The use of a botanical importance rating to assess changes in the flora of the Swartkops Estuary over time

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Abstract

The Swartkops Estuary has the third largest salt marsh area in South Africa and conservation of this area is essential. Industrial and residential developments since 1939 have encroached into areas that were previously salt marsh and have reduced the botanical status of the Swartkops Estuary. Supratidal salt marsh was estimated to cover an area of approximately 40 ha before any development occurred, however presently only 5 ha remains (a reduction of 88%). The intertidal salt marsh was reduced in cover from 215 ha to 165 ha (a reduction of 23%). The reed and sedge communities and submerged macrophyte, *Zostera capensis* were affected by natural processes such as floods. This study showed that the supratidal salt marsh has been most affected by development and that which has survived remains vulnerable in terms of loss due to further developments.

A means of assessing changes in estuarine flora over time using a botanical importance rating system was tested on the Swartkops Estuary. The botanical importance score is based on the area covered by the different plant community types as well as an average primary productivity index for each plant community type. The most important botanical components in the Swartkops Estuary from the point of view of the importance score, are the intertidal salt marsh, and intertidal benthic microalgae. If the mouth remains open thus ensuring regular tidal flushing and providing bait digging does not escalate, these plant community types should continue to function optimally.

Introduction

Encroaching residential and industrial development and the increase in demand for freshwater threaten South African estuaries. In order to ensure their continued survival, there is a need to identify estuaries that have a high conservation status. An estuary might have a high conservation status if it is a reservoir of high species diversity, contains a high number of plant community types or its state of intactness is adequate to ensure continued functioning. A botanical importance rating system was developed to identify these estuaries (Coetzee et al., 1997). The botanical importance rating system can be used to assess changes in the botanical condition of an estuary over time. By comparing the present condition to the past, or pristine condition, an assessment can be made of the present botanical status of an estuary. The botanical status can be used as an indicator of ecosystem status as the plants are the primary producers and their condition will influence the status of higher trophic levels.

The Swartkops Estuary has the third largest area of salt marsh along the South African coastline and exhibits a variety of estuarine flora (Baird et al., 1986). There are six different plant community types, namely supra- and intertidal salt marsh, submerged macrophytes, reeds, sedges, phytoplankton and benthic microalgae. Plant community types not found in the estuary include mangroves and swamp forest. Macroalgae species occur in the Swartkops Estuary (Hilmer et al., 1988), but the area covered by this plant community type could not be measured from available maps or aerial photographs.

Maintenance of habitat has long been recognised as the essential 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 habitats. Ecologically, estuarine plants are a source of primary production and the community types which they comprise provide habitats for a large variety of faunal species (Davies, 1982, Bally et al., 1985; Whitfield, 1984; Adams et al., 1999). These species range from planktonic and benthic filter feeders to birds that utilise the marshes for food and breeding (Adams et al., 1999). The ability of plants to improve water quality by retaining pollutants and excess nutrients can have important implications for many beneficial water uses in the marine environment; for example mariculture, recreation and subsistence fishing. A large salt marsh will provide a more effective habitat than a small one (Daly and Mathieson 1981). A comparison of maintaining single large vs. numerous small seagrass beds has shown that density and diversity of species was higher in the many small seagrass beds. However, it was later shown that the single large seagrass continued to function longer if artificial changes were made to the surrounding environment (McNeill and Fairweather, 1993).

The Swartkops Estuary is surrounded by urban and industrial developments of the Port Elizabeth metropolitan area. These developments have resulted in a number of changes to the estuarine flora. These include physical elimination of plant community types as well as changes to the physical environment such as obstruction of water flow in the supratidal regions that has resulted in invasion by terrestrial plant species.

The objective of this study was to determine the effects of human impacts on the extent and distribution of the estuarine flora in the Swartkops Estuary. These effects were assessed from available literature, past aerial photographs, orthophoto maps and the application of a formula to calculate the comparative botanical importance score for the estuary under 'pristine' and present conditions.

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Materials and methods

Assessment of aerial photographs, orthophoto maps and past literature

The area covered by the different plant community types (ha) was measured from 1:50 000 topographic maps, aerial photographs (Directorate Surveys and Institute for Coastal Resource Management, UPE) and photographs and maps published in past reports (Jacot Guillard, 1974; Baird et al., 1986). These were converted into scaled digital images (Hewlett-Packard Scanner 4C). The digital images were then calibrated and the area covered by the plant community types was measured using image analysis software (analySIS 3.0). The area covered by residential and industrial developments and constructions such as road bridges was also measured from maps (Fig. 1). Development has mainly encroached into the supratidal salt marsh area. To estimate the past cover of this plant community type, vegetation distribution was assessed at six sites where development has encroached into the marsh. The area of supratidal marsh was measured as the area above the mean high water spring tide mark (MHWST) and below the 2.5 m contour line.

Application of the botanical importance rating formula

Botanical importance is a measure of the functional importance and is based on the area and number of different plant community types and their contribution in the form of energy input to higher trophic levels (i.e. primary production).

