Is there a relationship between White Shark presence and the management of city estuaries and river mouths?

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Abstract

Following the number of high profile shark attacks in Cape Town over the last five years, speculation around the role that estuary mouths, stormwater and wastewater outflows may have played in attracting sharks to the area has grown. Four attacks (two fatal) have all taken place within 500m of estuary mouths or outflows increasing perceptions that these areas are possible "hotspots" of white shark activity. This paper investigates the relationship between White Shark occurrence and river and estuary mouths and discusses the role that nutrient load and estuary mouth manipulation, as part of the City's catchment management strategy, may play in white shark presence. Sufficient evidence to make definitive statements is lacking, however preliminary research findings indicate a possible link between white shark behavioural patterns and river mouths. No evidence currently exists to suggest that this potential link is related in any way to either higher nutrient loads as a result of urban run-off, or the manipulation of estuary mouths as part of holistic catchment management practises. Further research is required before definitive statements are made. It is argued in this paper that the first priority for recreational safety is identifying if and where white shark "hotspots" exist as well as the spatial and temporal trends around those "hotspots" as opposed to why "hotspots" may exist. The current research project investigating White Shark ecology and behaviour in False Bay is likely to provide greater clarity on the role of estuaries and outflows in white shark behavioural patterns, thereby providing significant and crucial information to recreational safety within Cape Town.

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1. Introduction

Cape Town Cape Town has a number of estuaries and river mouths along its coastline, which in comparison to other areas along the South African coast are relatively small with low flow outputs. Nevertheless, they are an integral part of the City's terrestrial and coastal landscape and ecology.

Many of the City's estuaries and rivers that drain into the ocean are heavily impacted by urban run-off, waste water effluent and development. As such, the rivers and estuaries that do enter the ocean off Cape Town are generally impacted, flow affected systems with high nutrient loads. In addition to the rivers and estuaries, there are a number of wastewater effluent outfalls and stormwater outlets, illustrated in Figure 1, spread along the City's coastline.

Figure 1. Illustration of the high number of wastewater and stormwater outlets along a section of the False Bay coast between Muizenberg and Strand

Following the attack on JP Andrew in April 2004, much speculation surrounded the timing of the attack with that of the scheduled opening of the Zandvlei Estuary mouth by the City of Cape Town. The suggested association was that the opening of the mouth released a pulse of concentrated nutrient rich water and nursery fish into the shore break, thereby attracting the related chain of predators to the area, including Great White Sharks. The Zandvlei mouth is approximately 500 metres from Muizenberg corner where JP Andrew was attacked.

This speculated association of attacks with that of river outflows is further increased when it is considered that the other three attacks (two fatal) that have taken place in the inshore in the last five years, took place within 500m of outflows; namely the Silvermine River at Fish Hoek and Wildevoelvlei at Noordhoek Dunes.

This paper investigates the relationship of White Shark occurrence with river and estuary mouths and discusses the role that nutrient load and estuary mouth manipulation, as part of

the City's catchment management strategy, may play in white shark presence and attack. Sufficient evidence to make definitive statements is lacking, however the paper presents the available information and attempts to deduce whether this issue as a whole deserves further investigation.

2. Rivers and Estuary Management

The City's rivers and catchments are managed by the Department of Catchment, Stormwater and River Management. In terms of this paper, the focus around the association of white sharks to estuaries and outflows, and therefore the possible risk to recreational users, sits within two distinct water management issues, namely;

- The physical intervention by the City in opening and closing estuary river mouths and how this may influence the presence of White Sharks
- The higher nutrient load of certain City rivers', estuaries and stormwater outfalls entering the inshore region and how this may influence white shark presence.

Physical Intervention: Opening and Closing of Estuary and River Mouths

The City's policy on actively opening and closing river and estuary mouths is to refrain from doing so unless absolutely necessary so as to avoid a possible flood situation, or in mitigation against a build up of nutrients and/or loss of salinity within the systems.

