rating system, the Olifants had a normalized score of 100, whereas the Buffels Oos rated 59 – the latter area had only one plant community, but was in good condition. In the South African context, the Buffels Oos is an important estuary because of its condition rather than its size. The size of our estuaries is catered for by virtue of the fact that the small estuaries have fewer plant communities. This aspect may need attention in countries where size does not have such a big impact.

The impacts contained in the scoring system are those that can be readily observed. An impact which is included is water quality, but this is difficult to assess and quantify. Plant communities may not be degraded as a result of poor water quality, indeed communities such as reedbeds thrive under conditions of high nutrient input (Brix 1993).

In the present scoring system all impacts were considered to have an equal effect on the plants, e.g. the presence of invasive plants is comparable to the negative effect of bait digging or the construction of a road through a plant community. The scoring system could be improved by including the degree of impact on a plant community, i.e. determining the area of the plant community disturbed by the impact. This information is not readily available for South African estuaries but can be obtained from aerial photographs. This would be a time-consuming process and is probably only justified when comparing two estuaries rather than for the overall importance rating of numerous estuaries. In many cases aerial photographs are not available for the estuary before an impact occurred, e.g. in the Kowie estuary the mouth was canalized in 1836 (Heinecken & Grindley 1982). An extensive knowledge of the history of the estuary would be necessary to determine the extent of different impacts.

Other impacts that are not readily quantifiable are those that result in a change in species composition. For example, an increase in salinity as a result of decreased freshwater inflow from the catchment, might cause the disappearance of *Potamogeton* –a brackish submerged macrophyte genus– and an increase in *Zostera* – a marine submerged macrophyte genus (Adams et al. 1992). Decreased tidal flushing as a result of a weir or bridge may change the species composition of an intertidal salt marsh to a more supratidal or freshwater type. It is difficult to calculate the area of a plant community affected by these impacts. For these reasons the degree of impact is not included in the present botanical scoring system. Only the number of impacts are included. This is advantageous as the condition of the plant community can be rapidly assessed with an impact checklist after a single visit to the estuary. In the development of any index, detail is often sacrificed for perspective (Ramm 1988). In the case of this botanical scoring system, detail on the degree of impact on a plant community is omitted in preference to a perspective on the number of impacts affecting the community.

The importance rating does not incorporate the dynamic nature of estuarine plant communities. Periodically open estuaries, and some permanently open estuaries are characterized by fluctuating biomass of submerged macrophytes (Adams et al. 1992; Talbot & Bate 1987; Talbot et al. 1990). The formula does not take this into account as it only considers maximum area cover and the potential of the estuary to support a high plant biomass.

In South Africa, narrow channel-like estuaries that have a large freshwater input also support rich phytoplankton communities. Alterations to the freshwater input and the associated nutrients can impact these communities. Microalgal communities were excluded from the botanical scoring system due to lack of knowledge. They should be included at some stage because in certain estuaries microalgae are the dominant primary producers.

The conservation status or importance of a system is often determined using species richness or diversity. Turpie (1995) successfully used the diversity of bird species as a component of an index which rated the importance of South African estuaries based on avifauna. This botanical scoring system does not include species richness. Monospecific communities such as *Zostera capensis* or *Phragmites australis* beds are common in estuaries. In the salt marsh habitat, diversity is influenced by the degree of elevation above the high water mark or the salinity gradient. Salt marsh plants occur in distinct zones along this gradient. If the gradient is absent then fewer species occur. It is for these reasons that plant community richness was included instead of species richness.

The botanical scoring system developed in this project can be used to identify estuaries that have a high botanical conservation status. The freshwater input into these estuaries should be managed accordingly. From a knowledge of the dominant plant communities in the estuary, general comments can be made about the management of freshwater flow into the estuary in order to maintain the plant communities. For example, an estuary that has extensive brackish plant communities needs freshwater to maintain the environment in that condition rather than allowing it to become more saline.

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References

Adams, J.B., Knoop, W.T. & Bate, G.C. 1992. The distribution of estuarine macrophytes in relation to freshwater. *Bot. Mar.* 35: 215-226.

