ATTACHMENTS

WORKS AND SERVICES
COMMITTEE MEETING

12 August 2015

5.30pm

City of Albany Council Chambers

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C	**WS**	**Works and Services Committee**	
	WS084	• Review of the Dunsborough Beach Enclosure Trial, Hydrobiology 2014	1

Hydrobiology

Review of the Dunsborough Beach Enclosure Trial

Completed for the Department of the Premier and Cabinet, Western Australia

September 2014

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EXECUTIVE SUMMARY

In response to recent shark attacks in Western Australia, the state government funded the installation of a netted beach enclosure at Old Dunsborough Beach (Dunsborough, Western Australia) consisting of permanently installed pilings between which shark-proof netting was installed. The enclosure provided an area of shallow water which was inaccessible to sharks and thus provided a safe swimming area. This report provides a review of the success of this trial, relevant considerations in future net installations and potential sites across Western Australia. This review was conducted at the request of the Department of the Premier and Cabinet (Government of Western Australia) and was facilitated by provision of information and advice from the City of Busselton.

The nets at Dunsborough beach fulfilled their requirements and with minor adjustments maintained a complete beach barrier. The netting did get fouled by longshore movement of wrack and required frequent attention to remove the detritus. Biofouling occurred but did not hinder the performance of the net and no bycatch was recorded. The ability to relatively easily (cheaply) remove and deploy the netting mitigates the longer-term biofouling risk. The net can be removed during the lower beach use/storm season (winter) and cheaper land-based cleaning employed.

Analysis of data regarding local shark sightings suggested that sharks large enough to pose a risk to humans were regularly observed in the local area and thus the enclosure was effective in preventing potential interactions between those sharks and beach goers.

Community and operator feedback indicates that the Dunsborough Beach Enclosure trial was considered successful. Ongoing management and maintenance costs for the system deployed at Dunsborough are considered low to moderate and favourable in comparison to other methods of shark risk mitigation.

Other shark barriers such as the Coogee Beach shark net installation trial were also successful in creating an underwater fence that was impervious to sharks and had large a large enough mesh size to prevent build-up of wrack and other detritus whilst retaining a rigid nature preventing marine life from becoming entangled in it. The system also acted as an artificial reef that attracted marine life increasing its popularity with local beach users. In comparison to the netting installed at Dunsborough, the Coogee Beach trial was evaluated to be more expensive and had difficulties with installation and removal. The growth of marine organisms on the net at Coogee was not an issue in the short term however, given the economic pressure for longer-term deployments, this may become an issue.

Beach usage statistics, provided by Surf Life Saving Western Australia, were analysed in combination with coastal morphology and tidal regime information in order to identify numerous locations along the coast of Western Australia that could provide conditions sufficient to install further beach enclosures and thus provide beach users with further peace-of-mind regarding the risk of shark attack when entering the water.

Review of the Dunsborough Beach Enclosure Trial

Completed for the Department of the Premier and Cabinet, Western Australia

September 2014

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1 BACKGROUND

In Australia there have been a total of 892 Shark attacks of which 217 were fatal in approximately the last 200 years according to the Australian Geographic (2014). Of these attacks, 14 have occurred in Western Australia since 1995, with no prior attacks after 1967. Half those most recent attacks occurred in the last three years (Table 1-1). The increase in attacks has resulted in a public concern for safety during marine related recreation. The State Government response to this has been expansive and has included the development and independent testing of electronic shark deterrents (Huveneers *et al.* 2012), extensive funding into research regarding deterrent mechanisms and shark physiology (Oceans Institute, 2014), baited drum line shark culling (ABC 2014) and the installation of an enclosed bathing area at Old Dunsborough Beach.

Table 1-1 Recent fatal shark attacks in Western Australian waters (Australian Geographic, 2014)

Month	Year	Location
March	2014	Mandurah
November	2013	Gracetown
July	2012	Wedge Island
March	2012	Port Geographe
October	2011	Rottnest
October	2011	Cottesloe
September	2011	Bunker Bay
August	2010	Gracetown
December	2008	Port Kennedy
March	2005	Abrohlos
July	2004	Gracetown
November	2000	Cottesloe
January	1997	Geraldton
September	1995	Hopetoun

In the context of this review it is important to establish the difference between shark 'barrier' nets and shark nets used to capture and control sharks. This report uses the terminology 'barrier nets' or 'beach enclosure' to refer to non-lethal/non shark-capture nets. The deployment of barrier nets to prevent the movement of sharks into bathing areas is a well-established method for mediating the risk of shark attack and provides peace-of-mind to beach goers who feel unsafe in this environment. Barrier nets prevent sharks from coming into contact with swimmers while bottom or surface 'shark nets' act like gill nets to ensnare sharks and thus deplete their population in an attempt to reduce the risk of them encountering humans.

The New South Wales Department of Primary Industries have implemented shark netting programs since 1937 with a current total of 51 beaches protected by these installations and

only one fatal attack at a protected beach during this period, however by-catch of birds and marine mammals have caused criticisms of the approach (Green *et al.* 2009). The Queensland Shark Control Program (QSCP) manages a system of both netted beaches and drum lines to mitigate shark attacks by both reducing their numbers and preventing them from reaching bathers, the system also receives criticism regarding by-catch and employs a series of acoustic 'pingers' to deter marine mammals (Gribble *et al.* 1998; Erbe and McPherson, 2012).

In South Africa, the KwaZulu Natal shark board maintain a series of shark nets to protect beach users from shark attack along that stretch of coastline. Again, the system provides beach goers with sufficient peace-of-mind when entering the water, however the nets are responsible for a considerable amount of by-catch including turtles, small sharks, dolphins, whales, rays and birds. This causes concern for the environment and poses the possibility of attracting sharks into the area by the feeding opportunity created by the animals entangled as by-catch (Kearney and Jones 2009).

After a series of fatal shark attacks in Hong Kong, a network of beach enclosures was established in order to protect beach goers from marine predators. This is the only other existing substantial implementation of a network of shark barriers that successfully protects swimmers by preventing sharks from entering the same water-space as humans rather than relying on a system of population depletion to reduce risk.

In response to the increased perception of risk of shark attacks in Western Australia's waters the State Government provided the City of Busselton with funding to install a beach enclosure to allow swimmers to enter the water and swim without the risk of encountering a shark. The installation consists of a series of permanently installed pilings traversed by a net with mesh size sufficient to avoid ensnaring other marine life whilst providing an impervious barrier to sharks (Figure 1-1).

Figure 1-1 Dunsborough beach enclosure plan, designed to prevent sharks entering the designated area of water

2 INSTALLATION AND MAINTENANCE LOGISTICS

The Dunsborough beach enclosure net was constructed by installing 6 piles roughly parallel to the shoreline to which the net could subsequently be secured. This took a construction team 14 days to complete and required heavy plant equipment capable of installing piles in a marine environment and probably constituted the majority of the cost of the installation. Incorrect information regarding water depth and local geology caused delays in the pile installation and resulted in extra costs.

Figure 2-1 Design and layout of Dunsborough beach enclosure

Net installations are subject to bio-fouling both from marine growth on the nets themselves and the trapping of 'wrack' (detached macro algae, seagrass etc.) that is transported into the nets via near-shore current circulation. In Geographe Bay 'wrack' consisting mainly of detached seagrass fronds moves in an easterly direction collecting on the western side of groins and natural impediments (Oldham et al. 2010). After the installation, the nets were initially inspected on a daily basis to identify possible fouling from wrack and any marine fauna that may have become entangled in the nets. On the 5th and 6th days stingrays were found in the enclosure which had slipped under the foot rope. This was remedied by adding chain to the foot rope to secure it against the sea bed. During subsequent weeks growth was observed to increase on the nets but did not cause loss of function. 'Weed' (presumably wrack) became repeatedly entangled in the net during windy or wavy periods but could be

adequately removed by inspection staff by simply lifting the net and allow the weed to pass under.

The cost of the Dunsborough beach enclosure is outlined in Table 2-1, a total of approximately $200,000. Of this, approximately $150,000 comprised purchasing the nets and installing the infrastructure required to secure those nets. For half the season (nets were installed Jan-April) maintenance cost approximately $25,000 and therefore would cost roughly $50,000 per year assuming the nets were only installed during the summer period (Nov-April), once initial piles etc. had been installed. One beach enclosure would cost roughly $225,000 for the first year including initial installation and maintenance followed by $50k per year for the next two years for maintenance costs equating to roughly $325,000 for a three year deployment. In terms of cost effectiveness, one could argue that the beach enclosures provided guaranteed protection for those concerned by the risk of a shark attack occurring whilst also providing both peace of mind for those beach users and for those with environmental concerns regarding alternative programs that attempt to reduce shark populations. Conversely these enclosures, based on their current design and costing, would not be able to protect divers and surfers and other water users in locations characterised by larger wave heights and or deeper water.

Table 2-1 Budgeted and actual costings for the various aspects of beach enclosure design and implementation for the Dunsborough beach enclosure

Agreed expenditure of State Government ARP grant	Agreed costings $	Actual costings $	Variance $
Survey, design and approvals	10,000	5,253	-4,747
Net supply	45,000	44,764	-236
Pile supply and installation	87,000	111,000	23,230
Marine safety	11,000	7,337	-3,663
Net installation/removal	7,800	20,443	12,634
Net maintenance	3,800	4,714	914
Total	**165,370**	**193,511**	**28,141**

It should be noted that risks and liabilities incurred by the installation body (e.g. Municipal Councils) would need to be assessed on an individual site basis. While nets are considered relatively safe, correct installation and maintenance is critical to reducing risk of user harm.

3 PUBLIC AND SOCIAL BENEFITS

Shark sightings at beaches in the vicinity of the Dunsborough beach enclosure reported to Surf Life Saving WA, the Water Police and Department of Fisheries WA are shown in Figure 3-1 and show a significant number of shark sightings in the general area particularly at Eagle Bay and Meelup beaches which are approximately 4km from the enclosure. The shark sightings data are not corrected for effort inasmuch as the larger number of sightings at Eagle Bay and Meelup may be the result of a larger number of observers rather than a larger number of sharks.