Flood situations may arise if a river mouth has been closed due to natural factors such as low flow conditions and sand build up on the beach, common during the Cape summer, in conjunction with a heavy rain episode. In this instance, if surrounding property is potentially under threat of flooding, the City may physically open the mouth as a preventative measure. In other cases, higher than normal nutrient levels (caused by a wastewater treatment works malfunction) and which could lead to algal blooms, have in the past been mitigated through the opening of river mouths. Finally, the Silvermine River Mouth is manipulated if the river mouth migrates towards Clovelly Station potentially undermining infrastructure. These interventions are by far the exception rather than the norm.

There is one exception however, to this policy, and that is the planned and ongoing opening and closing of the Zandvlei Estuary mouth. The Zandvlei Estuary mouth is left open throughout winter due to the higher flow as a result of seasonal winter rainfall. However, during summer months, the mouth is actively closed following a spring high tide and then breached (opened).

The primary reason for manipulating the Zandvlei Estuary Mouth is to attempt to keep the salinity levels in the vlei above 8 – 10ppt. Adequate levels of salinity are required to support floral and faunal components (such as Sago pondweed and their associated communities of epiphyton and periphyton, tube worm and sand prawn), all of which are essential

components of estuary ecology and water quality maintenance. In addition, the estuary mouth is manipulated at certain times of the year (usually at the end of winter) to regulate the water level to ensure enough recreational water depth. Using spring tides, and manipulating the mouth, the Catchment Management Department "flushes" the estuary aiding the ecological functioning and integrity of the estuary. This "aided flushing" of the Zandvlei estuary has significantly boosted the ecological condition of the estuary and is considered a highly successful environmental intervention. Zandvlei Estuary recorded Total Phosphorous mg/lire results of below the Eutrophic and Hypertrophic limit of 0,125 mg/l for 2000, 2001, 2002, 2003 and 2004 (Catchment, Stormwater and River Management Report, City of Cape Town, 2003-2004). However, as a result of this intervention, there is a periodic release of moderate concentrations of nutrients into the inshore area.

Rivers, Estuaries and Stormwater outflows: High nutrient Content

The City of Cape Town has a urban population of 3,2 million people and is currently experiencing a growth and development boom. This translates into greater surface-area of hard surfaces increasing levels of urban run-off, increased capacity demands on existing and dated sewage treatment works, natural river flow interruptions, greater levels of nutrients and chemical pollutants in the environment (fertiliser, animal and human waste products, solvents and soaps and industrial by-products) and a loss of natural water ecosystem services such as purification and attenuation through seasonal wetlands having been lost to development. The cumulative effect of these urban pressures is a decrease in the ecological state of the City's river and catchment system. This results in poor water quality high in nutrients entering the inshore at many river, estuary and stormwater outflows. However the impact on City rivers and estuaries is not uniform across the City, some are highly altered heavily impacted systems while others retain relatively high water quality standards. Of the three outlets in question (Zandvlei Estuary, Silvermine River and Wildevoelvlei) only one, the Wildevoelvlei has a high nutrient load as a result of receiving treated wastewater effluent. Wildevoelvlei exceeded the Eutrophic and Hypertrophic phosphorous limit of 0,125 mg/l for 2000, 2001, 2002, 2003 and 2004 by more than 400% each year (Catchment, Stormwater and River Management Report, City of Cape Town, 2003-2004). The Zandvlei Estuary is classed as moderate in terms of nutrient load, receiving only urban and stormwater run-off, while the Silvermine River is one of the cleanest urban rivers in Cape Town with 100% compliance with DWAF Ecoli guidelines and phosphorous levels well below the limit (0,016 mg/l) (Catchment, Stormwater and River Management Report, City of Cape Town, 2003-2004).

This is in comparison to other outlets such as the Zeekoevlei outlet that is permanently open and flowing with high nutrient loads from the Cape Flats Wastewater Treatment Works and the Eerste River Estuary, also permanently open, which carries the treated effluent from the Macassar Wastewater Treatment Works. Both outlets have high phosphorous levels above eutrophic and hypertrophic levels.

