An Introduction to the Knysna Estuary

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Introduction

An estuary is defined by CEC331Z Study Guide 1 (2006) as a river system flowing into the sea, where there is a gradual transition in physical, chemical and biological features from freshwater to sea-water. The nature of the vegetation, for example in mangrove swamps or halophytic plant communities, are determined by the influence of the sea-water.

According to Forbes (2011), there are approximately 289 estuaries, with only 37of them maintaining permanent tidal inlets with the sea. The following classifications have been suggested by Forbes (2011)

- Estuarine bays (large tidal prism, tidal mixing process, average salinity 20-35 ppt)
- Permanently open estuaries (moderate tidal prism, tidal/riverine mixing process, average salinity 10-35 ppt)
- River mouths (small tidal prism, riverine mixing process, average salinity <10 ppt)
- Estuarine Lakes (negligible tidal prism, mixing process-wind, average salinity1->35 ppt
- Temporarily closed estuaries (tidal prism absent, mixing process-wind, salinity 1->35 ppt)

Forbes (2011), states that estuaries are dynamic systems and virtually any physical or chemical feature associated with them is subject to rapid and sometimes extreme changes. Forbes (2011) also states that the mouths of South African estuaries, unless pinned by some rocky feature (i.e. the Knysna heads), tend to meander under the influence of currents, wind and wave action and sediment movement.

High salinities are less frequent but are nevertheless a feature of west coast estuaries and St Lucia is a typical example where during drought years, this very large, shallow system is subject to high evaporation rates (Forbes, 2011). Most estuarine invertebrate animals seem to be able to tolerate salinities up to about 500 ppt (normal sea water is 35ppt) (Forbes, 2011)

This report focuses on one of the many habitats found in South Africa, the estuarine environment, and serves to explain how plants and animals are adapted to survive in their environment.

Study Area

The town of Knysna is located on the northern shore of the Knysna estuary, and is situated between George (33^0 57' S, 22^0 28' E) and Plettenberg Bay (34^0 05' S, 23^0 21' E) some 530 km east of Cape Town and 230 km west of Port Elizabeth (Marker, 2002). The entrance to the Knysna Heads is 34^0 04.752' South and 23^0 03.545' East (see figure 1).

Figure 1. Satellite view of the Knysna Estuary. (Google Earth, 2010)

The Knysna River rises in the Outeniqua Mountains. It is approximately 60 kilometres in length but has a small drainage basin and is tidal for the final 20 kilometres (Watling and Watling, 1982). The catchment of the Knysna River lies within the Cape Fold Belt with its long faults and folds that strike east-west (Heydorn, 1985). The catchment area for the Knysna Estuary is 335 km^2, Allanson (1999).

The oldest rocks in the area of late Precambrian age are found south of the Outeniqua Mountains to the west of Knysna. They consist mainly of contorted bands of schist, phyllites and feldspathic quartzites of the Kaaimans Formations (Heydorn and Grindley, 1985).

The Knysna-Amatole montane forests is a subtropical moist broadleaf forest eco-region of South Africa. It covers an area of 3100 square kilometres in South Africa's Eastern Cape and Western Cape provinces (Wikipedia 2010). In this region, indigenous forest forms a nearly continuous belt along the Outeniqua and Tsitsikamma Mountains from Mossel Bay to Humansdorp and is widest (18 km) east of Knysna (Koen and Crowe, 1987).

With its Mediterranean climate, the average summer temperature during the day is 22°C which falls to 14°C at night. In the mid-winter months (June, July and August), days are often mild and warm 19°C, but evenings brings crisp and cold temperatures (Pezula, 2010). The mean maximum temperature was 20.1° C and the mean minimum temperature 11.0° C (Koen and Crowe, 1987).

Rainfall in the study area tends to be evenly distributed throughout the year (Weather Bureau 1954, 1977), contrasting with the marked seasonal rainfall which predominates throughout most of Southern Africa (Jackson, 1961). The mean annual rainfall ranges from 700mm at the coast to 1161 mm at Buffelsnek station 30/265 (Heydorn and Grindly, 1985).

