Water quality in the Knysna estuary

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Measurements of water temperature, salinity, pH, dissolved oxygen, secchi disk depth, turbidity and total suspended solids were taken monthly in the Knysna estuary between 1991 and 1994. Measurements of turbidity and total suspended solids of waters entering the Knysna estuary via rivers and man-made inlets were also taken on an ad hoc basis. These results are described and compared to published data on past water quality conditions. No clear long-term changes in water quality in the estuary were evident. High inputs of sediments from minor catchments indicate the necessity for remedial actions.

Key words: Knysna estuary, water quality changes, temperature, clarity, TSS, salinity, pH, dissolved oxygen.

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Introduction

The Knysna estuary (34°04'35"S; 23°03'40"E), the largest permanently tidal estuary on the southern Cape coast, has been utilised since the mid-1700s (Grindley 1985). The estuary was initially utilised primarily as a harbour, though recent emphasis has shifted towards recreation (boating and fishing) and mariculture. Residential and industrial development has occurred around much of the periphery and on islands within the estuary,,and large portions of the catchment have been cleared of natural vegetation for agriculture or silviculture (Moll & Bossi 1983). Considerable anecdotal evidence generated over the last few decades has raised concerns that catchment development is resulting in deleterious environmental changes within the estuary (Grange & Allanson 1994). Among these concerns are the impact of reduced freshwater inflows (Haw 1984), discharges from residential and industrial areas (Grindley & Eagle 1978; Grindley & Snow 1983; Barker undated) and sedimentation (Reddering & Esterhuizen 1984) on water quality. Despite these concerns, study of water quality in the Knysna estuary has been sporadic, consisting predominantly of brief investigations of trace metals in the water column and sediments (Watling & Watling 1980) and tissues of cultivated oysters (Watling & Watling 1976), and short-term studies of various physical and chemical aspects of water quality (Day *et al.* 1952; Korringa 1956; Day 1967, 1981; Grindley & Eagle 1978; Grindley & Snow 1983; Haw 1984).

The objectives of this study were to document aspects of physical (temperature, clarity, suspended solid concentrations) and chemical (salinity, pH, dissolved oxygen) water quality in Knysna estuary between 1991 and 1994, and compare these to published data on past water quality conditions to ascertain whether notable changes have occurred in the water quality of the Knysna estuary.

Methods

Water quality parameters of surface waters in the Knysna estuary were measured monthly from January 1991 to December 1994 at eight different localities (Fig. 1). Measurements undertaken in the field at 30 cm depth were water temperature (°C) and salinity (g/kg) using a YSI Model 33 S-C-T meter, dissolved oxygen (mg/l) using a SG 867 digital O_2 meter, and pH with a Knick 751 pH meter. Secchi