The botanical importance rating formula has been applied to the Swartkops Estuary to show the effect of human activities on the estuarine flora over time. The formula includes all estuarine plant community types namely; salt marsh, reeds and sedges, benthic microalgae found in the intertidal sand and mudflats and phytoplankton. The extent of the phytoplankton community type within the Swartkops Estuary was calculated as the area covered by water on the slack tide in hectares thus allowing comparison with other plant community types. The average primary productivity values were calculated from available South African literature, the exception being the values for the supratidal salt marsh (Appendix Table 1). The formula is as follows:

$$\begin{aligned} BIR = {} & a(Area_{sup}) + b(Area_{int}) + c(Area_{sub}) + d(Area_{ree}) \\ & + e(Area_{man}) + f(Area_{ben}) + g(Area_{phy}) + h(Area_{macro}) \\ & + i(Area_{swamp}) \end{aligned}$$

where:

BIR = botanical importance rating and:

Plant community type (cover in ha)		Productivity abbreviation	Productivity value ($g \cdot m^{-2} \cdot yr^{-1}$)
$Area_{sup}$	= Supratidal salt marsh	a	836
$Area_{int}$	= Intertidal salt marsh	b	651
$Area_{sub}$	= Submerged macrophytes	c	1 316
$Area_{ree}$	= Reeds and sedges	d	1 400
$Area_{man}$	= Mangroves	e	1 811
$Area_{ben}$	= Intertidal benthic microalgae	f	124
$Area_{phy}$	= Phytoplankton	g	163
$Area_{macro}$	= Macroalgae	h	196
$Area_{swamp}$	= Swamp forest	i	1 780

A wide range of botanical importance scores is usually obtained, therefore the scores are normalised to make the differences easier to conceptualise. The highest score obtained was regarded as 100 and the lower scores are represented as a percentage of the highest score.

Estuaries can be rated on a national basis using the botanical importance rating formula. Comparisons can thus be made between estuaries along the South African coastline in order to gain a better perspective on the importance of an estuary. Seven systems were selected from the Cape and KwaZulu-Natal regions and compared with the present botanical importance score of the Swartkops Estuary.

Results

Phytoplankton

The water surface area of 135 ha was used as a measure of phytoplankton and extended from the mouth of the estuary to Perseverance Bridge (16 km upstream of the mouth) (Fig. 5, Appendix Table 2). For use in the botanical importance rating, this area was considered to have remained unchanged despite the changes caused by development. Changes in freshwater input (water quantity) and water quality may have affected phytoplankton production within the estuary. These changes, however, are not included in the botanical importance formula because, as yet, we have no way of estimating the magnitude of this effect, as it is impossible to predict what phytoplankton production may have been under pristine conditions.

Benthic microalgae

The area covered by intertidal benthic microalgae was based on the extent of exposed intertidal mud and sandbanks in the estuary. This was calculated to be 174 to 180 ha. An average value of 177 ha was used in the botanical importance formula (Fig. 5, Appendix Table 2). It was assumed that there has been no significant reduction in size or change to the geomorphology of these banks over time. The scour of one bank generally results in the deposition and creation of a new bank on the opposite side (Reddering and Esterhuysen, 1988).

Submerged macrophytes - *Zostera capensis* Setchell (eelgrass)

MacNae (1957) found the seagrass *Zostera capensis* abundant along the entire length of the Swartkops Estuary and it covered an area of 15 ha (Table 1). *Z. capensis* was found in the subtidal zone in the upper reaches of the estuary but was most abundant in the intertidal regions of the middle and lower reaches. In the upper reaches of the estuary the species was observed growing on sandy substrata in contrast to the lower and middle reaches, where it grew on mud banks.

Talbot and Bate (1987) studied the population dynamics of *Z. capensis* in the Swartkops Estuary and showed that the plant is sensitive to flooding and sediment deposition. Thorough surveys of seagrass beds during the winter and summer of 1981 indicated the presence of a thriving community with up to 90% of the beds found within the first 6 km of the estuary. A significant but small difference was observed between the winter area coverage of 13.7 ha and the summer extent of 16.1 ha in 1981 (Table 1).

A survey of the Swartkops estuary in late 1984 (Hilmer et al., 1988) indicated a complete disappearance of the entire *Z. capensis*

TABLE 1
SUMMARY OF THE POPULATION DYNAMICS OF *ZOSTERA CAPENSIS* FOUND IN THE SWARTKOPS ESTUARY

Survey	Standing biomass - $g \cdot m^{-2}$ (Dry mass)	Productivity	Cover (ha)	Comment
MacNae, 1957	-	-	15	Pristine
Talbot and Bate (1987) - surveyed in 1981	76 - 125	20 x 106 g C·yr^{-1}	Increased from 13.7 - 16.1	Fluctuations due to floods
Emmerson, 1983	160 decreased to 40	-	-	Between 1982 - 1984 flood led to complete removal
Hilmer et al., 1988	-	-	0.6	Slow recovery phase
Adams and Haschick (in press)	250 - 310	-	-	Recovery hampered by trampling
Aerial photographs 1996	-	-	12.5	-