The trees are of tropical and afro-montane origin, and include Ironwood *(Olea capensis)*, Stinkwood *(Ocotea bullata)*, Outeniqua Yellowwood *(Afrocarpus falcatus)*, Real Yellowwood *(Podocarpus latifolius)*, Cape Holly *(Ilex mitis)*, White Pear *(Apodytes dimidiata)*, Cape beech *(Rapanea melanophloeos),* Bastard Saffron *(Cassine peragua),* Cape Plane *(Ochna arborea),* assegai tree *(Curtisia dentata)*, Kamassi *(Gonioma kamassi)*, White Alder *(Platylophus trifoliatus)*, and Red Alder *(Cunonia capensis) (Wikipedia, 2011).*

The forests are home to African Elephant (*Loxodonta Africana*), African leopard (*Panthera pardus*), Bushbuck (*Tragelaphus scriptus*), Blue duiker (*Cephalophus monticola*), Bushpig (*Potamochoerus larvatus*) and other mammals (Wikipedia, 2011). It has a rich assortment of birds, reptiles, amphibians, and insects (Wikipedia, 2011).

Discussion

The Knysna Estuary is known as an estuarine bay where water area exceeds 1 200 ha. Natural bays (Knysna) and artificially formed bays (Durban Bay) are permanently linked to the sea and the salinity within them reflects this. Knysna estuary is the only one so listed in the warm temperate region (Whitfield, 1995). Hyper-saline conditions are not common and water temperatures are strongly influenced by the sea. Marine and estuarine organisms dominate these systems and extensive wetland/mangrove swamps occur. (Turpie et al, 2004).

The Knysna Basin, on the southern Cape coast, is the catchment for the Knysna estuary (Marker, 2003). The Knysna estuary, which has a tidal water area of approximately 20 km2, is the largest along the southern coast of South Africa (Marker, 2003). Since the estuary is permanently open to tidal ingress (one of only 13% of South African estuaries) and no dam restricts freshwater inflow from the Knysna River, the natural salinity gradient is maintained (Marker, 2003).

The tidal region is a broad valley between sandstone and conglomerate escarpments. Two high sandstone cliffs, the Knysna heads constrict the valley where the estuary joins the sea. The large input of tidal marine water and the limited inflow of freshwater ensure that much of the Knysna Estuary's faunal diversity is of marine origin. The coexistence of marine, diadromous and endemic estuarine forms results in the Knysna Estuary having the highest biodiversity of any South African estuary (Heydorn and Grindley, 1985), and the presence of at least two rare fish species, the Knysna goby, figure 2 (*Pandaka silvana*) and the Knysna seahorse, figure 4 (*Hippocampus capensis)* (Teske et al 2003).

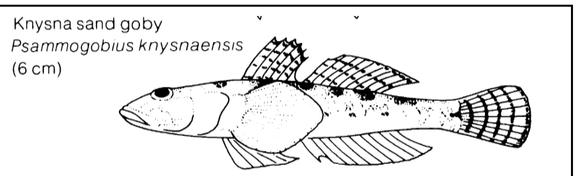

Figure 2. Diagram of the Knysna Goby. (Doergeloh)

The Knysna estuary has been calculated (based on size, habitat importance, zonal type rarity and biodiversity importance), as the most important estuarine system in South Africa (Turpie and Clark 2007) and is currently under the management jurisdiction of South African National Parks. All estuaries are subject to certain regulations under the Marine Living Resources Act (MLRA), and thus enjoy some level of protection, at least on paper. The Knysna Estuary has a medium level of protection and this includes:

- part of estuary within a protected area,
- some restrictions on activities,

• some restrictions on surrounding development.

Estuaries are well-known for their biodiversity, productive fish and invertebrate fisheries and for the important functions that they perform, such as providing nursery areas for marine fish, conduits for species which move between ocean and rivers (e.g. some eels and invertebrates) and feeding and staging sites for significant populations of migratory birds (Turpie et al, 2002).