Stormwater outflows are seasonal, with very little or no flow during the Cape's dry summer months and with increased flow in winter as a result of high rainfall episodes. Further, it should be noted that nutrient pollutant inflow levels to the City's rivers, estuaries and stormwater outlets are highest at the beginning of winter with initial winter rains flushing accumulated nutrients from streets, urban areas and pipe networks, whilst conversely being lowest during the summer months.

Shark Presence: Is there a relationship?

Preliminary evidence from False Bay (Kock pers.com)

There is a large-scale research project monitoring white shark presence within False Bay. Monitoring equipment has been placed all along the coast and to date white sharks have been detected on all 30 monitors located between Cape Point and Koeël Bay (Kock pers.com). Preliminary data indicates that inshore areas with the highest recorded shark activity are Simon's Town, Fish Hoek, Kalk Bay, Muizenberg, Standfontein and Macassar. Less activity has been recorded at Cape Point, Partridge Point, Gordon's Bay and Koeël Bay.

In certain key areas, like Muizenberg, more than one monitor has been deployed to address specific questions related to that area. Monitors have been deployed at Baily's Cottage, Joan's Bouy, Zandvlei and Sunrise Beach approximately 500 m from shore. Preliminary data indicates that the monitor closest to the Zandvlei mouth at Muizenberg detected the highest relative shark activity (Kock pers. com) (Fig 2), however it's not possible at this stage to differentiate between whether this is a natural 'hotspot' for white sharks or whether they are attracted locally to the breaching of the Zandvlei mouth. Such confirmation will only be reached after more months of monitoring. However, because all four monitors show the same seasonal pattern of shark presence (Fig. 2) and this seasonal pattern is reflected at other inshore sites around the bay, like Simon's Town, Gordon's Bay and Fish Hoek (Kock *et al*. 2006), it suggests that the presence of white sharks at Muizenberg is not governed by bi-monthly events, like the breaching of the Zandvlei mouth.

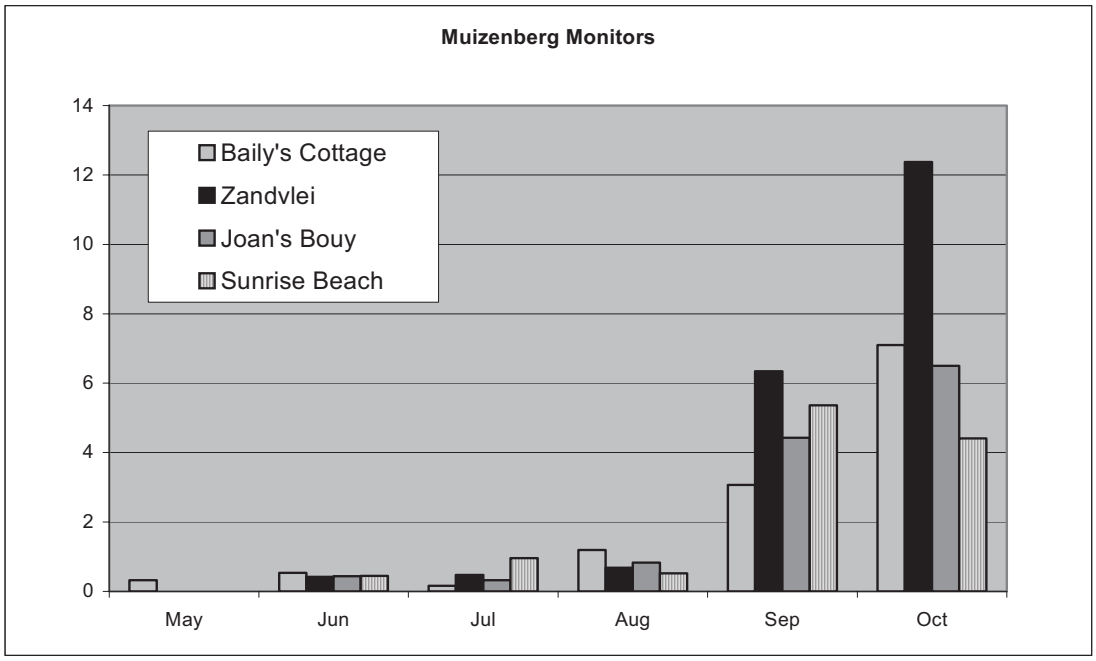

Figure 2. Shark activity (acoustic detections per shark per day) recorded on four acoustic monitors deployed in Muizenberg from May – October 2005.