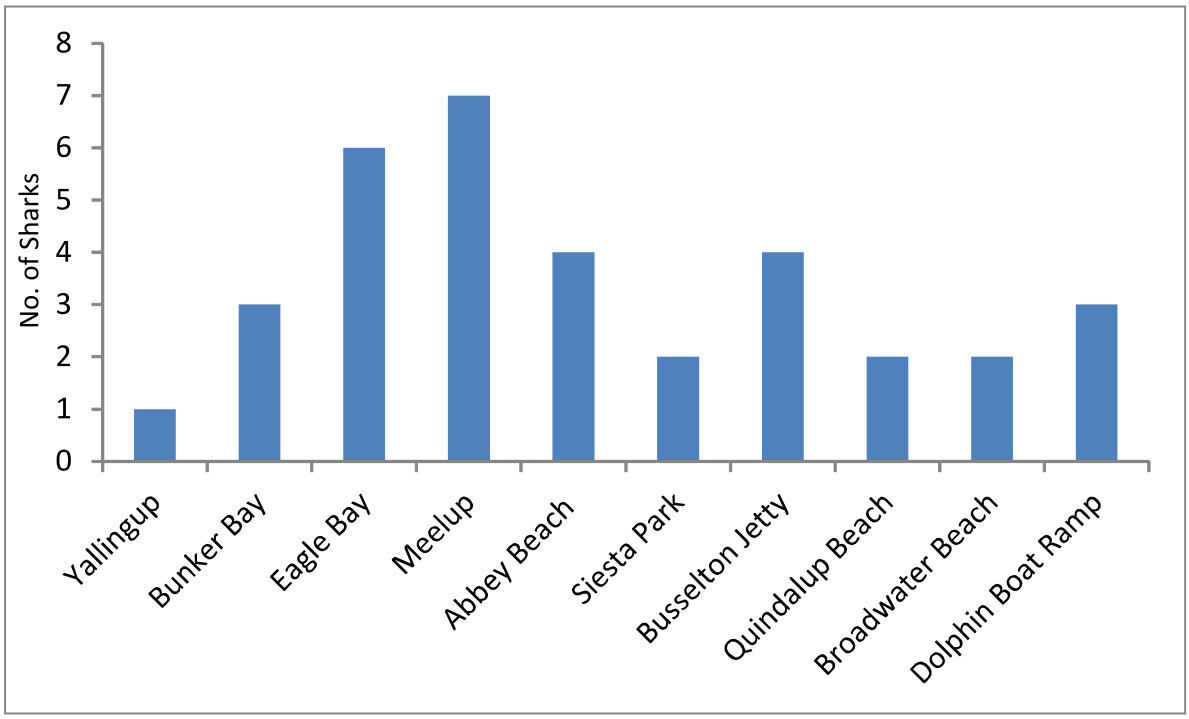

Figure 3-1 Number of shark sightings at various beach locations in shire of Busselton from October '13 to April '14

Approximate sizes of sharks were also recorded when possible and are presented in Figure 3-2. Of the sharks for which an approximate length was recorded, approximately half were greater than the 3m length deemed dangerous to humans by Department of Fisheries (DoF 2014). Only three of the 34 sightings were reported as Great Whites, the species attributed to the majority of attacks in Western Australia, however it should be noted that over half the sharks sighted couldn't be positively identified.

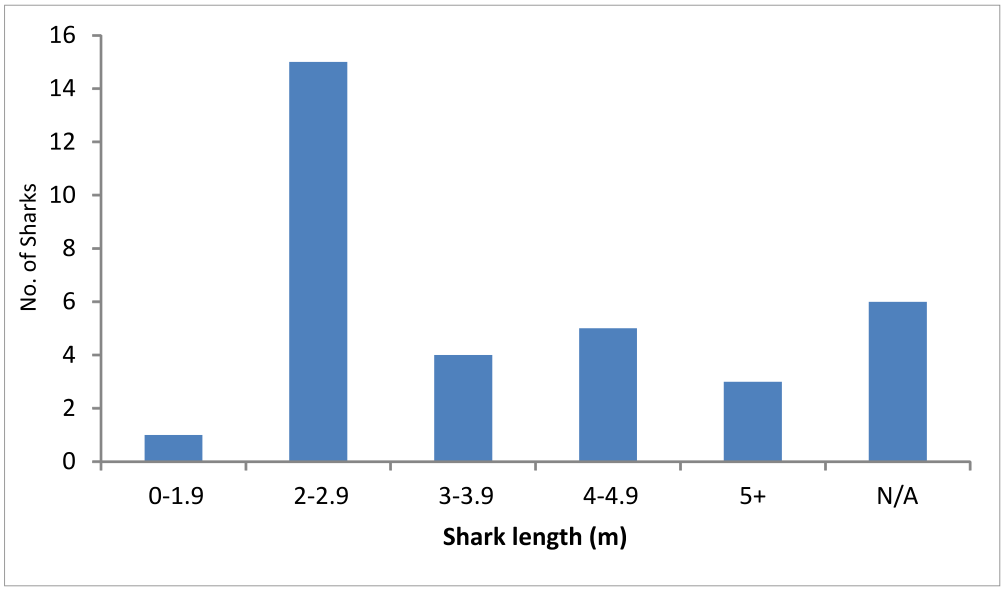

Figure 3-2 Frequency of occurrence of shark sizes based on Shark sightings in shire of Busselton from October '13 to April '14

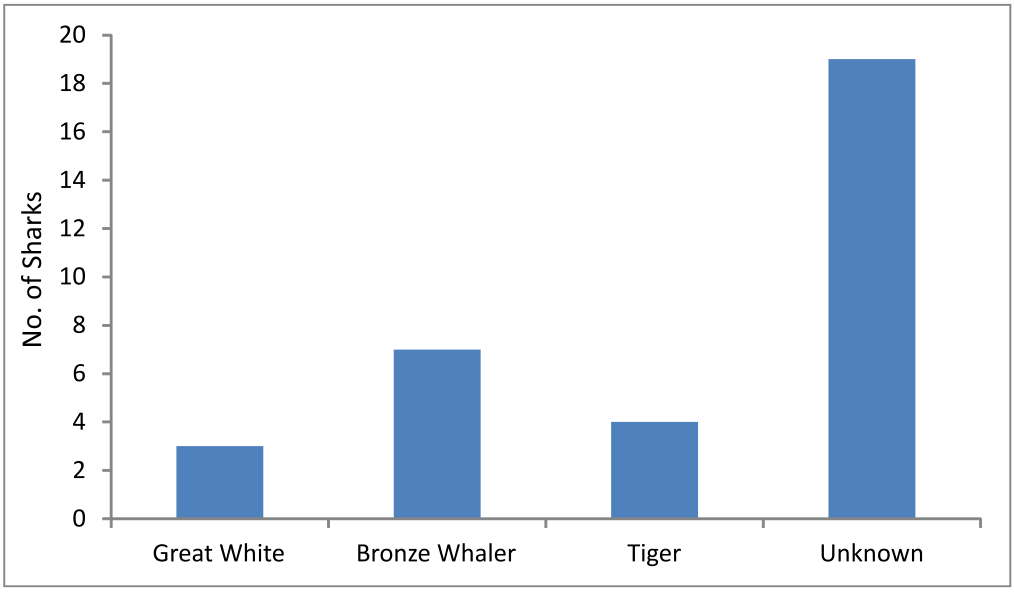

Figure 3-3 Frequency of occurrence of shark species based on Shark sightings in shire of Busselton from October '13 to April '14

A quantitative estimate of the risk of shark attacks given the reported occurrence of shark sightings in the area is not feasible in this context as the current knowledge regarding shark foraging behaviour and population size is not sufficient. However, data does clearly demonstrate that sharks are present in the area and that they are large enough to pose a risk to water users. The shark net does therefore provide a guaranteed safe enclosure in which bathers can enter the water knowing they are safe for shark attack. It also provides beach users with the choice to enter the water at a safe location alternative to a beach where there is no protection.

The peace-of-mind and feeling of safety when entering the water within the Dunsborough beach enclosure is exemplified by comments recorded by the public (below) which help to demonstrate the social benefits of introducing the system.

"*My family and I stayed in Dunsborough recently and swam in the Dunsborough Beach Enclosure and were all very impressed. Great feeling of safety from sharks... making it a very relaxed swim. I wish more popular beaches were able to install these enclosures. Hopefully the net will stay there permanently in Dunsborough.*"- Leanne Groser

"*I would like to comment on the shark net that is on the Dunsborough beach. I was recently holidaying at Dunsborough with a group of friends and was hesitant to go into the water because of the recent attacks by sharks. As soon as we saw the bay with the net we went in and enjoyed our swim so much having great peace of mind. It made a huge difference to our holiday in Dunsborough. Great initiative , there should be more of them along our coast especially in the metro area.*"- Molly Alchin

During maintenance and inspection, data regarding the number of swimmers utilising the beach enclosure were recorded by city of Busselton staff (Figure 3-4). The data show initially high numbers of users dwindling towards the end of the deployment period. It should be noted that the surveys were not taken on the same day each time or at the same time of day and therefore some of the fluctuation in numbers is likely due to increased usage at weekends, during school holidays and around the middle of the day.

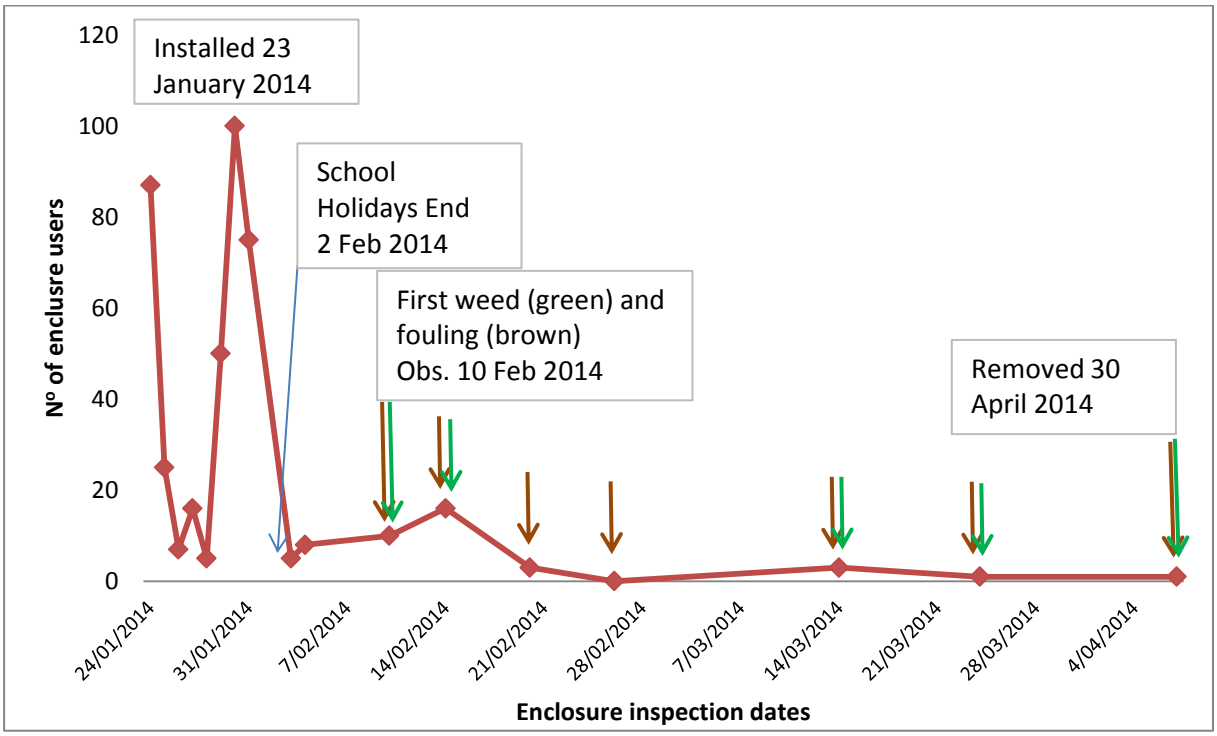

Figure 3-4 Usage of the Dunsborough beach enclosure from January to April 2014

3.1 Local government support

Feedback on the success of the Dunsborough Beach Enclosure Trial was obtained from the City of Busselton councillors through a brief questionnaire. In addition to general comments, the following questions were asked.