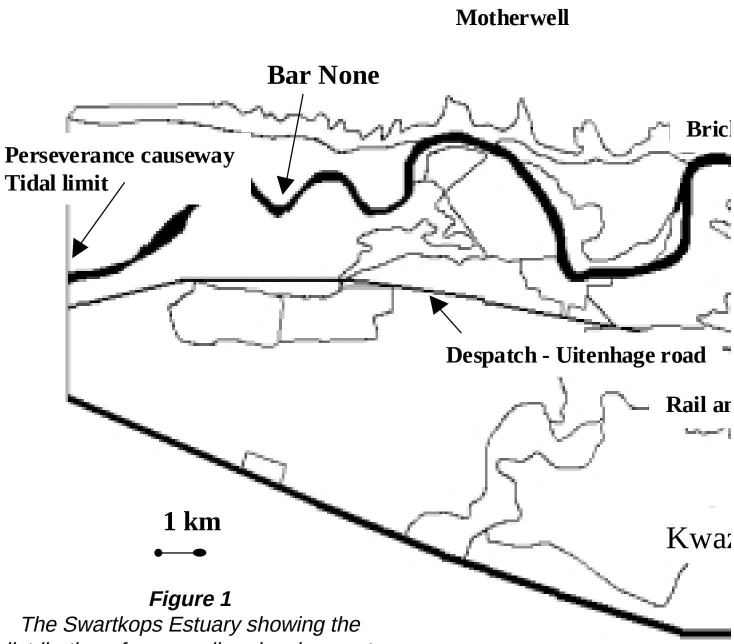

Figure 1
The Swartkops Estuary showing the distribution of surrounding developments

population from the estuary after heavy flooding. Recolonisation of the estuary by this species was only apparent in August 1988 when about 4 % of the 1981 population size had returned, covering approximately 0.6 ha (Table 1) mostly in the mouth region (Hilmer et al., 1988). In this study the area covered by *Z. capensis* was 12.5 ha (Table 1, Figs. 1 and 2).

Salt marsh

Intertidal salt marsh

For this study, it was estimated that the intertidal salt marsh covered an area of 215 ha before any development took place in the basin of the Swartkops Estuary (Table 2, Fig. 2). This would represent the pristine condition for intertidal salt marsh. Aerial photographs taken in 1939 indicate that large areas of intertidal salt marsh (45 ha) were lost when the Swartkops and Redhouse Villages were developed (Table 2, Fig. 2). In later years, smaller areas of marsh were lost to the solar salt works, the power station, the Uitenhage road and to other roads and bridges. MacNae (1957) described the Swartkops Estuary vegetation found in the lower estuarine reaches, between Amsterdamhoek and Swartkops Village. From MacNae's vegetation map it was estimated that in 1957 the intertidal salt marsh covered 168 ha. Above the railway bridge, salt marsh occurs mainly along the north bank as far as the saltworks, while beyond Redhouse Village it extends along the southern bank approximately 10 km from the mouth ("Bar – None") in a narrow belt (Fig. 1). From later maps and aerial photographs area covered by the intertidal salt marsh was 166 ha for the period 1983 to 1987

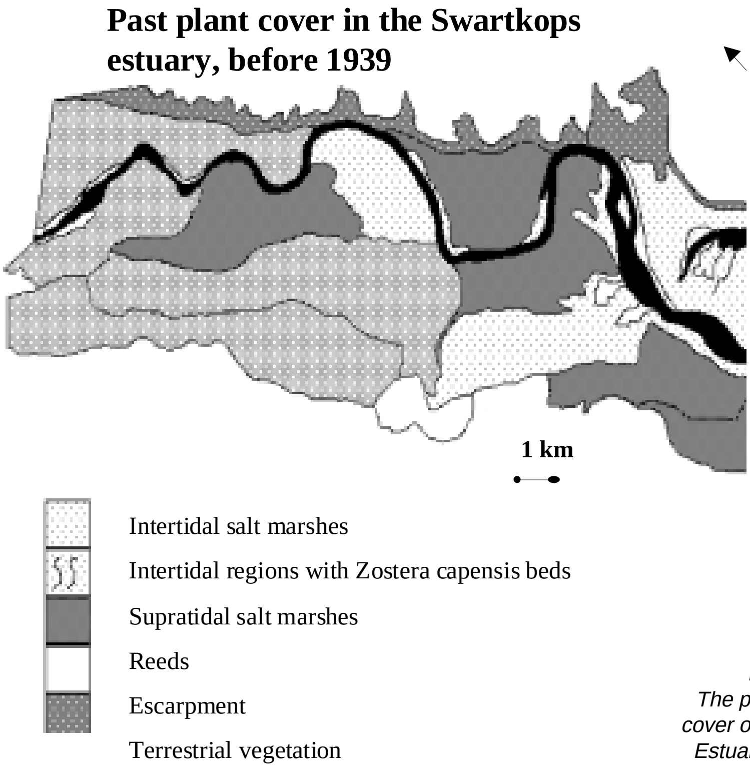

Figure 2
The past vegetation cover of the Swartkops Estuary before 1939

(Table 2). Since the construction of Settlers Bridge (N2 Highway) in 1974 there has been little change in the area covered by intertidal salt marsh (165.8 ha, Table 2, Fig. 3). In 1996 the intertidal salt marsh covered 165 ha, the reduction of 0.8 ha due to the upgrading of road interchanges in the Fishwater Flats region (Table 2).

Supratidal salt marsh

The area covered by supratidal salt marsh was measured from aerial photographs and maps drawn in previous studies (Table 3). For the pristine or pre-development condition, supratidal salt marsh was estimated to cover approximately 40 ha in extent (Fig. 2). Approximately 31 ha of supratidal salt marsh had already been eliminated by 1957 because of developments (Table 3). From 1957 to 1997 construction of Fishwater Flats Sewage Works, Settlers Bridge (N2) and the M19 bridge to Uitenhage resulted in the further removal of approximately 4 ha of marsh (Fig. 3).