Preliminary evidence from Mossel Bay (Johnson pers.com)

Research conducted at Mossel Bay did reveal a possible association between white sharks and river mouths. However, at present it is impossible to determine the causative influence that river mouths may be having on white sharks distribution within Mossel Bay.

Three sharks were manually tracked for a combined effort of over 600 hours during which position, water depth, water temperature and bottom structure were routinely recorded at 10 minute intervals. The results revealed distinct behavioural patterns unique to individual size classes.

The largest sharks, a circa 420cm female was primarily associated with waters near to Hartenbos river mouth and Seal Island. On only one occasion was this shark located outside of these core areas. The shark's behaviour was typified by patrolling behaviour in the early mornings and late afternoons in waters adjacent to the seal Island apparently hunting for seals departing from or returning to Seal Island (Fig. 3). The remainder of the time, the shark swam circa 3kms towards Hartenbos river mouth and swam in a restricted area 'opposite to' and 'south of' Hartenbos river mouth (Fig 1). The northern edge of the river mouth appeared

to represent the northern most limit of the sharks' home range over the various 24hour periods.

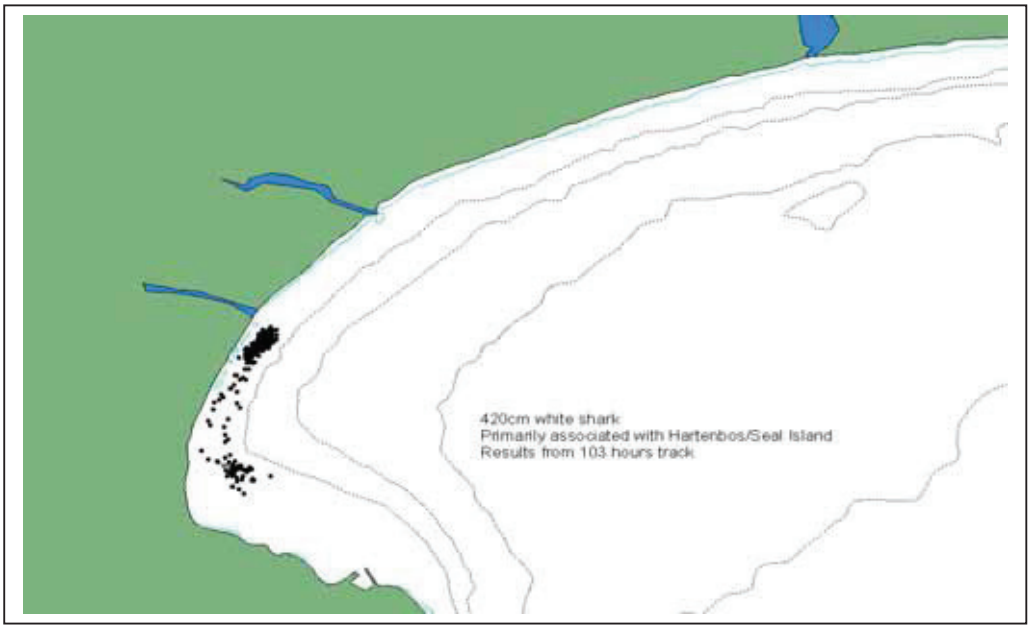

Figure 3. Illustration of the behavioural patterns of a 420cm female White Shark in Mossel Bay over 103 hours of tracking

The smallest white shark was exclusively observed in the Grootbrak region. Its small size and behaviour suggested that it occupied this area to feed off available fish. Its absence from Seal Island further suggests an inability or unwillingness to hunt seals. These findings are consistent with other work on white sharks that has shown a shift in diet from fish to seals as sharks grow in size. The sharks patrol area stretched from the north eastern edge of Grootbrak river mouth along the coastline some 5km to the South west (Fig. 4). The apparent patrolling area was larger than the aforementioned larger shark and we suspect this is related to the more variable spatial distribution of available fish prey (in comparison to pinniped prey).