Q.1 - How do you feel about the cost of the beach enclosure trial in relation to the benefits obtained?

Q.2 - How do you feel about the management effort required in relation to the benefits obtained?

Q.3 - In general, would you support an ongoing deployment of a similar beach enclosure?

Q.4 - What were your overall impressions of the trial?

The majority (five of the eight councillors) were available to respond including Mayor Ian Stubbs. Overall the local government feedback was positive and ongoing deployment of the beach enclosure or a similar structure was supported. Specific feedback comments were as follows:

"*After a number of fatal shark attacks in the region people were reluctant to venture in the water down here. The barrier obviously gave people more confidence as the area was well utilised. I don't know how it would work elsewhere, as the current spot being a cove was ideal for the trial.*" Councillor R. Bennett (email cons. 26/08/2014).

"While I am sure it gave some comfort to the swimmers using the area, it does not seem practicable to provide enclosures at all swimming areas frequented by sharks so I am unsure what has really been gained from the trial." Mayor I. Stubbs (email cons. 27/08/2014).

"*Many residents were very appreciative of the enclosure; those who like swimming laps and those with children. I understand that both Primary Schools either have or are considering using the enclosed area for student swimming lessons thus saving them the turnaround time and transport costs of getting the students and staff to the Busselton based Geographe Leisure Centre pool. Dunsborough has no public swimming pool and this shark barrier provides a safer and cost effective alternative."* Councillor J. McCallum (email cons. 26/08/2014).

"*I would like to see this trial continued and extended to other areas in Busselton as this a major tourist* [magnet]." Councillor T. Best (email cons. 26/08/2014).

"*This has my support as I feel many people, local community and those holidaying in Dunsborough felt more secure with the enclosure. Also a great advantage to the schools locally as they do not have to bus the children into Busselton GLC, for swimming lessons, saving at least an hour travelling time. All round a good outcome."* Councillor C. Tarbotton (email cons. 1/09/2014).

Figure 3-5 summarises the questionnaire results.

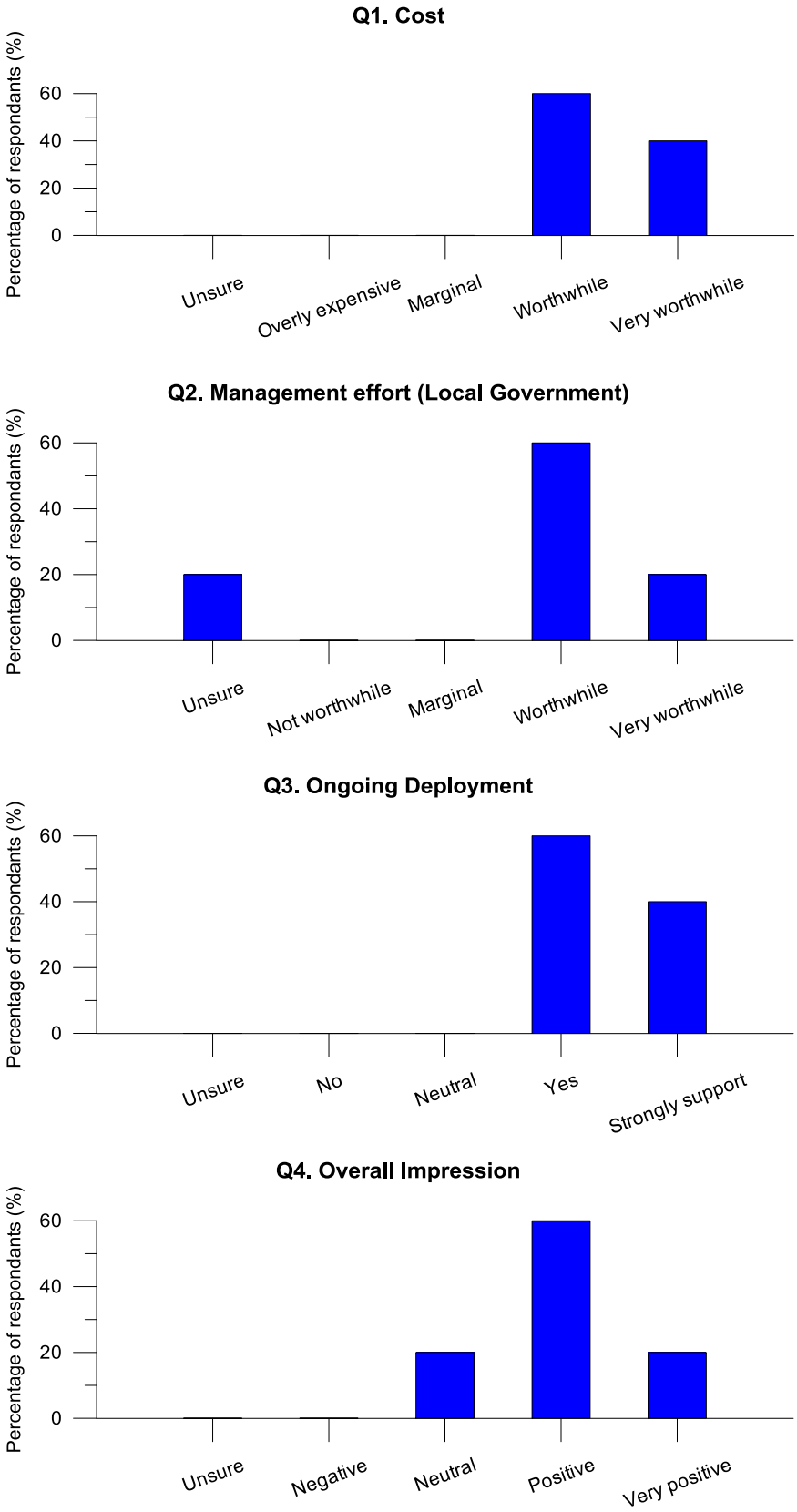

Figure 3-5 City of Busselton Councillor feedback on the Dunsborough Beach Enclosure Trial

4 LOCATIONS FOR ADDITIONAL ENCLOSURES

4.1 Beach usage

The beaches at Bunker Bay, Meelup, Smiths, Yallingup and Busselton are patrolled by life guards that collect beach usage data that provides useful information regarding the positioning of potential enclosures. During the 2013-14 season beach usage was greatest between 10am and 2pm with a maximum average hourly attendance of 407 at Yallingup, 338 at Smiths, 230 and Meelup and 156 at Bunker bay (SLSWA, 2014).

A study on beach usage by Blackweir and Beckley (2004) showed that approximately half the total beach user population in Perth's metro region (Avalon to Two Rocks) was concentrated at Scarborough, Trigg, North Cottesloe, Cottesloe, Port and City beaches. North Mulalloo, Mindarie, Scarborough, Trigg and Secret Harbour were the most popular locations for board riding. Swimming was the most popular water based activity at all monitored beaches except for North Beach, Trigg, Scarborough, Brighton and Secret harbour where board-riding was the most important.

Elliot *et al.* (2005) conducted a survey of beach usage in the metropolitan area which identified Hillarys boat harbour, Scarborough Beach, Cottesloe Beach and Mullaloo Beach as the four beaches with the highest number of attendees during the survey period (Table 1-1).

Table 4-1 Numbers of beach attendees according to aerial surveys conducted by Elliot *et al.* (2005)

Beach Names	5-Mar-05	9-Mar-05	Total
Hillarys Boat Harbour	217	172	389
Scarborough Beach	180	150	330
Cottesloe Beach	206	118	324
Mullaloo Beach	226	96	322
Rockingham Beach	202	75	277
City Beach	139	108	247
Whitfords Beach	132	112	244
Mettams Pool	130	79	209
Peasholm Street	79	90	169
South Beach	78	81	159
Yanchep Lagoon	90	68	158
Shoalwater Bay	50	78	128
Challenger Beach	57	22	79
Secret Harbour	35	42	77
Total	1821	1291	3112

The maximum number of attendees viewed at each beach by Surf Life Saving WA as reported by Elliot *et al.* (2005) are listed in Table 4-2 and shows that the Christmas period

received the highest numbers of beach goers with Mullaloo, Cottesloe and Scarborough receiving the most visitors.

Table 4-2 Maximum observed numbers of beach goers as reported by Elliot *et al.* (2005)

Beach		Number of observed people
Mullaloo	6-Mar-00	20,000
Mullaloo	27-Dec-99	18,000
Mullaloo	26-Dec-00	18,000
Cottesloe	25-Dec-99	11,000
Mullaloo	25-Dec-02	10,500
Mullaloo	26-Jan-01	10,150
Cottesloe	26-Dec-02	10,000
Port	4-Mar-01	9,900
Scarborough	27-Dec-99	9,000
Scarborough North	2-Mar-03	8,550
Cottesloe	22-Nov-03	8,500
Port	7-Dec-03	8,475
Mullaloo	24-Jan-99	8,400
Mullaloo	9-Feb-03	8,100
Port	26-Dec-03	7,920

Surf Life Saving Western Australia provided hourly head counts of beach goers at patrolled beaches throughout the state during the 2013-14 season. The mean number of beach goers was calculated at each beach by dividing the total number of counts by the number of patrolled hours and is presented in Figure 4-1. The top 5 busiest beaches during this period were identified as Cottesloe, Scarborough, Hillarys marina, Mullaloo and Fremantle.

A review of the VacSwim program (Government of Western Australia swimming lesson program) has indicated that the vast majority of locations used for training are in swimming pools. However, a "surf" program is offered as part of the summer training (January) which includes beaches listed in Table 4-3. It is probable that the peace-of-mind generated by the presence of a beach enclosure, such as that trialled at Dunsborough, would provide additional comfort to those learning to swim and to parents placing their children in the VacSwim "surf" program.