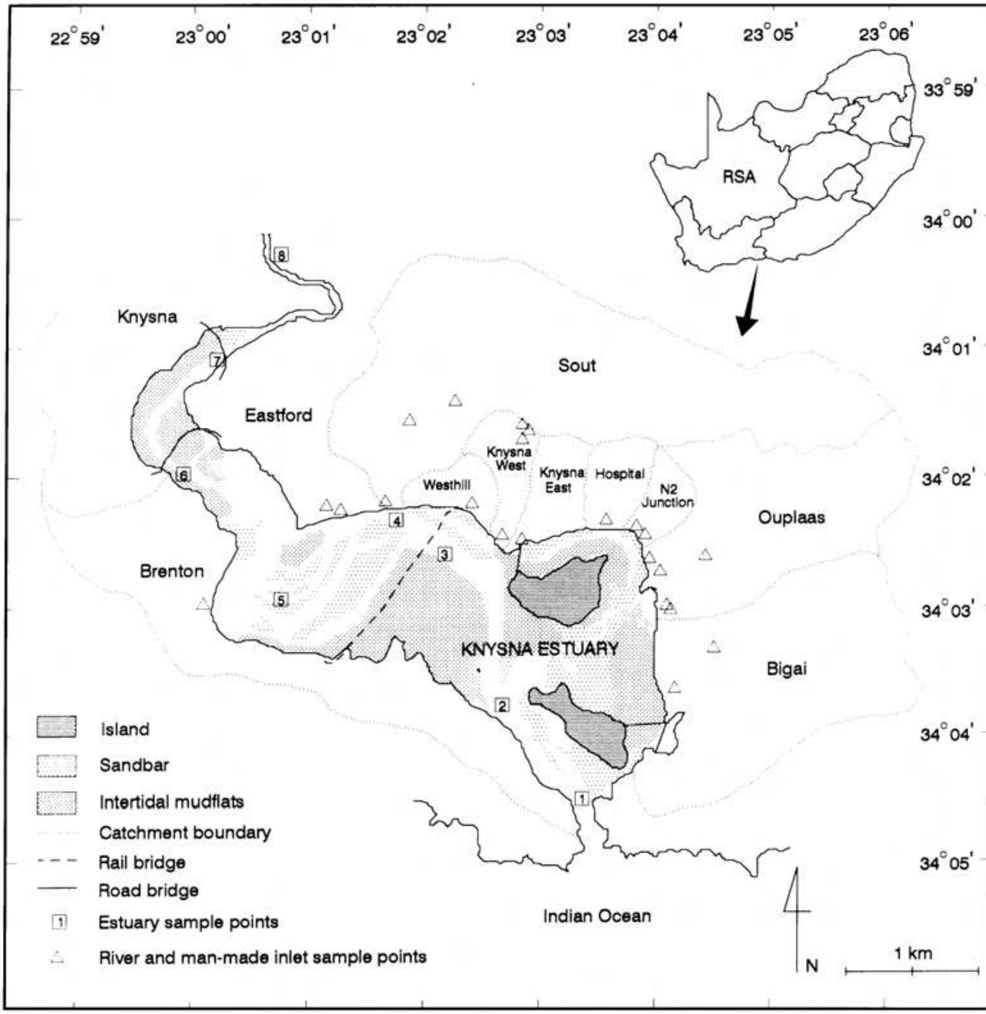

Fig. 1. Locality map. Distribution of sandbars, intertidal mudflats and catchment boundaries after Reddering (1994).

disk readings were taken to the nearest 0.01 m. Water samples were collected at 30 cm depth and transported to a laboratory where, within three hours of sample collection turbidity (NTU) was measured with a Hach 16800 turbidimeter, and total suspended solids (TSS) (g/l) determined by filtering samples through Whattman GF/C or equivalent glass fibre filters. These filter papers were dried at 60 °C for more than three hours prior to filtering, and 24 hours after filtering, and weighed on an electronic balance to the nearest 0.0001 gram.

Samples of water entering the Knysna estuary via rivers and man-made inlets (Fig. 1) were collected on an ad hoc basis between 1991 and 1993 during or shortly after rainfall events. Measurements were taken of turbidity and TSS as described above. Where these samples could not be processed on the day of collection they were stored for not longer than 48 hours at 4 °C.

As in some previous studies (Day *et al.* 1952, Day 1967) the Knysna estuary was divided into four reaches for the purpose of describing water quality, namely the mouth, lagoon, middle and head reaches. These divisions were used to facilitate the comparison of results between studies.

Results

Water temperature in the estuary varied between 11.4 °C and 29.3 °C (Table 1). Mean temperature varied longitudinally, with higher temperatures (20.7 °C) in the upper reaches, and lower temperatures (17.9 °C) near the mouth (Table 1).

Salinity in the estuary ranged from 36.5 g/kg near the mouth, to 0.0 g/kg in the upper reaches (Table 1), and a strong axial salinity gradient frequently occurred. Variation in salinity was lowest near the mouth (13.2 g/kg) and increased through the lagoon (21.2 g/kg), middle (31.3 g/kg) and head (35.5 g/kg) reaches of the estuary.