Reeds and sedges

The area covered by reeds and sedges has not been documented nor identified in previous reports. For this study, estimates of the area covered by reeds and sedges were based on visual presence in photographs provided in reports and from recent colour aerial photographs (Table 4). Dense reed and sedge beds are usually found in the upper reaches of estuaries where the salinity is less than $15\ g \cdot \ell^{-1}$. *Phragmites australis* (common reed) is the dominant species in the Swartkops Estuary and extends from Redhouse Village to Perseverance causeway (head of the Estuary, Fig. 1). Table 4 shows that for the pristine condition or until 1957 reeds covered approximately 10 ha, after this a series of floods and bank erosion reduced the cover to 6 ha in 1983. Futher floods and quarrying in the channel and floodplain for stone at the head of the estuary reduced the cover to 4.5 ha in 1997.

TABLE 2
SUMMARY OF THE CHANGE IN THE AREA COVERED BY INTERTIDAL SALT MARSH AS CALCULATED FROM AVAILABLE MAPS, AERIAL PHOTOGRAPHS (TRIG. SURVEY AND DEPARTMENT OF ENVIRONMENTAL AFFAIRS) AND ORTHOPHOTO MAPS (1:10 000)

Survey/Author	Cover (ha)	Comments
Aerial photos and field survey	215	Estimate of intertidal area before any development at current MSHWM
Aerial photos 1939	170	Post development of Swartkops and Redhouse Village
MacNae, 1957 - estimated from maps	168	Post-construction of power station, salt works, Uitenhage road and railway bridges
Jacot Guillard (Hill, Kaplan and Scott) 1974 - Aerial photographs	165.3	Reduction in intertidal salt marsh after construction of Settlers Bridge (N2), 1968-1974
Orthophoto maps 1983	166	-
Aerial photographs 1985	165.8	-
Talbot and Bate, 1987	166	-
Orthophoto maps 1996	165	Reduction due to further road construction (M19 to Uitenhage)

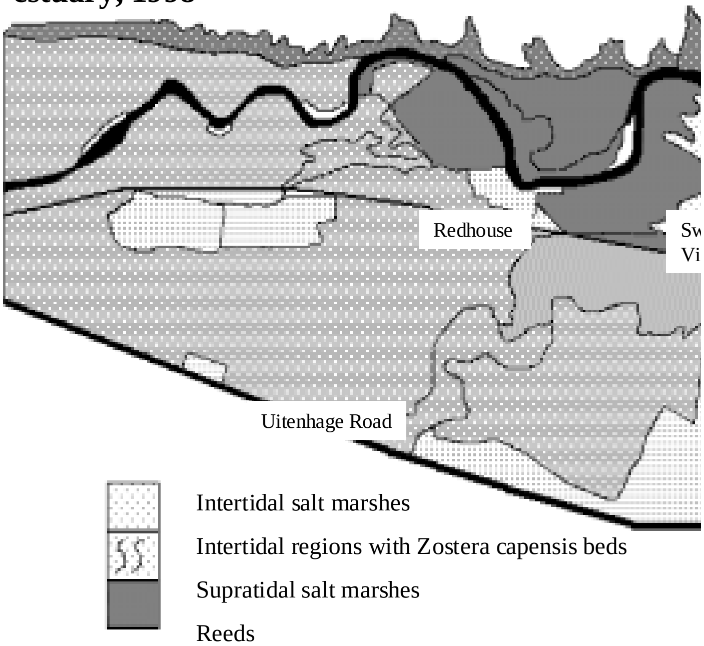

Figure 3
The present estuarine vegetation cover of the Swartkops Estuary (1998).

TABLE 3
SUMMARY OF THE CHANGE IN THE AREA COVERED BY SUPRATIDAL SALT MARSH CALCULATED FROM AVAILABLE MAPS, AERIAL PHOTOGRAPHS (TRIG. SURVEY AND DEPARTMENT OF ENVIRONMENTAL AFFAIRS) AND ORTHOPHOTO MAPS (1:10 000).

Survey/source	Cover (ha)	Comments
Aerial photos 1939	40	Estimate of supratidal area before any development at 2.5 m contour
MacNae 1957 - estimated from maps	9	Post development of Swartkops Village and Redhouse Village, power station, salt works, Uitenhage road and railway bridges, Neave industrial area
Jacot Guillard, 1974	8	Post construction of Fishwater Flats Sewage Works (1972) and the Settlers Bridge (1968-1974)
Orthophoto maps 1983	6	Road construction (M19 to Uitenhage)
Aerial survey 1996/1997	5	Further road construction and extension of Fishwater Flats

Botanical importance rating

Calculations of the botanical importance scores are shown in Table 2 of the appendix. Changes in the botanical importance score over time have been summarised in Fig. 4. In the pristine state the Swartkops Estuary had the highest normalised botanical importance score (100) with a steady reduction in score over time as shown in Fig. 4.