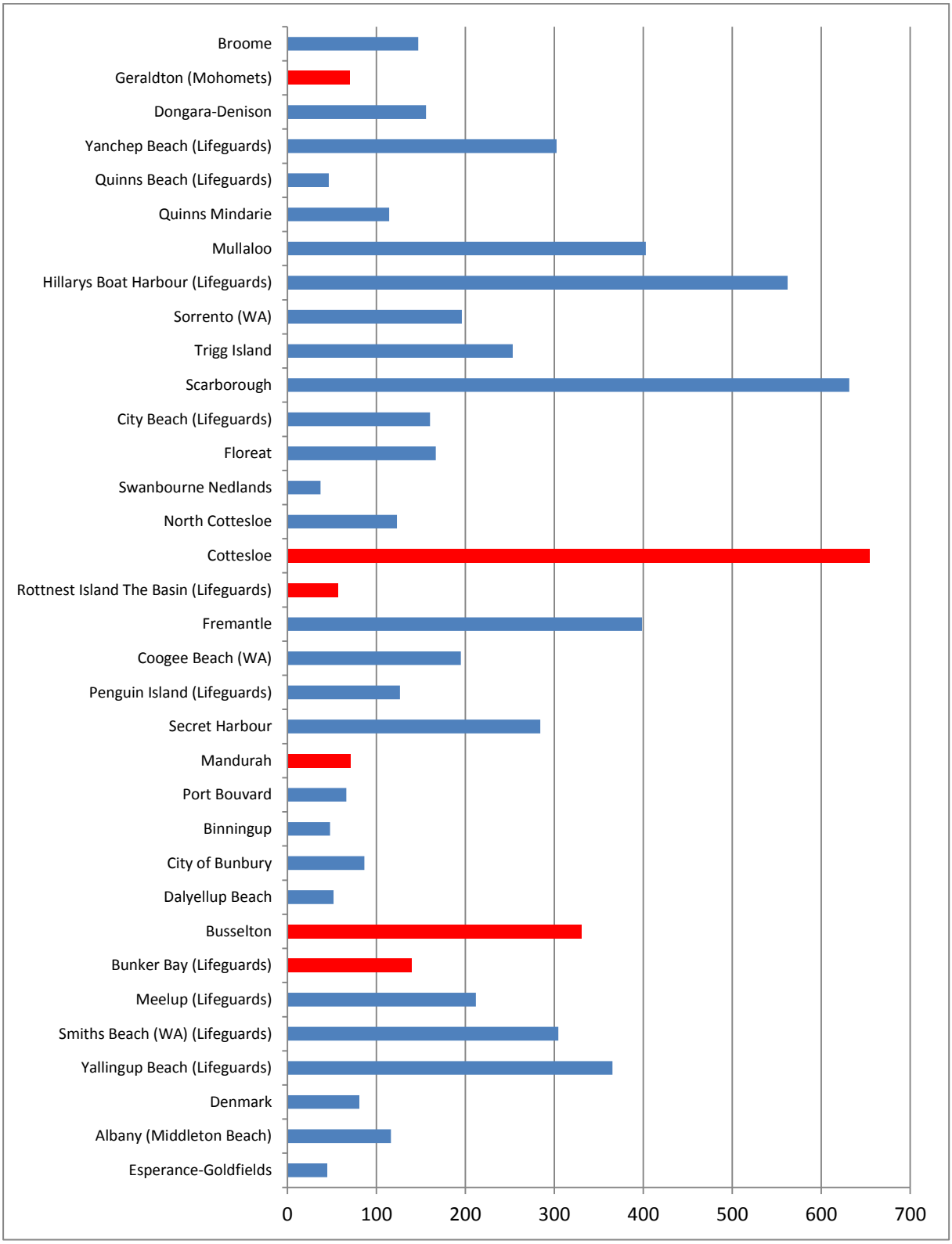

Figure 4-1 Mean number of beach goers at Western Australian beaches patrolled by Surf Life Saving Western Australia's life guards. Red fill indicates beaches where fatal attacks have occurred.

Table 4-3 VacSwim "Surf" locations in Western Australia

Perth Metropolitan Area	Country Areas
Coogee Beach	Albany – Middleton Beach – Ellen Cove
Cottesloe Beach	Binningup Beach
Leighton Beach	Bunbury Back Beach
Mettams Pool	Dawesville - Pyramid's Beach
Mullaloo Beach	Geraldton Back Beach
Quinns Beach	Hamelin Bay
Sorrento Beach	Kalbarri Beach
Waikiki Beach	Lancelin Beach
Watermans Beach	Ledge Point Beach
Yanchep Lagoon	Leeman Beach
	Mandurah – Doddies Beach
	Margaret River (Gnarabup Beach)
	Moore River Beach
	Yallingup Beach

4.2 Coastal and oceanographic conditions

Beach enclosures, unlike bottom or surface set nets, are deployed to create an impenetrable barrier to sharks and therefore must be installed in the surf zone and extend all the way to the high tide mark. Naturally, this means that the installation of beach enclosures in areas where there is a large tidal range and/or significant levels of dissipating surf pose a significant engineering challenge and thus sheltered beaches in areas of little tidal range provide ideal locations for beach enclosure installation. Enclosures can and have (see Hong Kong beach enclosures in Appendix 1) been designed and implemented to withstand large storm surges and are simply built to more robust design standards than those installed at Dunsborough and are therefore likely to be more expensive.

Table 4-4 summarises the conditions at beaches throughout WA where beach enclosures could be potentially installed. These locations were qualitatively assessed based on three criteria; tidal height, beach usage and wave exposure. Locations with larger tidal ranges were deemed less suitable as the change in water level complicates the design criteria at that location. Locations with high beach usage were favoured as installations at such locations have the potential to benefit a larger number of people. Based on available satellite imagery, bathymetry, wave prediction models and prevailing wind information, a qualitative assessment was made of locations that received adequate shelter from wind waves and swell and thus were suitable for the installation of potential beach enclosures. Colour coding of the table refers to the relative suitability of the location for beach enclosure installation with green shading representing favourable conditions, amber representing marginal conditions and red representing adverse conditions.

Table 4-4 Potential locations for beach enclosures on the West Australian coastline. Usage ranking based on Surf Life Saving WA 2013-14 season. Green highlighting indicates good suitability for installation, orange indicates potentially suitable conditions, red indicates less than adequate suitability.

Location	Usage	Tide range	Wave exposure	Conclusion
Broome	18/34	Large >5m	Moderate. Dry season receives low wave action wet season can receive storm surf from cyclones.	Busy tourist area in dry season. Would provide bathers with crocodile and shark protection. Logistical/engineering issues to overcome tide and wave action.
Exmouth	NA	Medium <2.5m	Low. Sheltered from ocean swell and short wind swell fetch length.	Physical conditions favourable for installation, low local population and thus limited public benefit.
Shark Bay (Monkey Mia, Denham etc.)	NA	Low 1m	Low. Sheltered from ocean swell and short wind swell fetch length.	Physical conditions favourable for installation, low local population and thus limited public benefit.
Geraldton	27/34	Low. c 1m	Some sheltered beaches protected from swell and seabreeze that would suit installation.	Physical conditions favourable for installation. Significant local population, shark attacks have occurred in the area.
Lancelin	NA	Low. c 1m	Protected lagoon, no swell or wind chop	Physical conditions favourable for installation. Small local population but popular day trip destination for Perth residents.
Yanchep Lagoon	9/34	Low. c 1m	Protected lagoon, no swell or wind chop	Physical conditions favourable for installation. High level of visitors and significant public benefit. Potential environmental implications of netting across entrance to lagoon
Hillarys Boat Harbour	3/34	Low. c 1m	Protected water body within marina	Ideal physical conditions, one of Perth's busiest beach locations suggesting greatest

Location	Usage	Tide range	Wave exposure	Conclusion
				level of public benefit. Easy to install netting given existing promenade. Unlikely interference with other water users.
Cottesloe Beach (in front of Indiana Tea Rooms)	1/34	Low. c 1m	Calm during summer, some protection provided by groin/sea wall. Receives significant swell during winter, popular surf spot.	Conditions favourable during summer months due to sea wall shelter. Winter months receives significant swell. Potential stakeholder conflict as popular surf spot during winter and entrance/egress for Cottesloe Surf Lifesaving Club watercraft. Perth's busiest and most iconic beach also the location for two fatal shark attacks. Potential for limited net deployment e.g. Dec-Feb.
Rottnest Island	29/34	Low. c 1m	The north-east side of the island is sheltered from swells and sea breeze but exposed from easterly and northerly wind and swell (rare).	Favourable conditions during summer months. Rottnest is a popular tourist attraction for Perth locals, interstate and international visitors. A fatal attack on the north side of the island highlights the potential risk to water users.
Fremantle Bathers Bay	5/34	Low. c 1m	Calm Year round, rarely receives any form of breaking wave even in winter.	Ideal Physical conditions for installation. Fremantle is one of Perth's major recreational destinations and so provides significant public benefit. Beach is well protected from the environment. Can receive significant amounts of wrack deposits.
Fremantle south Beach	5/34	Low. c 1m	Calm Year round, rarely receives any form of breaking wave even in winter.	Ideal Physical conditions for installation. Fremantle is one of Perth's major recreational destinations and so provides significant public benefit. Beach

Location	Usage	Tide range	Wave exposure	Conclusion
				is slightly less protected than Bathers Bay, similar to Coogee.
Coogee	14/34	Low. c 1m	Calm Year round, rarely receives any form of breaking wave even in winter.	Successful trial installation, see review.
Point Perron, Safety bay, Penguin Island	20/34	Low. c 1m	Potential for location sheltered from wind/wave action due to coastal morphology.	Potential for suitable location, close to Perth and southern suburbs to benefit large populous. Shark attacks have occurred locally.
Mandurah Marina breakwater	26/34	Low. c 1m	Potential for location sheltered from wind/wave action due to coastal morphology and Marina breakwater wall.	Potential for suitable location, close to Perth and southern suburbs to benefit large populous. Shark attacks have occurred locally.
Busselton area	7/34	Low. c 1m	Somewhat sheltered due to position in Geographe Bay.	Probably limited by wave action to summer months. High level of beach visitation indicating significant public benefit. Existing structures that could aid installation (walkway and jetty).
Meelup	12/34	Low. c 1m	Situated on eastern side of Cape Naturalist, sheltered from westerly swells and sea breeze.	Receives surf during large winter swells but would be well suited to net deployment during calm summer months. Popular swimming beach with local populous, Perth, interstate and international visitors.
Eagle Bay	NA	Low. c 1m	Situated on eastern side of Cape Naturalist, sheltered from westerly swells and sea breeze.	Receives surf during large winter swells but would be well suited to net deployment during calm summer months. Popular swimming beach with local populous, Perth, interstate and international visitors.

Location	Usage	Tide range	Wave exposure	Conclusion
Bunker Bay (north west)	19/34	Low. c 1m	Situated on eastern side of Cape Naturalist, sheltered from westerly swells and sea breeze.	Receives more surf than Meelup and Eagle Bay but still usually only during large winter swells especially the north-western end. The South eastern end is popular with surfers and is the location of a recent fatal shark attack. Popular swimming beach with local populous, Perth, interstate and international visitors.
Gracetown	NA	Low. c 1m	The headlands of Gracetown bay receive considerable surf however a bathers beach with a swimming pontoon exists in the apex of the bay and receives little wave action and is also protected from sea-breeze windswell.	One of the few west facing locations in the capes region that receives enough shelter from wave and wind action to be considered a potential beach enclosure site. Popular with capes region tourists and locals. Gracetown area has been the location for three recent fatal attacks.
Middleton Beach	33/34	Low. c 1m	Situated in King George Sound providing shelter from ocean swells. Some limited exposure to easterly wind swells during summer.	King George Sound provides shelter from wave and wind action making conditions favourable for net deployment. Would provide town of Albany, surrounding region and visiting tourists with safe swimming.
Esperance yacht club	34/34	Low. c 1m	Situated in Esperance Bay and sheltered from ocean swells. Port development and yacht club provide shelter from easterly wind swell.	Provides safe swimming for Esperance-Goldfields populous and visiting tourists. Well protected site with low wave action. Potential risk of fouling due to wrack accumulation.