The pH-values in the mouth, lagoon and middle reaches of the estuary were similar (Table 1), ranging between 6.0 and 8.8. Low pH-values (< 6) were occasionally recorded in the head reach, presumably resulting primarily from the inflow of acidic waters from the Knysna River.

Dissolved oxygen ranged from 3.1 mg/l to 10.2 mg/l (Table 1) with mean concentration decreasing longitudinally up the estuary. Low dissolved oxygen concentrations (<5 mg/l) were periodically recorded throughout the estuary.

A progressive decrease in the clarity of water up the estuary was indicated by decreases in the mean and range of secchi disk depths, and increases in the mean and range of turbidity readings from the estuary mouth to the head waters (Table 1). These axial gradients suggested that suspended particulate matter resulting in decreased clarity was primarily of fluvial rather than marine origin. In contrast, the concentration of suspended solids (TSS) was on average higher near the mouth of the estuary compared to the middle and

Table 1

Summary statistics for seven water quality parameters recorded in the Knysna estuary between 1991 and 1994 (See Fig. 1 for the numbering and locality of sample sites)

Reach (site No)		Temperature (Celcius)	Salinity (g/kg)	pH	Dissolved oxygen (mg/l)	Secchi disk (m)	Turbidity (NTU)	TSS (mg/kg)
Mouth (1)	max	26.1	36.5	8.8	10.2	7.21	7.0	96.8
	mean	17.9	33.4	8.3	8.0	3.67	3.8	42.9
	min	12.0	23.3	7.7	4.0	1.55	1.3	6.3
	n	47	46	37	31	32	42	46
Lagoon (2,3)	max	27.0	36.4	8.8	9.7	5.57	13.0	102.2
	mean	18.7	32.2	8.3	7.3	2.81	5.0	44.1
	min	11.4	15.2	7.6	3.1	1.06	1.8	14.4
	n	94	92	74	62	66	85	92
Middle (4,5,6)	max	28.8	36.3	8.7	9.6	4.75	18.0	97.3
	mean	19.7	28.8	8.1	6.7	2.13	5.8	41.0
	min	12.5	5.0	6.0	4.3	0.84	2.0	7.8
	n	141	138	105	90	89	126	138
Head (7,8)	max	29.3	35.5	8.6	10.5	1.29	24.0	86.0
	mean	20.7	19.8	7.5	6.8	1.19	5.7	30.8
	min	12.0	0.0	5.1	4.1	0.79	1.6	1.6
	n	93	91	70	60	6	81	92

upper reaches (Table 1). Higher TSS values near the estuary mouth could have been the result of high concentrations of planktonic organisms of marine origin which did not contribute to decreased water clarity as much as inorganic particulate matter of fluvial origin.

High TSS and turbidity values were periodically recorded from waters emanating from all minor catchments (Table 2). Waters from the Eastford, Knysna West and N2 Junction catchments (Fig. 1) in particular, frequently exceeded a TSS of 1 000 mg/kg and turbidity of 2 000 NTU during rainfall events.

Discussion

Temperature ranges in the lagoon, middle and head reaches of the estuary were similar to the findings of previous studies (Fig. 2a), indicating little long-term change in these reaches. Maximum temperatures in the estuary mouth, however, were substantially higher than that recorded by both Day *et al.* (1952) (3.9 °C) and Haw (1984) (5.9 °C). Past recordings in the estuary mouth suggest that estuarine water temperature is influenced predominantly by sea water temperature (range 13.5 °C to 22.4 °C, Isaac 1937; Day 1981). Data from this study, however, indicates that temperatures in the estuary mouth can, at times, be higher than the recorded range for sea water, presumably resulting from the outflow of warmer waters from the upper reaches of the estuary.