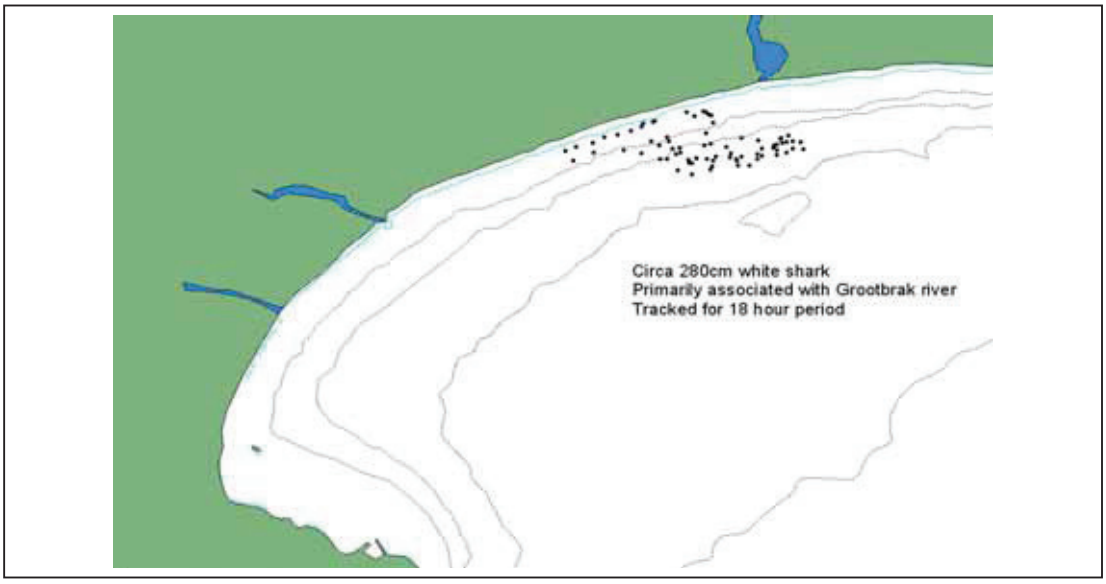

Figure 4. Illustration of the behavioural patterns of a 280cm White Shark in Mossel Bay over 18 hours of tracking

A 350cm female shark was also extensively tracked, and her behaviour varied between the larger and smaller sharks behavioural patterns. That is, occasionally the shark would be located in the Hartenbos/Seal Island region, where she would perform early morning and late afternoon patrols of Seal Island. Such patrols would be interspersed with 'resting' periods opposite Hartenbos river mouth (Fig 5. Track C).

Alternatively she was frequently located at Grootbrak, where her behaviour was typified by patrolling the 5km stretch of coastline from Grootbrak river mouth extending to the South west (Fig. 5 Track B). On three occasions we had the opportunity to track her swimming between Grootbrak and Hartenbos (Fig 5. Track A). These movements were direct and coastal occurring at both day and night. On all occasions, 'the turn back point' occurred 'at' or 'just beyond' Grootbrak's river mouth. This suggests that the river mouth and associated abiotic changes (e.g. salinity) may have been utilised as a navigational clues.

Although the behaviours of these three sharks in Mossel Bay appear closely aligned with river mouths, a number of other possibilities exist to explain the observed patterns of habitat use. The area opposite Hartenbos river mouth (extending to the South) is characterised by extensive exposed reef, as opposed to sand bottom which dominates the remainder of the area. As such, the attraction to this area may be 'as' strongly related to the presence of reef, as it is to the presence of the river mouth.