Allanson, B.R. 1982. The energy base of aquatic systems in South Africa. *J. Limnol. Soc. S. Afr.* 8: 47-53.

Allanson, B.R. 1992. *An assessment of the SANCOR estuaries research programme from 1980 to 1989.* Committee for Marine Science Occasional Rep. 1, Cape Town.

Begg, G.W. 1975. *The estuaries of Natal.* Natal Town and Regional Planning Rep. 41. Blackhouse, Pietermaritzburg.

Begg, G.W. 1985. *Policy proposals for the estuaries of Natal.* 2nd ed. Natal Town and Regional Planning Commission, Pietermaritzburg, Supplementary Report, Vol. 14.

Blaber, S.J M. 1974. Field studies of the diet of *Rhabdosargus holubi* (Pisces: Teleostei: Sparidae) *J. Zool.* 173: 407-417.

Brix, H. 1993. Wastewater treatment in constructed wetlands: system design, removal processes and treatment performances. In: Moshiri, G.A. (ed.) *Constructed wetlands for water quality improvement*, pp. 9-22. Lewis Publishers, Boca Raton, FL.

Campbell, I.C. 1994. The challenges of stream habitat assessment. In. Uys, M.C. (ed.) *Classification of rivers and environmental health indicators.* Proceedings of a Joint South African / Australian workshop. February 7-14, Cape Town, South Africa. Water Research Commission Report No. TT 63/94, Pretoria.

Childers, D.L. & Day, J.W. 1990. Marsh-water column interactions in two Louisiana estuaries. II. Nutrient dynamics. *Estuaries* 13: 404-417.

Chutter, F.M. 1972. An empirical biotic index of the water quality in South African streams and rivers. *Water Res.* 6: 19-30.

Coetzee, J.C., Adams, J.B. & Bate, G.C. In press. A botanical importance rating of selected Cape estuaries. *Water SA* 23.

Connolly, R.M. 1994. The role of seagrass as preferred habitat for juvenile *Sillaginodes punctata* (Cuv. & Val.) Sillaginidae, Pisces): habitat selection or feeding? *J. Exp. Mar. Biol. Ecol.* 180: 29-47.

Day, J.H. 1981. *Estuarine ecology with particular reference to southern Africa.* A.A. Balkema, Cape Town.

Fredette, T.J., Diaz, R.J., van Montfrans, J. & Orth, R.J. 1990. Secondary production within a seagrass bed (*Zostera marina* and *Ruppia maritima*) in Lower Chesapeake Bay. *Estuaries* 13: 431-440.

Harlin, M.M. 1973. Transfer of products between epiphytic marine algae and host plants. *J. Phycol.* 9: 243-245.

Harper, D.M., Smith, C.D. & Barham, P.J. 1992. Habitats as the building blocks for river conservation assessment. In: Boon, P.J., Calow, P. & Petts, G.E. (eds.) *River conservation and management*, pp. 311-320. Wiley, Chichester.

Haslam, S.M. 1971. Biological flora of the British Isles *Phragmites communis* Trin. *J. Ecol.* 81: 47-60.

Heinecken, T.J.E. & Grindley, I.R. 1982. *Estuaries of the Cape: Part II: Synopses of available information on individual systems.* In: Heydorn, A.E.F. & Grindley, J.R. (eds.) Report No. 70 Kowie (CSE 10). CSIR Research Report 409, Stellenbosch.

Hilton-Taylor, C. 1996. Red Data List of Southern African Plants. *Strelitzia* 4: 1-117.

Keddy, P.A. 1991. Biological monitoring and ecological prediction: From nature reserve management to national state of the environment indicators. In: Goldsmith, F.B. (ed.) *Monitoring for conservation and ecology*, pp. 249-267. Chapman & Hall, London.

Kokkin, M.J. & Allanson, B.R. 1985. On the flux of organic carbon in a tidal salt marsh, Kowie River estuary, Port Alfred, South Africa. *S. Afr. J. Sci.* 81: 613-617.

Margalef, R. 1958. Information theory in ecology. *Gen. Syst.* 3: 36-71.