The Knysna Estuary also supports a number of endemic species, many of which depend on estuaries for their survival (Turpie et al, 2002). It is a nursery for marine species and over 100 species of fishes, prawns and crabs in South African off-shore waters use estuaries as nurseries and/or feeding grounds (Enviro-Facts, 2011).

Salinity

Sea water flows in at the mouth of the estuary and river water at the head of the estuary, a gradient of salinity is established with the saltier water near the mouth (Branch and Branch, 1981). River is divided into 4 typical zones, head, upper reaches, middle reaches, mouth (Branch and Branch, 1981) see Table 1 and Figure 3.

Table 1 Division of rivers into 4 zones (Branch and Branch, 1981).

	Head	Upper Reaches	Middle Reaches	Mouth
Salinity %	< 5	5-15	15-25	25-35
Substratum	Coarse	Mud	Mud and sand	Sand
Current	Varies	Slow	Slow	Rapid
Animals	Fresh water and estuarine	Many estuarine. Few euryhaline marine	Mostly euryhaline marine	Euryhaline and stenohaline marine
Plants	Reeds	Salt marshes, mangroves	Mangroves, eelgrass, salt marshes	Seaweeds.

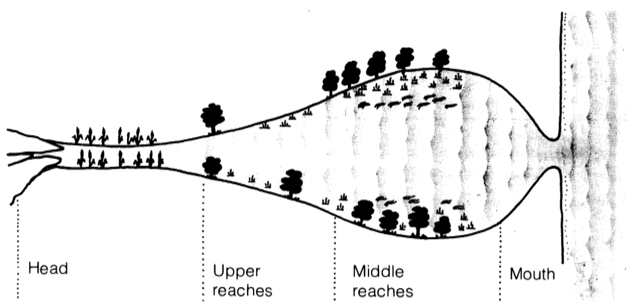

Figure 3. Diagram of the divisions of rivers into 4 zones (Branch and Branch, 1981).

Most biologically orientated definitions of estuaries emphasises variable salinity as an essential feature of estuarine systems (Day, 1981). Fluctuations in mood and character lie at the heart of estuarine ecology and demand special adaptations in organisms that live there. Those species that overcome these problems thrive on the nutrients and food provided by both rivers and the sea making estuaries among the most productive systems in the world (Branch and Branch, 2008).

Salinity is measured in parts per thousand (ppt) and will range between 0 ppt at the head and can reach 35 ppt at the mouth (Heydorn and Grindley, 1985). In general, every tide brings a change in salinity (Branch and Branch, 1981). Branch and Branch (1981) states that faced with the stresses of changing salinity, estuarine creatures have come to cope in different ways. Some species avoid stressful salinities by migrating when conditions become unpleasant. Others that are less mobile must tolerate the changes. For example, the Knysna Seahorse (*Hippocampus capensis*) as seen in figure 4, can tolerate salinities from 1 ppt to 59 ppt (CITES Appendix II).

Figure 4. Photo of the Knysna Seahorse.
Tracy Meintjes, Knysna, September 2009

Estuarine aquatic invertebrates are grouped into two major categories based on salinity; osmoconformers and osmoregulators. Osmoconformers maintain their body fluid isosmotic with sea-water. A few animals are however isosmotic over a wide range of concentrations (Doergeloh). Osmoregulators maintain their body fluids hyperosmotic to the medium, using lots of energy in the process. Some species may function as conformers and regulators (Doergeloh). Some species will migrate to other areas of the estuary where salinity levels are more tolerable.