Minimum water temperature recorded by Haw (1984) in the estuary mouth during a cold upwelling event (7.7 °C) was substantially lower than minima recorded by Day *et al.* (1952) and this study (Fig. 2a). Upwelling of cold water is reported to be a fairly common event along the Cape south coast (Schumann *et al.* 1988), and in particular off the Knysna coastline (Smith 1949). The ingress of sea water into the estuary during such events results in abrupt decreases in water temperature (Korringa 1956; Day *et al.* 1952). These phenomena are generally short lived (Korringa 1956) and were not recorded during this study.

Maximum salinity in the mouth and lagoon reaches, and minimum salinity in the middle and head reaches were similar to that recorded in previous studies (Fig. 2b). Maximum salinity in the middle and head reaches were similar to those recorded by Haw (1984), but were higher (> 6 g/kg) than maxima given by earlier authors (Fig. 2b). High salinities in the upper reaches of the estuary may be

Table 2
Summary statistics for turbidity and total suspended solids recorded between 1991 and 1994 in rivers and man-made inlets flowing into the Knysna estuary

Catchment	Turbidity (NTU)				TSS (mg/kg)			
	Mean	Max.	Min.	*n*	Mean	Max.	Min.	*n*
Brenton	1099	2900	5	5	227	557	24	6
Eastford	6486	18800	4	5	2337	10678	6	7
Sout	674	2520	3	16	591	5110	21	20
Westhill	179	247	111	2	705	750	660	2
Knysna West	2696	16600	14	26	698	5340	39	29
Knysna East	1277	4100	7	12	443	1475	28	12
Hospital	1000	-	-	1	-	-	-	0
N2 Junction	4684	9300	67	2	3088	6067	109	2
Ouplaas	77	490	3	12	106	628	3	12
Bigai	555	1800	5	7	144	429	24	9

indicative of reductions in freshwater inflows. Substantial differences were recorded in minimum salinity in both the mouth and lagoon reaches. The lowest previous recordings of salinity in the mouth and lagoon reaches are substantially higher (> 7 g/kg) than recorded in this study (Fig. 2b). It can be concluded, therefore, that salinity ranges, particularly in the mouth and lagoon reaches of the estuary, are larger than those reported in previous studies. These differences can be attributed to a higher sampling intensity and longer duration studies resulting in more accurate recording of natural variability, rather than inherent changes in water quality.

The range in dissolved oxygen concentrations in the Knysna estuary were substantially larger than that given by Grindley & Eagle (1978), with in particular, increases in the upper ranges in all reaches (Fig. 2c). The data of Grindley & Eagle (1978), however, comprised only two one-day-long surveys, and hence do not adequately reflect the natural range in dissolved oxygen concentration in the Knysna estuary. Day (1981) described dissolved oxygen concentrations in the Knysna estuary as being high, though unfortunately did not provide supporting data. High concentrations have previously been recorded in the Ashmead channel, with Grindley & Eagle (1978) reporting concentrations up to 10 µg/g, and Grindley & Snow (1983) concentrations as high as 15 ppm. These supersaturated concentrations are thought to have been the result of exceptionally high photosynthetic activity of phytoplankton at a sewage outfall (Grindley & Eagle 1978; Grindley & Snow 1983), and are thus possibly not characteristic of the estuary as a whole. A poor historic data base makes it difficult to assess the occurrence of long-term changes in dissolved oxygen concentrations.

Periodic low dissolved oxygen concentrations, particularly in the lagoon reach of the estuary (Fig. 2c) suggest extensive decomposition of organic matter. Deoxygenation has on occasions been recorded in localised areas in the adjacent Swartvlei estuary, resulting primarily from the decomposition of aquatic plants (Whitfield *et al.* 1983). It is unknown whether periodic low dissolved oxygen concentrations in the Knysna estuary are a natural phenomenon, or whether the input of pollutants from the catchments is a contributing factor.