Martin, I. & Fernandez, J. 1992. Nutrient dynamics and growth of a Cattail Crop (*Typha latifolia* L.) developed in an effluent with high eutrophic potential - application to wastewater purification systems. *Biores. Technol.* 42: 7-12.

Mueller-Dombois, D. & Ellenberg, H. 1974. *Aims and methods of vegetation ecology.* Wiley, New York, NY.

O'Callaghan, M. 1994. *Salt marshes of the Cape (South Africa): vegetation dynamics and interactions.* Ph.D. Thesis, University of Stellenbosch, Stellenbosch.

Pielou, E.C. 1966. The measurement of diversity in different types of biological collections. *J. Theor. Biol.* 13: 131-144.

Raal, P.A. & Burns, M.E.R. 1996. Mapping and conservation importance rating of the South African coastal vegetation as an aid to development planning. *Landscape Urban Plann.* 34: 359-401.

Railsback, S.F., Herricks, E.E. & Alavian, V. 1981. Modelling aquatic insect habitat. In: Armantrout, N.B. (ed.) *Acquisition and utilisation of aquatic habitat inventory information*, pp. 335-339. Western Division, American Fisheries Society.

Ramm, A.E.L. 1988. The community degradation index: A method for assessing the deterioration of aquatic habitats. *Water Res.* 22: 293-301.

Ramm, A.E.L. 1990. Application of the community degradation index to South African estuaries. *Water Res.* 24: 353-359.

Reddering, J.S.V. 1988. Coastal and catchment basin controls on estuary morphology of the south-eastern Cape coast. *S. Afr. J. Sci.* 84: 154-157.

Shannon, C.E. & Weaver, W. 1949. *The mathematical theory of communication*. University of Illinois Press, Urbana, IL.

Siegfried, W.R. 1978. Estuaries, ecology and conservation in South Africa. *S. Afr. J. Sci.* 74: 406-407.

Talbot, M.M.B & Bate, G.C. 1987. The distribution and biomass of the seagrass *Zostera capensis* in a warm-temperate estuary. *Bot. Mar.* 30: 91-99.

Talbot, M.M.B., Knoop, W.T. & Bate, G.C. 1990. The dynamics of estuarine macrophytes in relation to flood/situation cycles. *Bot. Mar.* 33: 159-164.

Taylor, D.I. & Allanson, B.R. 1995. Organic carbon fluxes between a high marsh and estuary and the inapplicability of the Outwelling Hypothesis. *Mar. Ecol. Prog. Ser.* 120 : 263-270.

Turpie, J.K. 1995. Prioritizing South African estuaries for conservation: A practical example using waterbirds. *Biol. Conserv.* 74: 175-185.

van Dam, H., Mertens, A. & Sinkeldam, J. 1994. A coded checklist and ecological indicator values of freshwater diatoms from the Netherlands. *Neth. J. Aquat. Ecol.* 28: 117-133.

Vernberg, F.J. 1993. Salt-marsh processes: A review. *Environ. Toxicol. Chem.* 12: 2167-2195.

Weisser, P.J. & Parsons, R.J. 1981. Monitoring *Phragmites australis* increase from 1937 to 1976 in the Siyai Lagoon (Natal, South Africa) by means of air photo interpretation. *Bothalia* 13: 553-556.

Whitfield, A.K. 1984. The effects of prolonged aquatic macrophyte senescence on the biology of the dominant fish species in a southern African coastal lake. *Estuar. Coast. Shelf. Sci.* 18: 315-329.

Whitfield, A.K. 1988. The fish community of the Swartvlei estuary and the influence of food availability on resource utilization. *Estuaries* 11: 160-170.

Whitfield, A.K. 1989. The benthic invertebrate community of a southern Cape estuary: structure and possible food sources. *Trans. R. Soc. S. Afr.* 47: 159-179.

Whitfield, A.K. & Bruton, M.N. 1989. Some biological implications of reduced fresh water inflow into eastem Cape estuaries: a preliminary assessment. *S. Afr. J. Sci.* 73: 121-122.

Zimmerman, R., Gibson, R. & Harrington, J. 1979. Herbivory and detritivory among gammaridean amphipods from a Florida seagrass community. *Mar. Biol.* 54: 41-47.

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