Tolerance mechanisms used by plants to adapt to salinity can be separated into those that allow the growing cells of the plant to avoid and those that permit the cells to cope with high ion concentrations. Salt avoiders or excretors include mangrove and salt marsh plants that possess salt glands or trichomes that are capable of removing excess salts to the exterior. Tolerance to salinity is a convenient means of categorising different estuarine faunal groups (de Villiers and Hodgson, 1999). Day (1981b) suggested the following components amongst the estuarine fauna based on the their salinity tolerance ranges:

- Stenohaline marine component – salinity tolerance 30-40 ppt
- Euryhaline marine component – salinity tolerance 15-60 ppt
- True estuarine component – salinity tolerance 2-60 ppt
- Migratory component – salinity tolerance variable to independent
- Terrestrial component – mostly independent

Branch and Branch (1981) states that estuarine creatures have come to cope in different ways. Some species avoid stressful salinities by migrating when conditions become unpleasant: fish and prawns are obvious examples. Others that are less mobile must tolerate the changes. When floods occur a low salinity condition occurs. One bivalve (*Dosina hepatica*) overcomes this problem by clamping its shell tightly shut excluding the water when salinities drop below 14ppt (Branch and Branch, 1981).

There are two methods that allow plants to tolerate salinity: those that permit the cells to avoid and those that allow the cells to cope with high ion concentrations (Adams et al, 1999). Salt avoiders or excretors include mangrove and saltmarsh plants that possess salt glands or trichomes that are capable of removing excess salts to the exterior. Exclusion mechanism are effective at low to moderate levels of salinity. Ion accumulation is the primary mechanism used by halophytes at high salt levels (Adams et al, 1999). Studies on *Sarcocornia natalensis* (see figure 5), by Naidoo and

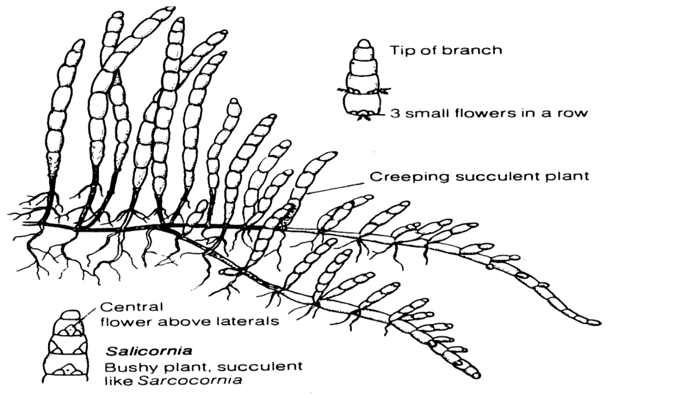

Figure 5. Diagram of Sarcocornia, Branch et al, 1981

Rughanan, 1990, showed that ion accumulation accounted for 86% of the osmotic adjustment.

Ion accumulation is the primary mechanism used by halophytes at high salt levels, presumable in conjunction with the ability to isolate ion into vacuoles and in the cell wall (Adam et al, 1999). Adams et al (1999) states that the vacuole comprises 95% of the mature leaf cell volume and it is commonly held view that ions are accumulated here for osmotic adjustment. According to Adams et al (1999) accumulation of ions in the vacuole can occur because of changes in membrane permeability and ion transport properties that facilitate transport against electrochemical gradients and membrane transport selectivity.

The changing salinity levels of estuaries often demarcate the areas of distribution of various species (Doergeloh). Estuarine species have adapted to those particular conditions in different ways (Doergeloh). As stated by Doergeloh, estuarine organisms can be classified according to their responses to salinities. According to Doergeloh, stenohaline marine species are intolerant of low or high salinities and enter only the lower reaches of estuaries. Most species found in estuaries are euryhaline marine species, that tolerate a wide range of salinities (Doergeloh). Only a few organisms are truly estuarine, being confined to estuaries and not found in the sea (Branch and Branch, 1981). Fresh water species may occur at the upper reaches of estuaries, but they are seldom found in salinities of over 5ppt.

Temperature

The sea has a relatively constant temperature, but because of their smaller volumes, rivers are warmer than the sea in the summer and colder in the winter. Therefore the head of the estuary experiences a far wider range of temperatures than the mouth.