Ranges in pH throughout the estuary were found to be wider than those given by Day *et al.* (1952) (Fig. 2d). The pH-values in the Ashmead channel reported by Grindley & Eagle (1978) (7.8 to 8.8) and Grindley & Snow (1983) (7.6 to 8.9), however, correspond closely with the range recorded in the lagoon reach (Table 1) into which the channel flows. Minimum pH in the head of the estuary was lower than the 6.6 recorded by Grindley (1985). This is possibly as a consequence of periodic high inflows from the Knysna River, in which pH-values as low as 3.4 have been recorded (DWAF unpublished data). Wider ranges in pH throughout the estuary possibly reflect, as with salinity, greater sampling intensity and duration rather than long-term changes in water quality.

Reddering (1994) emphasised the existence of perceptions of widespread sedimentation in the Knysna estuary. These perceptions have persisted despite the conclusions of Chunnett (1965) and Reddering & Esterhuysen (1984, 1987) that sedimentation from external sources is negligible. Were there to be a persistent heavy input of sediments primarily of fluvial origin, it follows that either decreases in water clarity within the estuary would be apparent, and/or the flocculation of suspended particles would have resulted in formation and increase of sediment bodies. Reddering (1994) concluded that very little change has occurred in the locality and size of sediment bodies between 1936 and 1990. The deposition of sediments of fluvial origin thus appears to have been minimal. With respect to water clarity, past records of secchi disk depth have indicated Knysna estuary to be relatively clear, with Day (1967) reporting readings of six feet (1.8 m) in the mixing basin (presumably lagoon reach), and Day (1981) maintaining that the substratum is visible at a depth of between two and three