4.3 Shark abundance, distribution and risk of attack

The most reliable record of shark sightings in the Perth metropolitan area and the South-West is that obtained by aerial surveys conducted by Surf Life Saving Western Australia (SLSWA). The results for the 2013/14 survey period have been used in this review.

In the Perth metropolitan area, the coastline north of the Swan River between Trigg and Fremantle recorded the highest frequency of Great White shark sightings (Figure 4-2) as well as the total number of sighting of sharks of all species (Figure 4-3). Great White shark sightings were less clustered in the South-west (Figure 4-4) with total shark sightings (all species) being more prevalent along the north-eastern coast of Cape Naturaliste (Figure 4-5). With respect to Great White sightings, and shark sightings in general, the Dunsborough beach enclosure trial location could be considered in a higher risk area. While the recent Western Australian shark attack locations have also included surf breaks between the Capes (Leeuwin and Naturaliste), it is unlikely that the type of enclosure trialled at Dunsborough would be suitable to provide protection to these more off-shore (surfing/diving) locations.

The distribution of shark sightings along the Perth metropolitan coastline would suggest that the northern beaches between Fremantle and Trigg would provide the highest risk of near-shore shark interactions and therefore the most suitable locations for beach enclosures. Similarly, the eastern shoreline of Cape Naturaliste through to Busselton would also be suitable in this regard. However, as peace-of-mind is a significant aspect of the benefits of these enclosures (as opposed to direct shark attack mitigation), it could be argued that the number of people using any particular beach is at least as important as the risk of shark interactions in locating an enclosure.

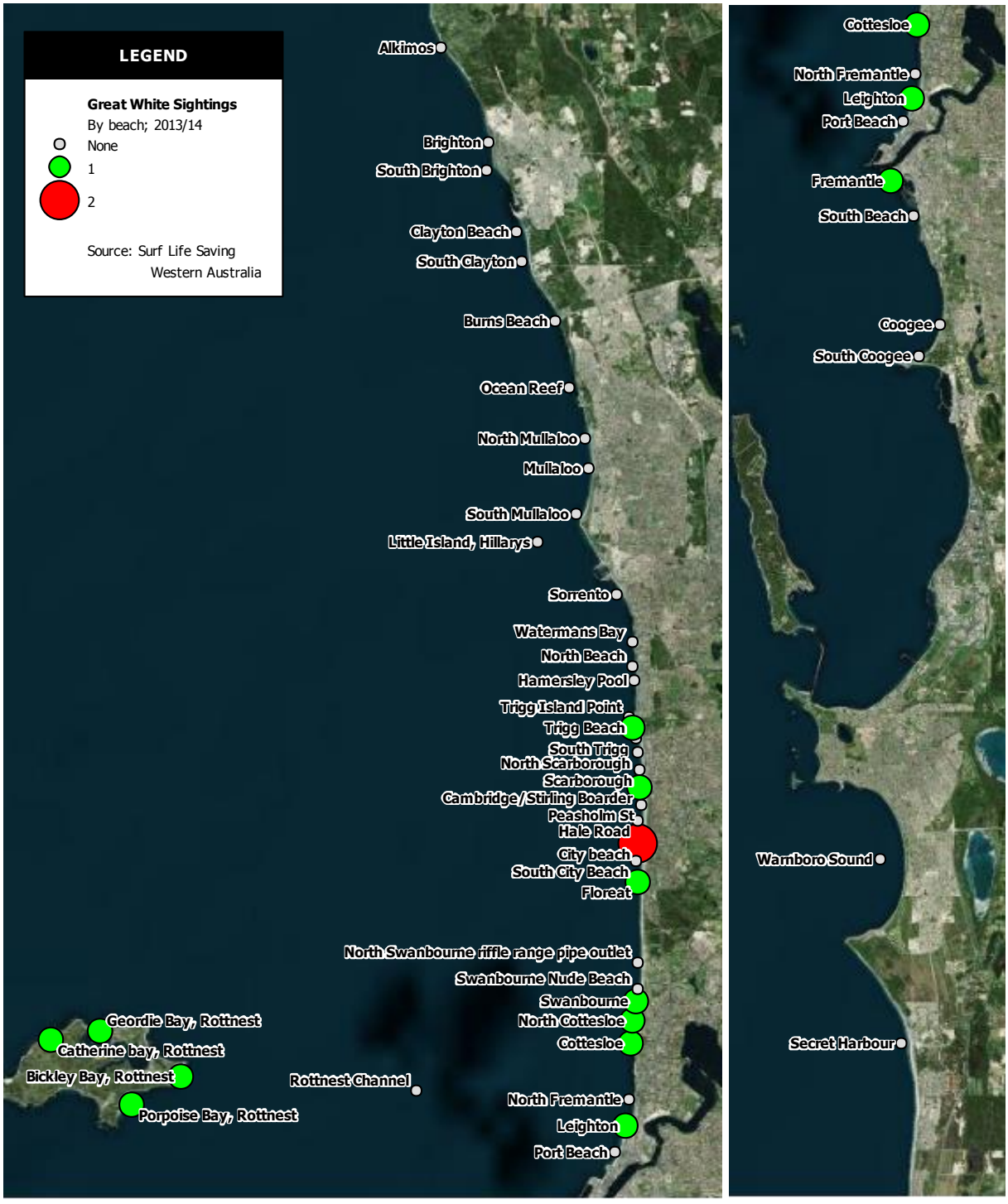

Figure 4-2 Perth area Great White shark sightings – 2013/14 (Source: SLSWA)

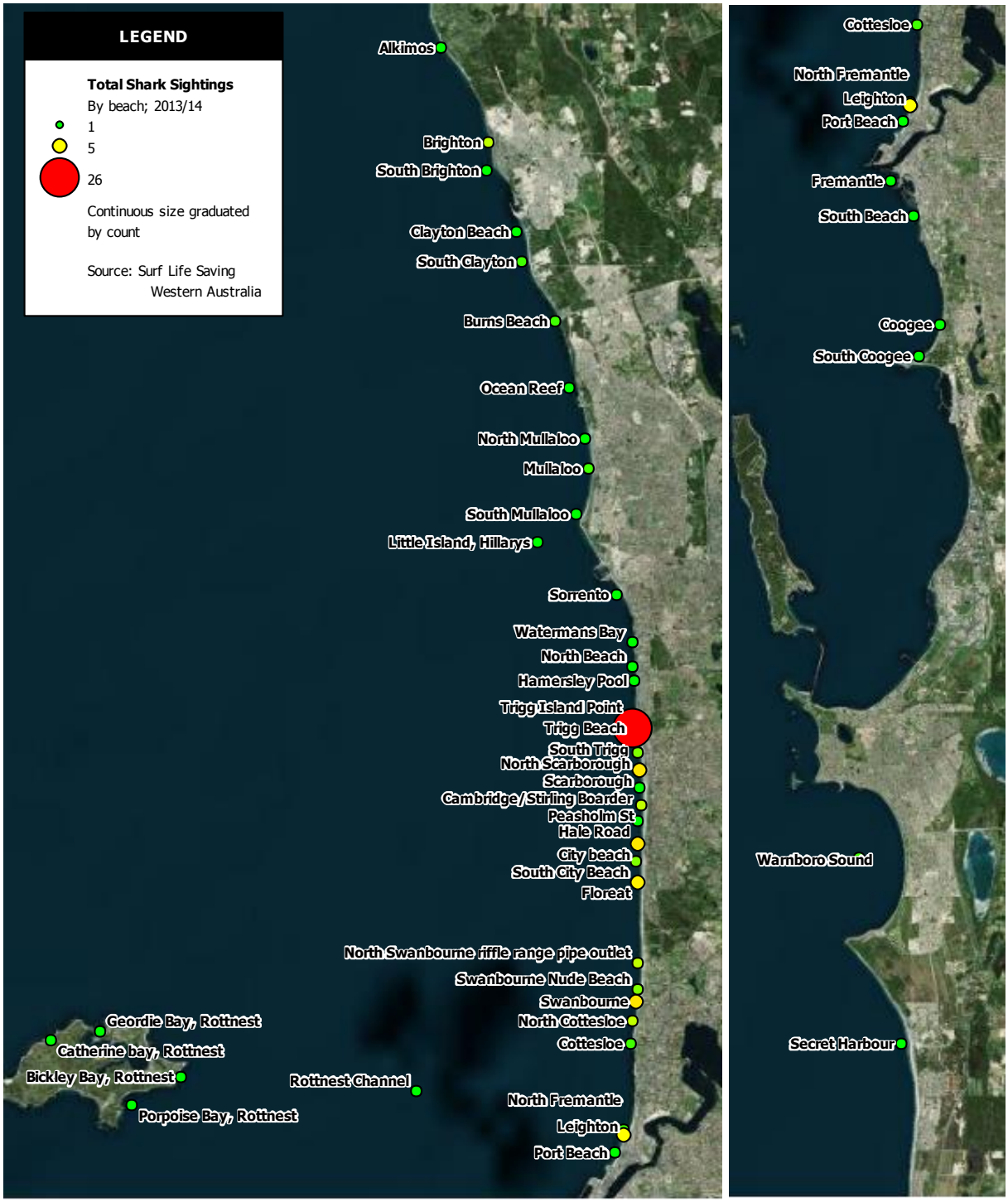

Figure 4-3 Perth area total shark sightings – 2013/14 (Source: SLSWA)