According to Barnes (1976) the shores of the estuaries are exposed during low tides and are subjected to wide fluctuations in temperature. Barnes (1986) states that the highest temperature on the exposed mud-flat is during a summer day and the lowest temperatures occur during the winter nights at low tide. Many of the warm temperate and subtropical species have been found to survive water temperatures of 35^0C and resist brief exposure to higher temperatures (de Villiers and Hodgson 1999). De Villiers et al (1999) also states that estuarine water temperatures vary seasonally but in addition many estuaries experience large, short-term, fluctuations in temperature 6-12^{0}C as a result of the tidal movement of cold sea water into the estuary during periods of coastal upwelling.

The initial response of animals, and the time taken to acclimate to different exposure temperature varies depending upon the conditions to which the animals were previously acclimated (de Villiers and Hodgson 1999). According to Kinne (1963) the general response follows the three phases for non-genetic adaptation i.e. immediate response to environmental change, stabilisation of this response and a new steady state. Animals previously acclimated to one temperature re-acclimated to a new temperature within 120-168 hours.

Estuarine organisms have developed both physiological and behavioural adaptations to various strategies of coping with changing water temperatures (Doergeloh). Mud prawns (*Upogebia africana*), for example, have a means of avoiding lethal temperatures: if the temperatures rises over 32^{0}C they stop pumping water through their burrows (Branch and Branch, 1981). Branch says that the sediment is a good insulator, the heat penetrates it slowly and the mud prawns remain comfortable, buried in the cooler sediments.

The temperature of the sandflats on which five species of crab feeds often exceeds 45^{0}C, well over the lethal body temperature (Branch, 1981). In spite of this, Branch (1981) states that they manage to spend much of their time feeding there because they cool their bodies by evaporation of body water, thus reducing their temperature by about 6^{0}C. To make up this water-loss they must periodically scuttle back to their burrows, which extend down to the water-table (Branch and Branch, 1981).

According to de Villiers et al, 1999, the effect of temperature on South African estuarine invertebrates has largely been overlooked and requires a great deal more investigation.

Temperature and Salinity

It must be stressed that temperature and salinity cannot be looked at in isolation. Organisms may have relatively wide tolerances of both temperature and salinity, but a combination of the two usually narrows the tolerance range (Doergeloh). An animals' success depends upon its ability to accommodate, tolerate and/or avoid unfavourable fluctuations in these two factors (de Villiers and Hodgson, 1999). De Villiers et al (1999) adds that in South Africa, very little research has been done which investigates the combined effect of temperature and salinity. According to Doergeloh, Juvenile stumpnose fish (figure 6) survive a wide range of salinities at 20^{0}C, but are much less tolerant of salinity at higher and lower temperatures.

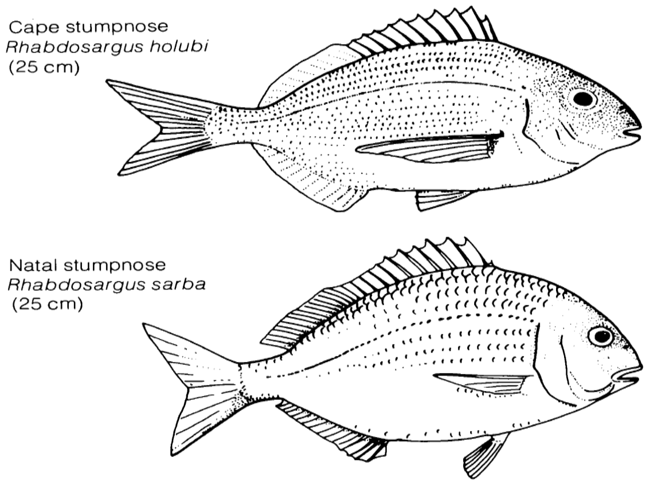

Figure 6. Diagrams of two adult stumpnose species. (Doergeloh)

Oxygen

Due to the large quantities of detritus that are deposited in estuaries, oxygen levels are under high demand. Microbial decomposition uses up much of the available oxygen. Because of fairly stable interstitial waters, the deoxygenated water cannot be replaced rapidly by new more oxygenated water. According to Barnes (1976), bottom dwelling organisms may be stressed by low oxygen conditions. Oxygen levels will also drop dramatically when fauna is trapped in small pools with no source of oxygen until the tide returns.

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