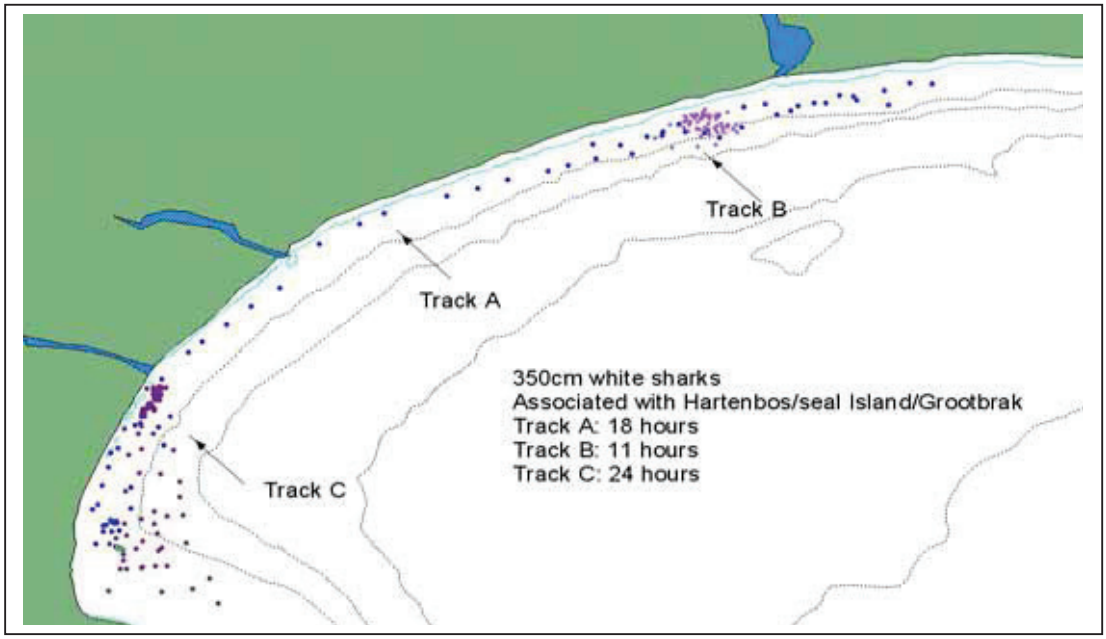

Figure 5. Illustration of the behavioural patterns of a 350cm female White Shark in Mossel Bay over 53 hours of tracking.

Furthermore, Kleinbrak River is consistently ignored by white sharks in the Mossel Bay region. Kleinbrak River is open almost consistently, in contrast to both Hartenbos and Grootbrak Rivers which open rarely and typically only following heavy rains. The status (open or closed) of both Grootbrak and Hartenbos river appear to have no effect on the behaviour of sharks in Mossel Bay, with sharks been attracted to these areas consistently. If the presence of the rivers are acting as a causative attraction for white sharks to congregate then it appears irrelevant whether the river mouths are open or closed. This would make sense particularly if the presence of such outlets are been used as navigational or orientation clues for patrolling white sharks. It is more feasible to expect that white sharks can detect small variations in salinity (associated with leaching) or other non apparent environmental clues that can enable white sharks to consistently orientate themselves in space independent of random and sporadic terrestrial weather patterns.

3. Discussion

Assuming that based on the research to date (the preliminary evidence shown on the bottom monitors in False Bay and tracking in Mossel Bay) that river and estuary mouths may be potential “hotspots” for white shark activity, for the purpose of this paper, a clear distinction needs to be made between the issues under discussion.

Opening and closing of the Zandvlei mouth

Although the preliminary evidence may suggest that white shark presence is higher at the Zandvlei mouth, it is still unclear whether the higher presence of sharks is as a direct result of the planned flushing of the estuary. The work by Ryan Johnson in Mossel Bay suggests that the status of the mouth (open or closed) had little influence. In other words, the presence of the white sharks at the Zandvlei mouth may very likely be a natural phenomenon with white sharks choosing the estuary mouth habitat for a range of ecological reasons. If this is the case, then the speculation around the attack on JP Andrew and the continued risk to recreational users due to the ongoing planned opening and closing of the mouth is not a valid concern.