The pristine condition (Fig. 4, Appendix Table 2) represents the estuary without any development and where the estuarine flora is assumed to have colonised all available habitats. There was a decrease in the botanical importance score for the Swartkops Estuary over time. A major decrease in area covered by supratidal and intertidal salt marsh is seen in the earlier years of development, with large-scale elimination becoming less evident in subsequent years. This is shown by the 49% reduction in the botanical importance score once development started taking place within the Swartkops Estuary (pristine condition to 1939, Fig. 4, Appendix Table 2). Developments such as Swartkops and Redhouse Villages, roads and bridges and the power station led to the removal of large areas of supratidal salt marsh. In later years (1939 - present, Fig. 4, Appendix Table 2) the gradual loss of vegetation lead to a 6% reduction in the botanical importance score (51 to 45). The removal of the highly productive submerged macrophyte *Zostera capensis* by flood accounts for the low importance scores for 1984 and 1988. Presently, the most important botanical components in the Swartkops Estuary are the intertidal salt marsh and intertidal benthic microalgae (Fig. 4, Appendix Table).

Changes in plant cover also alter the botanical importance of an estuary on a national basis when compared to other estuaries of different sizes or with other plant community types present. For example, the Quko Estuary covers a total area of 78 ha compared to the Mngazana Estuary that covers an area of 615 ha. The high importance score for the Olifants Estuary is a result of the large area

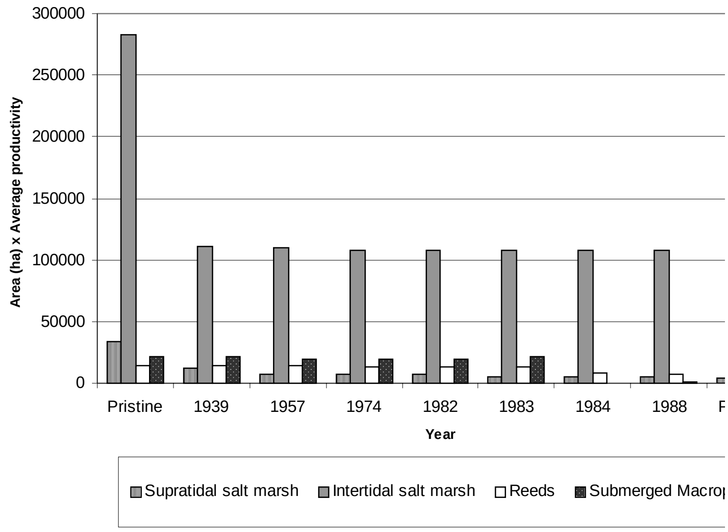

Figure 4
Graphs representing the change in area x productivity values over time for the respective plant community types

TABLE 4
SUMMARY OF THE CHANGE IN THE AREA COVERED BY REEDS AND SEDGES CALCULATED FROM AVAILABLE MAPS, AERIAL PHOTOGRAPHS (TRIG. SURVEY AND DEPARTMENT OF ENVIRONMENTAL AFFAIRS) AND ORTHOPHOTO MAPS (1:10 000). MSHWM = MEAN SPRING HIGH WATER MARK.

Survey/source	Cover (ha)	Comments
Aerial photos	10	Estimate of area before any development at current MSHWM
MacNae 1957 - estimated from maps	10	-
Jacot Guillard 1974	9.5	Steady reduction in cover after flooding events
Orthophoto maps 1984	6	Increased bank erosion below Perseverance causeway
Coetzee et al. 1997	5	Further erosion and quarries

TABLE 5
BOTANICAL IMPORTANCE SCORES RANKED IN DECREASING ORDER OF IMPORTANCE FOR A NUMBER OF SOUTH AFRICAN ESTUARIES. NORMALISED SCORES ARE ALSO PRESENTED.

Estuary	Botanical importance score	Normalised score
Olifants	402 567	100
Swartkops (pristine)	397 027	99
Mngazana	329 685	82
Swartkops ('39 - present)	203 857 - 179 936	51 - 45
Gamtoos	90 704	23
Kieskamma	83 298	21
Goukou	62 107	15

covered by supratidal salt marsh. The Mngazana Estuary has a high importance score because it has the largest mangrove community present in the Eastern Cape Province. In its pristine condition the Swartkops Estuary would have had a higher ranking (second place) in terms of its national botanical importance than it presently has (third place) (Table 5). This is due to the loss of area covered by the estuarine plants. Despite this because of the large area of estuarine flora still present in the Swartkops Estuary it is still ranked third based on its present condition within this group of estuaries.

Discussion

The majority of plant community types found in the Swartkops Estuary have been affected by anthropogenic development within the estuary basin. Bridges and roads have caused major changes in the Swartkops Estuary. As early as MacNae's (1957) study, changes in sediment deposition were noted to have led to the loss of intertidal salt marsh after the construction of the railway bridge near Swartkops Village. The embankments of this bridge and the N2 Settlers bridge led to the removal of both the inter- and supratidal salt marsh. Because of this, there has been a decrease in the botanical importance score of the Swartkops Estuary over the last 40 years. In order to protect river front properties in Swartkops Village and Amsterdamhoek area, retaining walls were constructed. In the case of the Swartkops Village, areas adjacent to the retaining walls have been built up, whereas the Bluewater Bay walls were constructed in an area of steep cliffs, where no intertidal area would have developed.

Small-scale anthropogenic impacts include footpaths and trampling, littering, bait digging, mooring of boats in vegetation and overgrazing. The effects of these impacts are not recorded in the botanical importance score, as it is difficult to determine the amount of area/productivity lost as a result of these activities. The extensive intertidal mudflats are an ideal habitat for bait organisms such as the mud prawn (*Upogebia africana*) and pencil bait (*Solen cyclindraceus*). Extensive bait digging has resulted in impacts such as trampling and uprooting of the *Zostera capensis* beds, littering (plastic bags containers and discarded fishing tackle) and numerous footpaths in the supra- and intertidal salt marshes.