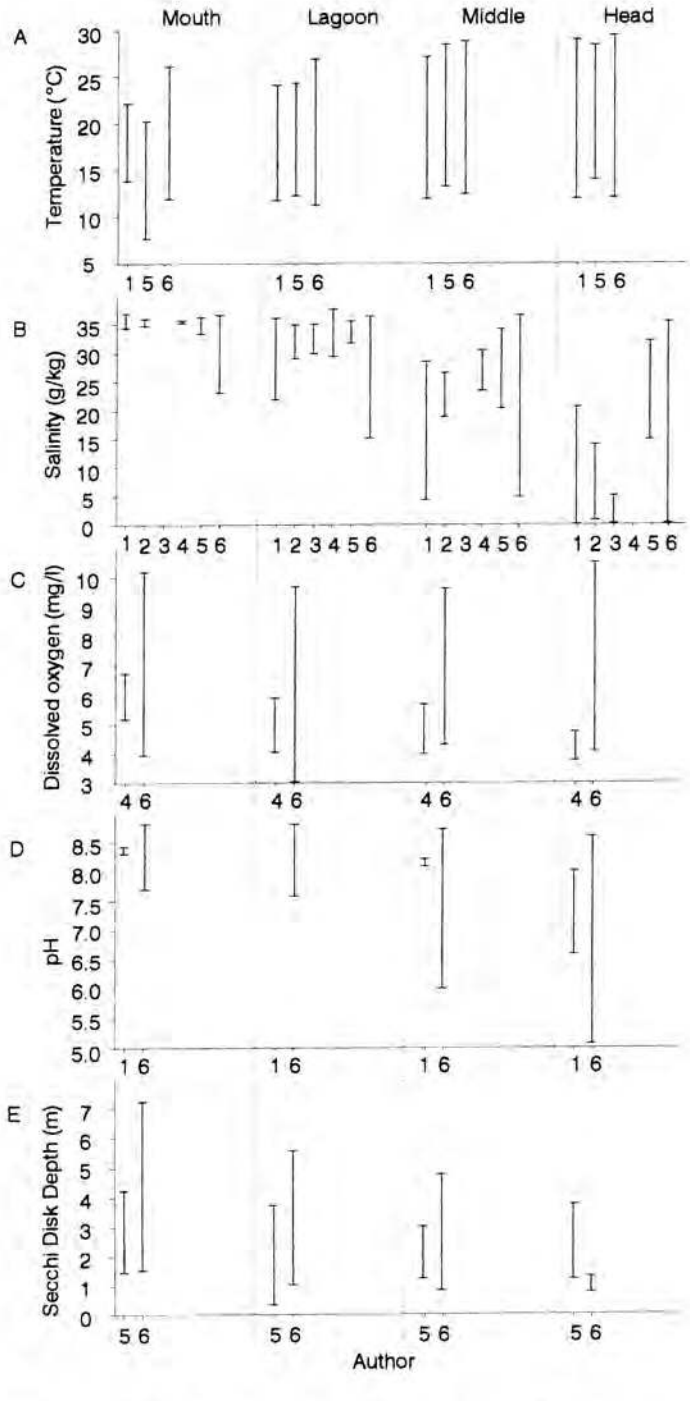

Fig. 2. Ranges in five water quality parameters recorded in the Knysna estuary where author 1 = Day *et al.* (1952), 2 = Day (1967), 3 = Day (1981), 4 = Grindley & Eagle (1978), 5 = Haw (1984) and 6 = this study.

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meters. More recent measurements of clarity undertaken by Haw (1984) indicated relatively clear conditions throughout the estuary, which correspond closely with minimum values determined in this study (Fig. 2e). Higher maximum secchi disk values in this study (Fig. 2e) indicate more frequent clear water conditions than recorded by Haw (1984). The small sample size for the head reach (Table 1) make comparisons unreliable. Thus, on the basis of comparisons of secchi disk readings, there appears to have been little long-term change in water clarity.

No published or historic records of turbidity or TSS in the Knysna estuary could be located. Mean turbidity in the Knysna estuary, which was below 5.9 NTU in all reaches, was marginally higher than that recorded between 1991 and 1994 in two neighbouring clear-water estuaries, namely Swartvlei estuary (4.5 NTU, $n = 380$) and Touw estuary (4.8 NTU, $n = 257$) (NPB unpublished data).

Dyer (1972) considers that a natural background of 10 to 20 mg/kg of suspensoids, consisting of planktonic organisms, organic matter and clay particles, is present in most northern hemisphere estuarine systems. This compares well with clear-water estuaries adjacent to Knysna, where mean TSS concentrations of 22.1 mg/kg (Swartvlei, $n = 380$) and 16.8 mg/kg (Touw, $n = 281$) have been recorded between 1991 and 1994 (NPB unpublished data). In comparison, relatively high TSS concentrations (mean = < 45 mg/kg) were recorded in the Knysna estuary. Higher turbidity and TSS in the permanently open Knysna estuary, in comparison to adjacent temporarily open estuaries, do not in themselves indicate increases in the input of suspensoids originating in the catchment. Tidal currents in the Knysna estuary could result in greater inputs of suspensoids of marine origin, as well as promote the resuspension of flocciltes, resulting in comparatively more turbid waters. High sediment loadings from some catchment streams (Table 2), however, do suggest that fluvial sediments may contribute to the comparatively higher turbidity and TSS of the Knysna estuary.

Reddering (1994) in his study of the distribution of sediment bodies, concluded that, in the past, only the Sout River has supplied a notable volume of sediment to the estuary, with the contribution of other catchments to the total sediment budget of the Knysna estuary being small. Recent high sediment loadings of waters from particularly from the Eastford, Knysna West and N2 Junction catchments, however, raises the concern that sediment loadings from minor catchments may be increasing. That high inputs of sediment are permitted to occur from extensively developed catchment basins demonstrates a lack of regard for environmental principles by local authorities. Measures suggested by Reddering (1994) to counter the influx of sediments (sediment trap construction, wetland restoration, riparian vegetation protection, promotion of community awareness) are clearly required to maintain the clear water status of Knysna.

Conclusions

No clear long-term changes in water temperature, salinity, pH and dissolved oxygen were evident. Recorded differences between this study and previous ones were possibly primarily a consequence of a higher sampling intensity and longer duration studies resulting in more accurate recording of natural variability, rather than inherent changes in water quality. Of concern is the periodic high inputs of sediments from minor catchments which primarily drain residential and industrial areas and the resultant influence on water clarity. Actions are required to counter the influx of sediments from these sources.

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