It may also be argued that the actual nutrient pulse created by the highly periodic opening of the estuary mouth is insignificant in comparison to the daily outflow of high nutrient water some 1200m to the east at the Zeekoevlei outlet. However on current information it is impossible to make the distinction between shark presence as a result of the estuary mouth or presence as a direct result of estuary flushing.

Before motivating therefore that further research must be undertaken to assess and determine this distinction or for the City to act in a precautionary manner and stop breaching, it is worth considering the practicality of this management intervention. Would the current situation of relatively few attacks and arguably low risk to recreational users warrant the review of the current catchment management policy to the detriment of the entire ecology of the estuary?

It is argued in this paper that the current situation (shark risk) would not warrant ceasing estuary manipulation and the ecological degradation of the Zandvlei estuary. Further, even if it was decided to stop active manipulation of the mouth, the natural flow regimes during winter rainfall would periodically open the mouth thus retaining some of the risk. Therefore to stop the active management of the estuary and risk significant ecological, health, social and economic impacts and costs, in order to only slightly lower the presently very low risk of shark attack, cannot be motivated. Rather, if estuary mouths are identified as shark hotspots, estuary management options should not be reconsidered, but a range of alternative management options implemented. These alternative management options could include

- ensuring that the public and recreational users are aware that estuary mouths are areas of increased shark activity and therefore increased risk of attack
- ensuring adequate warning signs are in place
- strengthening the shark spotting and warning programme

High nutrient river and stormwater outflows

Less information currently exists to determine if the nutrient load of small river outflows such as the Silvermine River are a factor in increasing white shark activity. The distinction again would need to be made to assess whether rivers alone are risk factors or whether high nutrient load of rivers increase the presence of White Sharks. Initial information suggests that there is no relationship between nutrient load and White Shark activity. Fish Hoek has recorded some of the highest summer White Shark activity by both the Shark Spotting Programme and by Alison Kock's research programme (Kock pers. Com). As described earlier, the Silvermine River is of some of the highest water quality in Cape Town. In addition, the greatest nutrient load is experienced during early winter and not mid-summer, which is the peak in shark presence. This alone would suggest that there is no relationship with nutrient load and White Shark presence. However, further research would need to be undertaken to determine definitively whether river mouths and / or nutrient load are factors in increasing White Shark activity in the inshore region and therefore increased risk of attack.

4. Concluding Discussion and Recommendations

Although preliminary evidence may suggest that some estuary and river mouths are areas of higher white shark presence and activity, there is little scientific confidence in this conclusion at present. Further, much more research would need to be done to determine whether the high nutrient loads of urban outfalls and river mouths is a contributing factor to this possible increased presence.

It suggested that from the arguments presented in this paper that the critical issue for recreational safety is not whether flushing or nutrient load is a pull factor for white sharks, but rather understanding if and where White Shark "hotspots" may exist. This question is currently being addressed by a research project investigating White Shark ecology and behaviour in False Bay. The aim of the study includes identifying spatial and temporal trends of white shark presence and activity.

However, for improved understanding of shark ecology and long-term conservation strategies, understanding shark spatial and temporal trends and the associated "pull" factors, does become critical. The current research therefore has the potential to not only greatly advances the ecological understanding of white sharks and their behaviour, but contribute significantly to recreational safety of coastal users by identifying shark "hotspots". Support of the current research programme is therefore essential.

It is therefore recommended that:

- The City actively supports and endorses the research that is underway that may identify 'hot spots of shark activity
- The City ensures that the research findings form part of its long-term planning
- If the information gathered as part of the research begins to suggest more strongly that a link between estuary, river and stormwater outflows with white shark presence does exist, that the City acts immediately to warn and inform the public through a range of mediums