The salt marsh has been divided into two plant community types. These are the intertidal marsh that occurs from the mean high water neap mark to the mean high water spring mark, and the supratidal marsh that occurs above the spring high-tide watermark. These two salt marsh types differ in species composition (Adams et al., 1999). Supratidal salt marsh species may have similar salinity tolerance ranges to that of intertidal species but they are more sensitive to inundation (Adams et al., 1992, Adams and Bate, 1994). Salt marsh has been affected by human development and subjected to higher pressures than the other plant community types. This is possibly due to the ease at which these areas are reclaimed for residential or industrial development by the reduction of tidal flow and the drying out of such areas.

The reed and submerged macrophyte plant community types have shown greater variation in area cover due to natural disturbance. Large floods have been shown to remove these reeds resulting in bank erosion and loss of potential habitat for subsequent recolonisation. Floods remove the riparian vegetation and scour the banks leaving behind unstable steep sided river banks where there appears to be little subsequent sediment deposition. These banks are later colonised by grasses and invasive plants such as *Acacia* spp. Quarrying activities in the Perseverance area have altered the channel geomorphology thus preventing reed establishment in this region of the estuary. Alien invasive plants such as *Acacia cyclops*, *Lantana camara* and *Senna didimobtyra* are found in small isolated clumps in the upper reaches of the estuary. Large floods remove the riparian vegetation which is mostly reeds, erode the river banks and open up areas for invasion by alien species, thus removing a habitat previously colonised by reeds.

The submerged macrophytes have also shown variation due to floods, with little seasonal variation evident. Seagrasses in more temperate climates have stable standing stocks with variation often correlated to flooding periodicity (Talbot and Bate, 1987)

In its pristine condition the Swartkops Estuary would have had a higher ranking (second place) in terms of its national botanical importance than it presently has (third place). This is due to the loss of area covered by the estuarine plant community types. Despite this because of the large area of estuarine flora still present in the Swartkops Estuary it is still ranked third based on its present state.

Conclusion

Application of the botanical importance rating system identified salt marsh as the estuarine plant community that has experienced the greatest loss due to human development. Emphasis should be placed on the protection of salt marsh as these areas make a significant contribution to the secondary production of the estuary. Any reduction in their area will affect higher trophic levels (Davies 1982; Bally et al. 1985; Whitfield, 1984). The most important botanical components in the Swartkops Estuary are the intertidal salt marsh and intertidal benthic microalgae. These areas should continue to function optimally provided the mouth of the estuary is allowed to remain open, thus ensuring regular tidal flushing. Supratidal salt marsh areas have suffered the greatest losses probably because they are only periodically inundated, and with suitable engineering are more prone to development (i.e. Fishwater Flats Sewage Works, Neave industrial area). In the future, the supratidal salt marsh may be the most vulnerable plant community type in terms of loss due to further developments.

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References

ADAMS JB, BATE GC and O'CALLAGHAN M (1999) Primary producers: Estuarine macrophytes. In: Allanson BR and Baird D (eds.) *Estuaries of South Africa*. Cambridge University Press. 101-118.

ADAMS JB and BATE GC (1994) The effect of salinity and inundation on the estuarine macrophyte *Sarcocornia perennis* (Mill.) AJ Scott. *Aquat. Bot.* **47** 341-348.

ADAMS JB and HASCHICK S (in press) The effect of recreational activities on the seagrass, *Zostera capensis*.

ADAMS JB, KNOOP WT and BATE GC (1992) The distribution of estuarine macrophytes in relation to freshwater. *Bot. Mar.* **35** 215-226.

BAIRD D HANEKOM NM and GRINDLEY JR (1986) Report No 23: Swartkops (CSE3). In: Heydorn AEF and Grindley JR (eds.) *Estuaries of the Cape: Part II: Synopses of Available Information.* CSIR Research Report No. 422, South Africa. 82 pp.

BALLY R, McQUAID CD and PIERCE SM (1985) Primary productivity of the Bot River Estuary, South Africa. *Trans. Royal Soc. S. Afr.* **45** 333-345.

BENFIELD MC (1984) Some Factors Influencing the Growth of *Phragmites australis* (Cav.) Trin ex Streud. M.Sc. Dissertation, Univ. of Natal, Durban.

BLABER SJM (1974) Field studies of the diet of *Rhabdosargus holubi* (Pisces: Teleostei: Sparidae). *J. of Zool., London* **173** 407-417.

BRANCH GM and DAY JH (1984) Ecology of southern African estuaries: Part 13. The Palmiet River Estuary in south-western Cape. *S. Afr. J. of Zool.* **19** 63-77.

COETZEE JC, ADAMS JB and BATE GC (1997) A botanical importance rating of selected Cape estuaries. *Water SA* **23** 81-93.

DALY MA and MATHIESON AC (1981) Nutrient fluxes within a small north temperate salt marsh. *Mar. Biol.* **61** 337-344.

DAVIES BR (1982) Studies on the zoobenthos of some southern cape coastal lakes. Spatial and temporal changes in the benthos of Swartvlei, South Africa, in relation to changes in the submerged macrophyte community. *J. Limnol. Soc. S. Afr.* **8** 33-45.