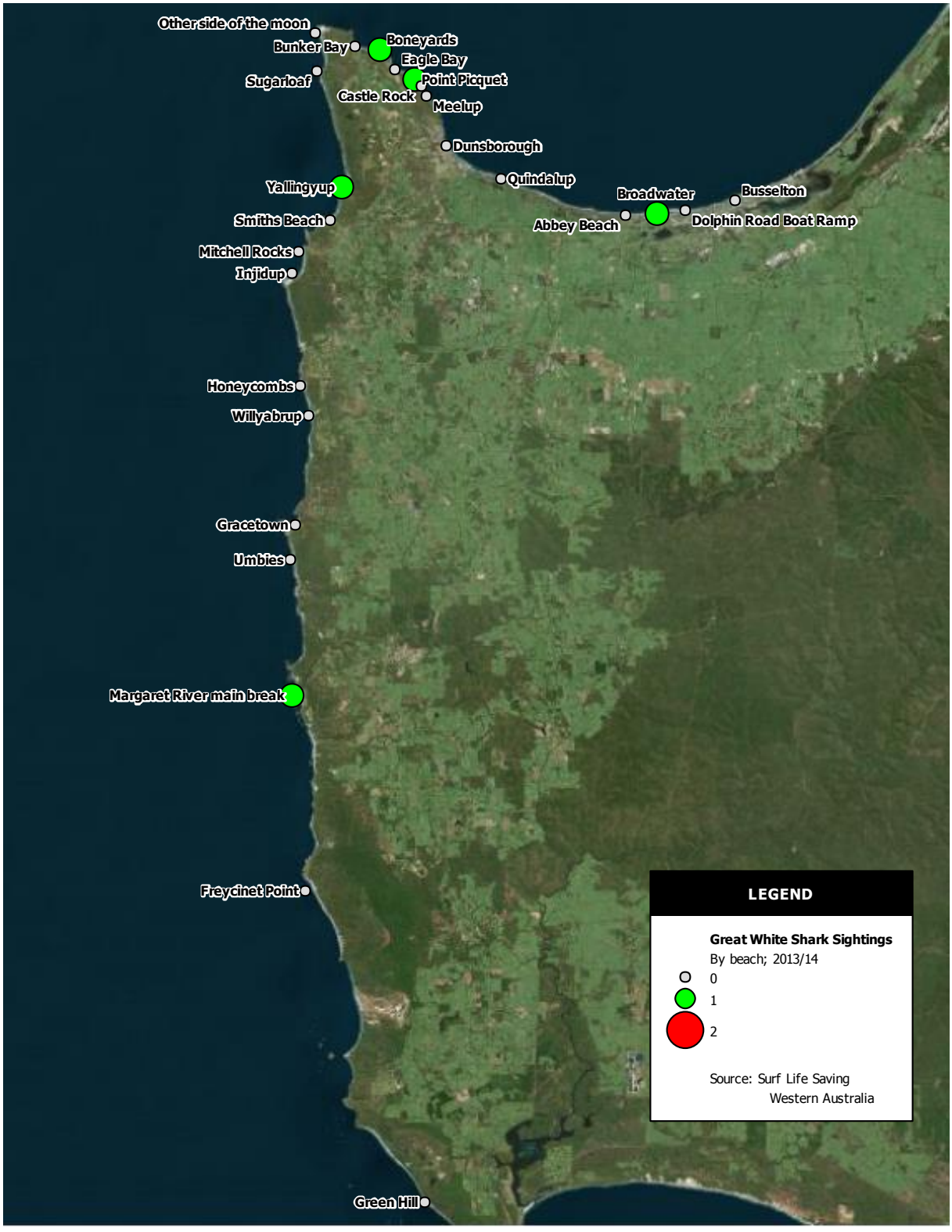

Figure 4-4 South-west area Great White shark sightings – 2013/14 (Source: SLSWA)

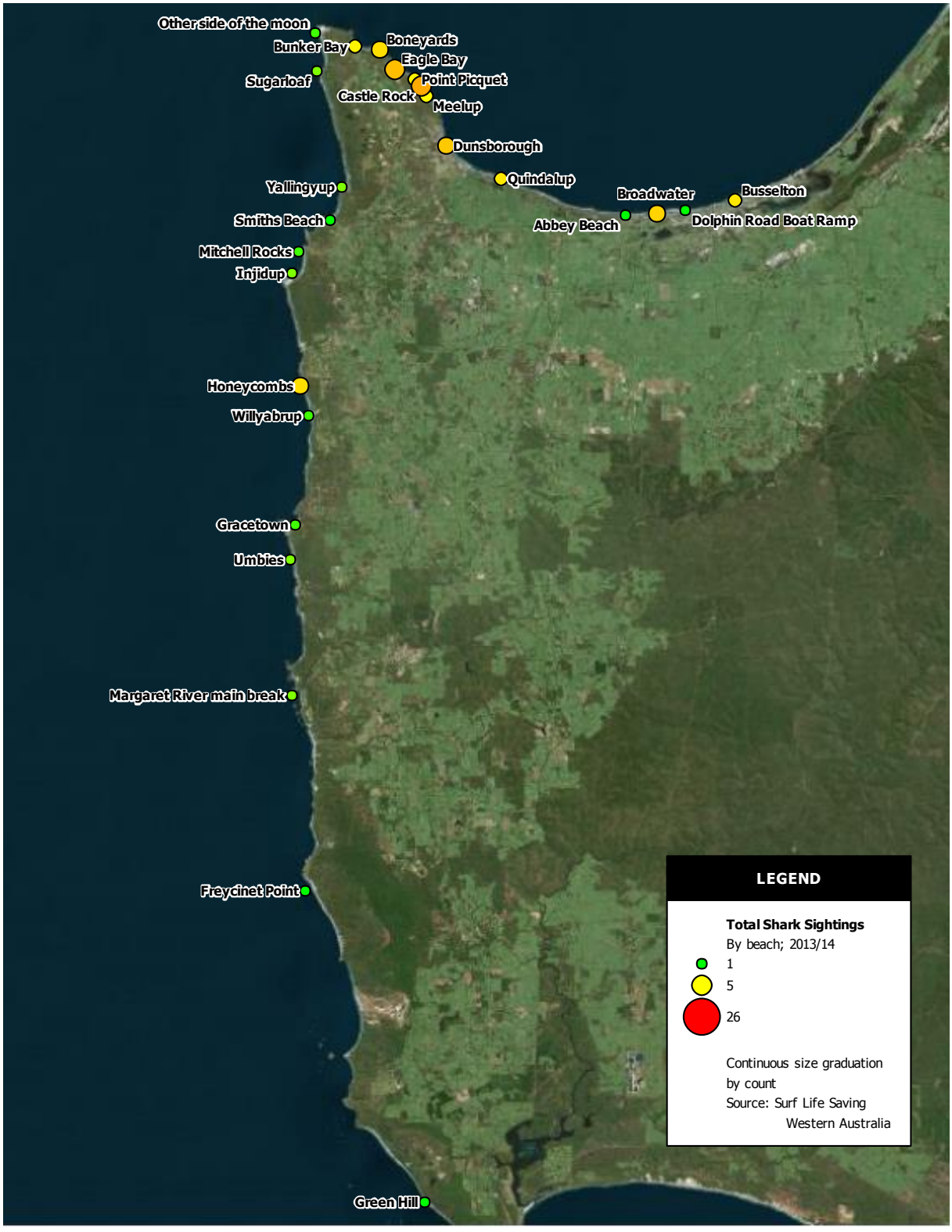

Figure 4-5 South-west area total shark sightings – 2013/14 (Source: SLSWA)

A recent study of the risk of shark attack in Western Australia (Sprivulis 2014) found the following points:

- Swimming offshore (greater than 5 m depth, 50 m offshore) is 50 times more likely to result in a shark bite than shallower water closer to shore;
- Shark attack risk was benchmarked against risk of death as a result of recreational cycling. Swimming at metro beaches during summer is *c.*50 x safer than recreational cycling;
- Death by shark attack during coastal water usage (excluding offshore diving) is roughly of similar risk to death due to cycling accident;
- Two thirds of all attacks occurred during winter/spring, half during spring coinciding with whale migration;
- There has been an exponential increase in shark attack risk over 10 years;
- No great white attacks occurred in water greater than 22 degrees c. or north of latitude 30.5° (Wedge Island); and
- Risk modelling predicts 1 shark bite per 53 million metro beach swimming events through to 1 shark bite occurring per 40 thousand offshore scuba diving events in the South-west region.

In addition, a recent Department of Fisheries (Western Australia) study found that risk of attack from Great White shakes is greater more than 30 m from shore, in water less than 20°C, deeper than 5 m and near whale carcasses and Sea Lion colonies (DoF 2012).

5 SUMMARY AND RECOMENDATIONS

The Dunsborough beach enclosure was successful in three main aspects. Firstly it was able to provide a barrier that protected swimmers from potential interactions with sharks and thus provided the public with the option to swim in an area where they could maintain peace-of-mind that they are safe from shark attack. Secondly, the enclosure maintained structural integrity throughout the trial period with only minor maintenance required in order to maintain the effective barrier. Thirdly the enclosure system did not become overwhelmed by wrack or bio-fouling inundation nor were any marine fauna entrapped of injured during its deployment. The installation did not result in any recorded incidents of interactions or accidents with boat traffic or other water users such as kite-surfers, windsurfers, kayak users or other small watercraft. Although the enclosure is unable, in its present design iterations, to protect surfers or divers from shark attack it does, so long as it is adequately maintained, provide guaranteed protection from shark attack for swimmers where as other shark mitigation systems are only able to reduce the risk of such occurrences.

Public opinion on the system as a method of providing protection from shark attacks, based on the Dunsborough installation and the Coogee trial was overwhelmingly positive and many interviewees posed the question of why the enclosures were not being instigated throughout the State. This included the operators of the trial (City of Busselton) with canvassing of the local government councillors indicating an overall positive response.

Much of the central and southern coastline of Western Australia, the most populated area, has a low tidal range which is ideal for installation of beach enclosures. This aspect, coupled with coastal geomorphology and oceanography that results in many stretches of coast receiving protection from prevailing swell and wind either by headlands and embayment's or offshore reefs, means that there are many locations that would facilitate the construction of further beach enclosure without initiating significant engineering works.

Current developments in shark barrier technology pioneered by Western Australian companies are in their infancy but show potential for innovations that may result in shark barrier design allowing for installations in areas with higher levels of tide and wave dynamics.

The points summarised above coupled with the relatively small cost involved with construction and maintenance of beach enclosures at Dunsborough suggests that the system provides a robust, repeatable, environmentally defensible and publically well received solution to water safety that could have significant benefits if implemented at further locations around Western Australia.

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APPENDIX 1 LITERATURE REVIEW - EXISTING BEACH ENCLOSURES AND NETTING PROGRAMES

New South Wales currently nets 51 beaches along it's coastline under its Shark Meshing Program (SMP) which was originally introduced in Sydney in 1937. The New South Wales netting program is fundamentally different from those instigated at Dunsborough in that they act as a method for removing sharks rather than a barrier that prevents those sharks from reaching bathers. The nets function in the same was as commercial gill nets with a mesh size of 50-60cm and are bottom set such that the base of the net rests on the seabed and the top floats 6m above the seabed and approximately 4m below the surface (Figure A1-1; NSWDPI 2009). Sharks are able to swim over the top of the net or around the ends and into beach areas however, the design of the net is such that is difficult to see and mesh and sizes are optimised to allow for a shark to become entangled.