EMMERSON WD (1983) Tidal exchange of two decapod larvae *Palaemon pacificus* (Caridae) and *Upogebia africana* (Thalassinidae) between the Swartkops River Estuary and adjacent coastal waters. *S. Afr. J. of Zool.* **18** 326-300.

FIELDING PJ, DAMSTRA KSJ and BRANCH GM (1988) Benthic diatom biomass, production and sediment chlorophyll in Langebaan Lagoon, South Africa. *Est. Coast. Shelf Sci.* **27** 413-426.

HENRY JL, MOSTERT SA and CHRISTIE ND (1977) Phytoplankton production in the Langebaan Lagoon and Saldanha Bay. *Trans. Royal Soc. S. Afr.* **42** 383-398.

HILMER T and BATE GC (1990) Covariance analysis of chlorophyll distribution in the Sundays River Estuary. *S. Afr. J. of Aquat. Sci.* **16** 37-59

HILMER T, TALBOT MMB and BATE GC (1988) A synthesis of recent botanical research in the Swartkops Estuary. In*:* Baird D, Marais JFK and Martin AP (eds.) *The Swartkops Estuary; Proc. of a Symp.*, South African National Programmes Report No. 156, CSIR, Pretoria. 107.

HOPKINSON CS, GOSSELINK JG and PARRONDO RT (1978) Above ground production of seven marsh plants species in coastal Louisiana. *Ecol.* **59** 760-769

HOWARD-WILLIAMS C (1978) Growth and production in aquatic macrophytes in a south temperate saline lake. *Int. Verein. fur Theor. und Ange wandte Limnol.* **20** 1153-1158

HOWARD-WILLIAMS C and LIPTROT MR (1980) Submerged macrophyte communities in a brackish South African estuarine-lake system. *Aquat. Bot*. **9** 101-116.

HOWARD-WILLIAMS C and ALLANSON BR (1981) Phosphorus cycling *in Potamogeton pectinatus* L. beds. *Oecologia* **49** 56-66.
JACOT GUILLARD A (1974) Vegetation. In*: Environmental Study Swartkops River Basin.* Technical Data Report, Part 2, Vol. 3 1-82.
MACNAE W (1957) The ecology of the plants and animals in the intertidal regions of the Zwartkops Estuary near Port Elizabeth, South Africa - Part 1. *J. Ecol.* **45** 113-131.
McNEILL SE and FAIRWEATHER PG (1993) Single large or several small marine reserves? An experimental approach with seagrass fauna. *J. Biogeogr*. **20** 429-440
MOUNTFORD K (1980) Aspects of the ecology of a small estuarine embayment. *Mar. Biol*. **61** 53-67.
PIERCE SM (1979) The contribution of *Spartina maritima* (Curtis) Fernald to the primary production of the Swartkops Estuary. M.Sc. Thesis, Rhodes Univ., Grahamstown.
REDDERING JSV and ESTERHUYSEN K (1988) The Swartkops Estuary: Physical description and history. In*:* Baird D, Marais JFK and Martin AP (eds.) *The Swartkops Estuary; Proc. of a Symp.*, South African National Programmes Report No. 156, CSIR, Pretoria. 107 pp.
RODRIQUEZ FDG (1994) The determination and distribution of microbenthic chlorophyll-a in selected south Cape estuaries. M.Sc. Dissertation, Univ. of Port Elizabeth.
SCHLEYER MH and ROBERTS GA (1987) Detritus cycling in a shallow coastal lagoon in Natal, South Africa. *J. of Exp. Mar. Biol. and Ecol.* **110** 27-40.
STEINKE TD (1995) A general review of the mangroves of South Africa. In: Gowan GI (ed.) Wetlands of South Africa. South African Wetlands Conservation Programme Series, Dept. of Environ. Affairs and Tourism, Pretoria. 53-73.
TALBOT MMB and BATE GC (1987) The distribution and biomass of the seagrass *Zostera capensis* in a warm temperate estuary. *Bot. Mar.* **30** 91-99.
TALBOT MMB, KNOOP WT and BATE GC (1990) The dynamics of estuarine macrophytes in relation to flood/siltation cycles. *Bot. Mar.* **33** 159-164.
WHITFIELD AK (1984) The effects of prolonged aquatic macrophyte senescence on the biology of the dominant fish species in a southern African coastal lake. *Est. Coast. Shelf Sci.* **18** 315-329.
WHITFIELD AK (1988) The fish community of the Swartvlei Estuary and the influence of food availability on resource utilisation. *Estuaries* **11** 160-170.

APPENDIX TABLE 1

Primary Productivity Values for the Nine Estuarine Plant Community Types. The Average Primary Productivity Value for Each Plant Community Type is Used in the Botanical Importance Rating Formula. The Locality of the Estuary is Given as Well as The Method Used to Measure Primary Productivity.