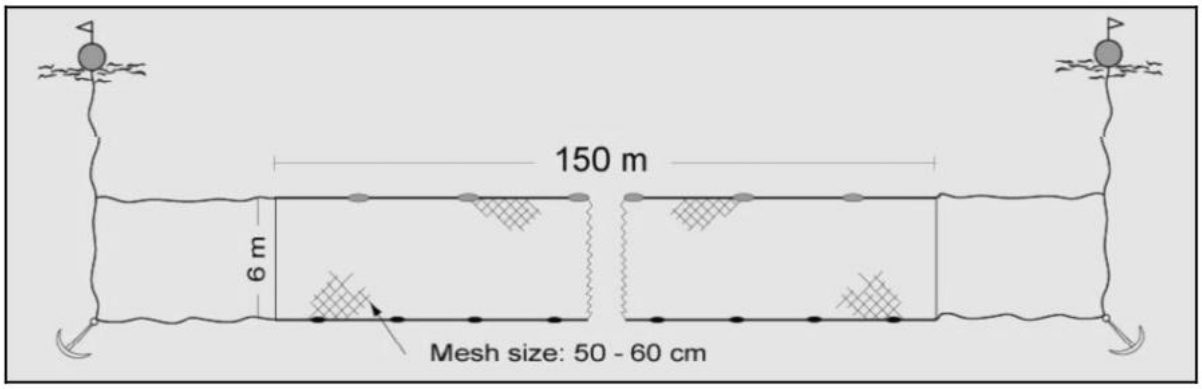


Figure A1-1 Shark mesh configuration employed by NSW Shark Meshing Program (NSWDPI 2009)

As a result of the functionality of bottom-set nets, they are also effective in capturing any animal able to partially fit into a 60x60 cm mesh openings which includes dolphins, small whales, dugongs, turtles and non-target sharks, the SMP program has recently introduced acoustic pingers that reduced dolphin by-catch. The bottom set nets require regular maintenance and must be checked at least every 96 hours which is a labour intensive operation involving lifting the float line to the surface and working along the length of each net in order to identify stranded animals which are then removed.

The NSW SMP does include some shark barrier nets like those trialled at Dunsborough however they are only installed in areas of little to no wave action (Sydney Harbour) but do offer a guaranteed exclusion of sharks and do not cause unwanted by-catch.

Bottom set netting has been implemented in New Zealand since 1969 at St Clair, St Kildas and Brighton beaches. The nets were 100m long and 5.5m high, since the beginning of record keeping in 1986 no great whites were caught nor were any other dangerous species although some great whites were reportedly caught in the 1970's.

Shark barrier nets were installed at 17 beaches in Hong Kong from 1993 onwards and were designed to prevent interactions between swimmers and sharks. The structures were heavily weighted to ensure no movement due to wave action and were designed to withstand typhoon wave conditions of up to 10m (Figure A1-2). During periods of high wave action, technical problems were encountered in maintaining nets (NSWDPI 2009).

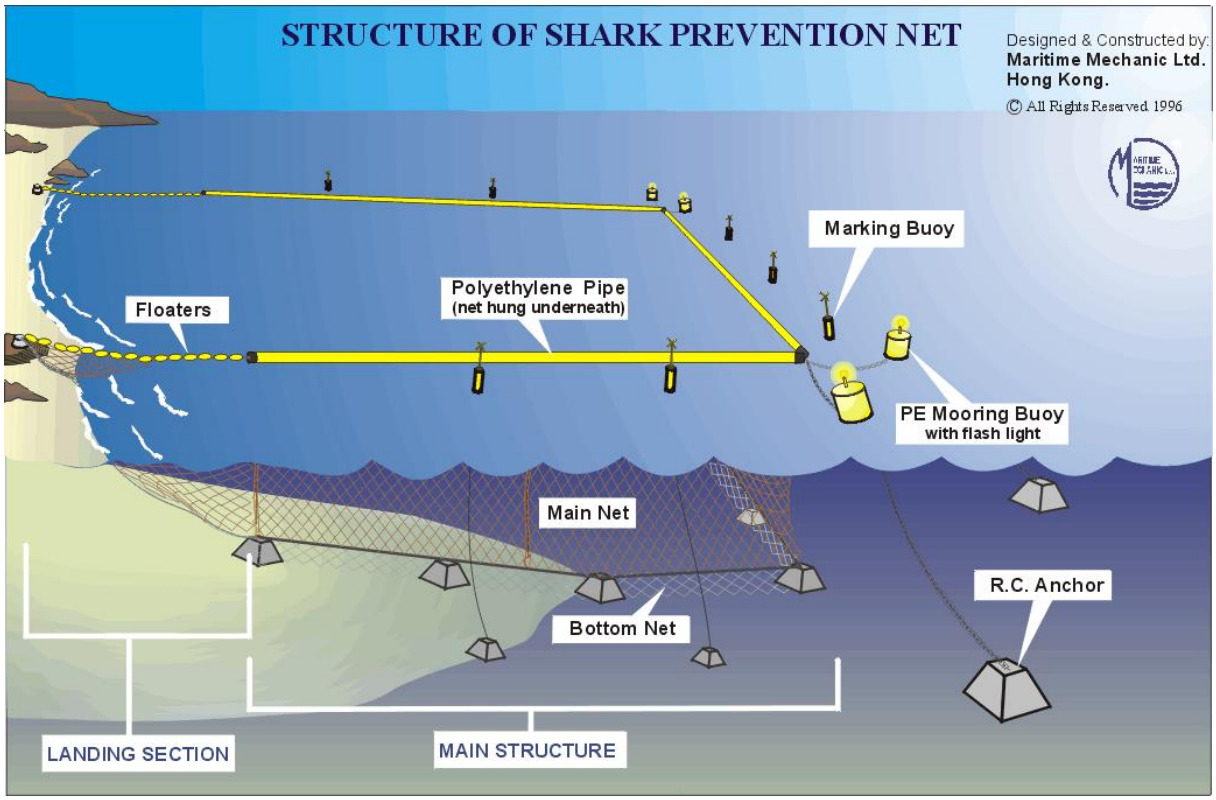


Figure A1-2 Shark exclusion nets installed at 17 Hong Kong beaches designed to withstand 10m cyclone swells

The QSCP consists of 344 baited drum lines and 6.5 km of surface set nets spanning 1,720 km of coastline and 84 beaches (NSWDPI 2009). Significant amounts of by-catch were recorded including humpback wales, turtles, dugongs and other non-target sharks. The combined effect of drum lines and nets allowed a diverse range of coastal environments to be protected accounting for different tidal regimes and coastal morphology.

The KawZulu-Natal shark board formed in 1962 operates combinations of drum line and shark nets at 38 locations along the coastal stretch of 320 km and including 23 km of nets in total (Kwazulu-Natal Sharks Board (2011); Figure A1-3). There are no currently installed beach enclosure nets under this program although plans are underway for an installation at Fish Hoek Bay near Cape Town.

A summary of bather protection methods used by Qld NSW and South Africa is provided in Table A1-1. The direct success of these various mitigation schemes is often difficult to

quantify however shark attacks at protected beaches in NSW have reduced by 62% while they have almost doubled at non protected beaches (NSWDPI 2009).

Table A1-1 Summary of bather protection schemes in Australia and South Africa (NSW DPI 2009)

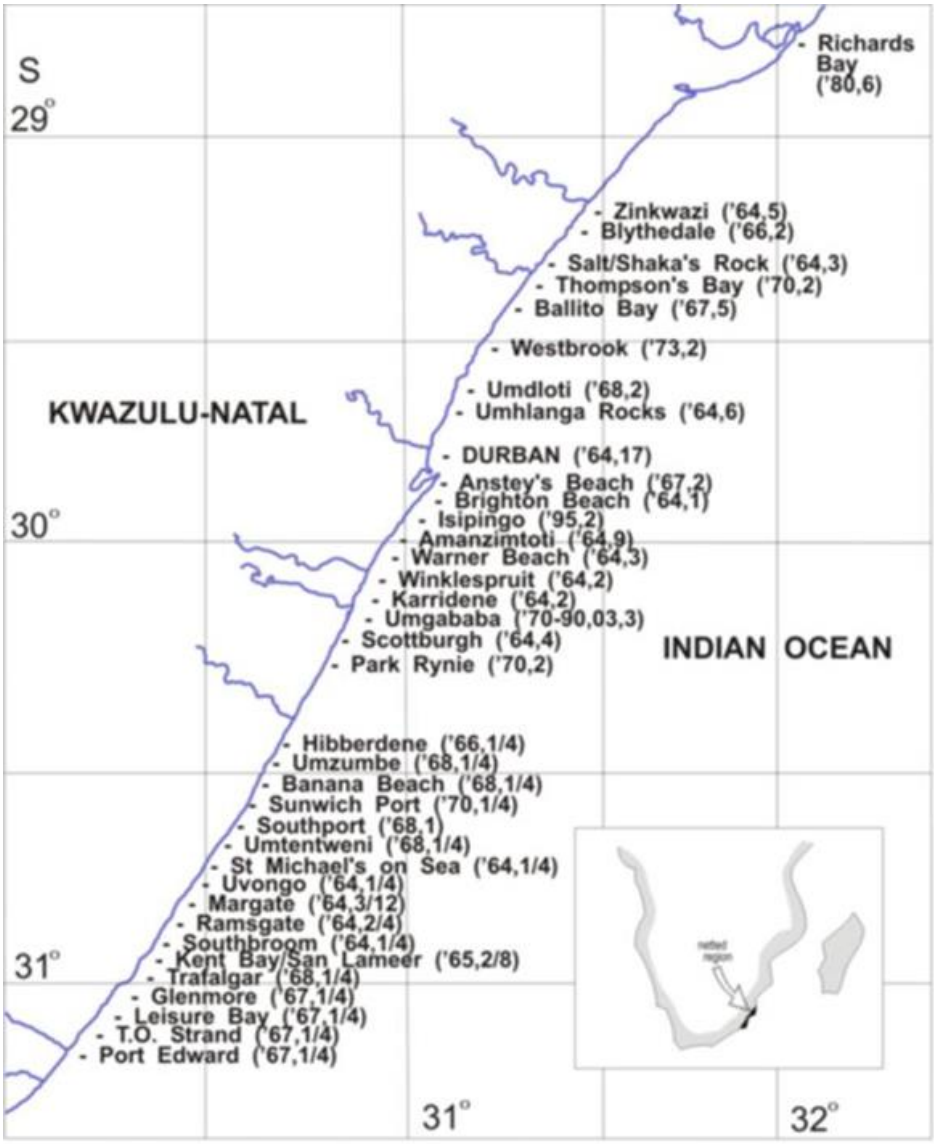
	NSW	Queensland	KwaZulu-Natal
Spatial extent			
Number of beaches	51	84	38
Distance of coastline in program	250 km	1,720 km	320 km
Coverage by nets	Varies - max. 7.65 km	6.5 km	23.4 km
Temporal extent	1 September - 30 April: every weekend; & 9 weekday sets per month per beach	All year	All year, but removed from beaches south of Durban for June-July during the annual sardine run
Methods			
Mesh nets - specifications			
Total number	Varies, maximum 51	35	101
Length	150 m	186 m	most 214 m; 305 m at Durban
Depth	6 m	6 m	6 m
Mesh size	50 - 60 cm	50 cm	51 cm
Hanging coefficient	0.67	unknown	unknown
Distance from shore	~ 500 m	Varies	400 m
Position in water column	Bottom-set	Surface-set	Surface-set
Drumlines - specifications			
Total number	0	344	80
Hook size	n/a	14/0	14/0
Bait type	n/a	Sea mullet & shark	Sea mullet
Bait checking frequency	n/a	daily	unknown
Catch[A] summary			
Annual average number of sharks[B]	143 (1987 - 2007 data)	787 (1987 - 2007 data)	666 (2003 - 2007 data)
Maximum number of sharks & year	234 in 1993/94 (1987-07)	1,063 in 1989/90 (1987-07)	2,272 in 1985 (1964-2003)
Minimum number of sharks & year	76 in 2001/02 (1987-07)	521 in 2003/04 (1987-07)	513 in 2002 (1964-2003)
Annual average number of non-sharks[C]	67 (1995-07)	unknown	433 (2003-07)
Number of reported non-shark groups	7	5	6
Cost	> $800,000	$1.7M in 2004/05	unknown

A - denotes total number of animals caught and is not indicative of mortality or of number of released animals

B - denotes that 'sharks' includes target/dangerous sharks and harmless sharks (e.g. angel sharks), but excludes stingrays

C - stingrays comprise 88% and 59% of non-shark catch in NSW and KwaZulu-Natal, respectively.