Species	Productivity ($g \cdot m^{-2} \cdot yr^{-1}$)	Locality	Reference	Methods
Supratidal salt marsh				
Sarcocornia cynosuroides	792	Louisiana, USA	Hopkinson et al., 1978	Change in biomass
Sarcocornia oleyni	880	Louisiana, USA	Hopkinson et al., 1978	Change in biomass
Average	**836**			
Intertidal salt marsh				
Spartina maritima	651	Swartkops Estuary	Pierce, 1979	Change in biomass
Average	**651**			
Reeds and sedges				
Typha latifolia	1 249	Swartvlei Estuary	Howard-Williams & Liptrot, 1980	Production/biomass ratios
Schoenoplectus littoralis	1 004	Swartvlei Estuary	Howard-Williams & Liptrot, 1980	Production/biomass ratios
Schoenoplectus littoralis	960	Bot River Estuary	Bally et al., 1985	Change in biomass
Phragmites australis	930	Swartvlei Estuary	Howard-Williams & Liptrot, 1980	Production/biomass ratios
Phragmites australis	1 621	Swartvlei Estuary	Howard-Williams & Allanson, 1981	Unknown
Phragmites autralis	1 790	Bot River Estuary	Bally et al., 1985	Change in biomass
Phragmites australis	2140	Siyaya Estuary	Benfield, 1984	Change in biomass
Average	**1770**			

APPENDIX TABLE 1 (CONTINUED)				
Species	**Productivity ($g \cdot m^{-2} \cdot yr^{-1}$)**	**Locality**	**Reference**	**Methods**
Submerged macrophytes				
Chara globularis	231	Swartvlei Estuary	Howard-Williams & Liptrot, 1980	O_2 Light/dark bottle method
Chara globularis	236	Swartvlei Estuary	Howard-Williams, 1978	O_2 Light/dark bottle method
Chara globularis	2 230	Bot River Estuary	Bally et al., 1985	Change in biomass
Potamogeton pectinatus	415	Swartvlei Estuary	Howard-Williams & Liptrot, 1980	Production/biomass ratios
Potamogeton pectinatus	2 506	Swartvlei Estuary	Howard-Williams & Allanson, 1978	O_2 Light/dark bottle method
Potamogeton pectinus	4 124	Bot River Estuary	Bally et al., 1985	Change in biomass
Ruppia cirrhosa	83	Swarvlei Estuary	Howard-Williams & Liptrot, 1980	Production/biomass ratios
Ruppia maritima	710	Bot River Estuary	Bally et al., 1985	Change in biomass
Average	**1 316**			
Mangroves				
Avicennia marina	1013	St Lucia Estuary	Steinke, 1995	Litter production
Avicennia marina	1056	Mhlathuze Estuary	Steinke, 1995	Litter production
Brugueria gymnorrhiza	698	Mgeni Estuary	Steinke, 1995	Litter production
Brugueria gymnorrhiza	729	St Lucia Estuary	Steinke, 1995	Litter production
Brugueria gymnorrhiza	824	Mgeni Estuary	Steinke, 1995	Litter production
Rhizophora mucronata	972	Mhlathuze Estuary	Steinke, 1995	Litter production
Average	**1 811**			
Intertidal benthic microalgae				
	57	Swartkops Estuary	Pierce, 1979	Fielding & Damstra conversion (Fielding et al., 1988)
	128	Sundays Estuary	Rodriguez, 1994	Fielding & Damstra conversion (Fielding et al., 1988)
	189	Bot River Estuary	Bally et al., 1985	Fielding & Damstra conversion (Fielding et al., 1988)
Average	**124**			
Phytoplankton				
	57	Swartkops Estuary	Pierce, 1979	Henry et al. (1977) conversion
	250	Sundays Estuary	Hilmer & Bate, 1990	$^{14}CO_2$
	182	Bot River Estuary	Bally et al., 1985	Henry et al. (1977) conversion
Average	**163**			
Macroalgae				
Enteromorpha sp.	129	Swartvlei Estuary	Whitfield, 1988	Change in biomass
Caulerpa filiformis	329	Sundays Estuary	Talbot et al.,1990	Production/biomass ratio
Cladophora sp.	132	Palmiet Estuary	Branch & Day, 1984	Change in biomass
Average area	**196**			
Swamp forest				
Hibiscus tiliaceus	2220	Siyaya Estuary	Schleyer & Roberts, 1987	Litter production
Barringtonia racemosa	1560	Siyaya Estuary	Schleyer & Roberts, 1987	Litter production
Average	**1890**			

APPENDIX TABLE 2

Summary of area (ha) covered by the different plant communities over time and calculation of the botanical importance scores for the Swartkops Estuary

	Change in area (ha) covered by plant community type over time								
	Pristine	**1939**	**1957**	**1974**	**1982**	**1983**	**1984**	**1988**	**Present**
Supratidal salt marsh	40	9	9	8	8	6	6	6	5
Intertidal salt marsh	215	170	168	165.3	166	166	166	166	165
Reeds and sedges	10	10	10	9.5	9.5	9.5	6	5	4.5
Submerged macrophytes	16	16	15	15	15	16	0	0.6	12.5
Intertidal benthic microalgae	177	177	177	177	177	177	177	177	177
Phytoplankton	135	135	135	135	135	135	135	135	135
	Area x productivity								
Supratidal salt marsh	33440	12540	7524	6688	6688	5016	5016	5016	4180
Intertidal salt marsh	282940	110670	109368	108066	108066	108066	108066	108066	107415
Reeds	14000	14000	14000	13300	13300	13300	8400	7000	6300
Submerged macrophytes	21056	21056	19740	19740	19740	21056	0	789.6	16450
Intertidal benthic microalgae	28851	28851	28851	28851	28851	28851	28851	28851	28851
Phytoplankton	16740	16740	16740	16740	16740	16740	16740	16740	16740
BI Score	397027	203857	196223	193385	193385	193029	167073	166463	179936
Normalised score	100	51	49	49	49	49	42	42	45
National normalised score	99	51	49	48	48	48	42	41	45