(Source: http://www.shark.co.za/statistics.htm; QDPIF 2006; NSW DPI unpub. data; Dudley and Simpfendorfer 2006)



Map of the KwaZulu-Natal coast showing beaches currently protected by nets and drumlines. The first number in parentheses indicates the year of net installation, the second/third indicate the number of nets/drumlines currently used. The total amount of netting is 23.4 km on a 320 km stretch of coast. The inset shows the location of the netted region in southern Africa.

Figure A1-3 Map of the KwaZulu-Natal coast showing beaches currently protected by nets and drumlines (Kwazulu-Natal Sharks Board, 2011)

A1.1 Case study: Coogee Beach

The City of Cockburn installed a shark exclusion barrier at Coogee beach using a similar method to the Dunsborough beach enclosure where a barrier was installed attached to fixed pilings and utilising weighted foot ropes to maintain contact with the seabed and floats at the surface. The system used a new form barrier produced by Eco Shark Barrier Pty Ltd which is constructed using a system of interlocking sections allowing a custom sized net to

be constructed easily for any given water depth and beach profile. The interlocking sections have in-built floatation providing the end structure with its own buoyancy and resultant vertical stability that prevents the base of the net sagging and becoming fouled by benthic detritus. As the structure has wide openings, (30cm), wrack, detached seagrass and other detritus that becomes entrained by near shore currents is able to pass through the large mesh size without it becoming entangled. Normally mesh sizes of 30cm would entangle smaller sharks, dolphins, turtles and large demersal fish species, however the mesh sections in this case are rigid, square structures that are far more visible and, as they do not flex around a potentially entrapped animal, as do normal non-rigid nets, they do not ensnare marine life (Figure A1-4).

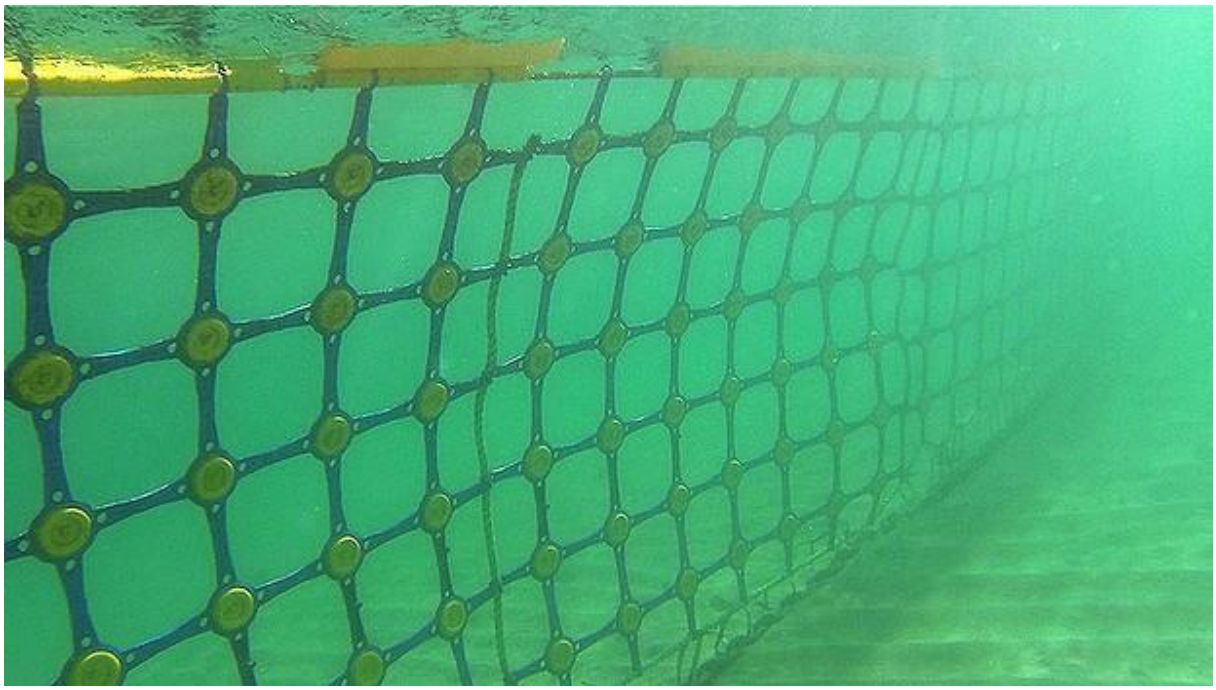


Figure A1-4 Section of interlocking Eco Shark Barrier installed at Coogee beach (WA Today, 2014)

The system does attract marine bio-fouling that grows on the interlocking plastic sections but this did not appear to hinder the performance of the barrier. Accounts from interviews with snorkelers and swimmers by the city council and from footage available on the manufactures website (www.ecosharkbarrier.com.au) also indicates that the system acts as an artificial reef that attracts a range of small demersal fish and invertebrates that provide additional interest to water users. This factor may act as a fouling and performance issue during longer deployments where cleaning is required to ensure structural integrity and facilitate water flow-through.

Form Designs Australia, who were also involved in the development of EcoSharkBarrier have produced an alternative design to the system installed at Coogee that improves the existing system, overcoming some of the issues encountered by the EcoSharkBarrier. The system provides increased flexibility by incorporating hinged panels that allow the barrier to

rise and fall with tide and wave action (Figure A1-5). They also provide greater flexibility between panels by increasing the movement in panel linkages. The structural performance of this system could not be assessed though it is assumed that it would need to be sufficiently engineered to withstand high energy (storm) events and resist destructive fouling.

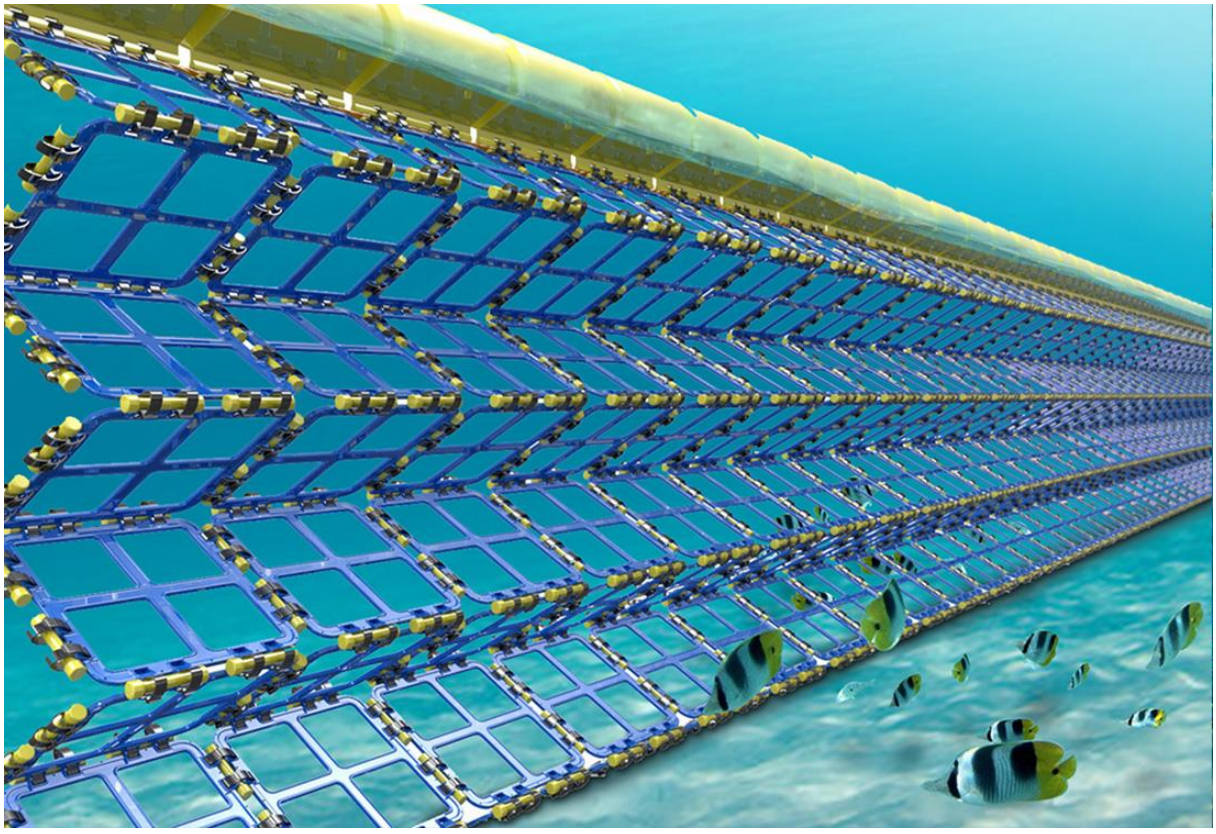


Figure A1-5 Flexible Shark barrier system developed by Form Design Australia that allows the barrier to flex with changing tide and wave action (Form Designs 2014)

The general response by the public to the beach enclosure at Coogee was positive (95%), a considerable amount of people made the comment that it was a more sensible solution to ensuring bather safety compared with shark culling. It was frequently pointed out that the barrier acted as a form of artificial reef or FAD (fish attracting device) which was seen as a positive thing providing an extra point of interest for swimmer/snorkelers. The point was also made that the enclosure could also be designed to exclude stingers and that Coogee was the ideal place to position for it given that there are very few sightings of sharks locally. Comments were also made that the enclosure was not positioned in the vicinity of the local surf life-saving patrol area which could have provided an extra level of swimmer safety. The responses to the questions posed to members of the public by City of Cockburn staff are summarised in Figure A1-6.

The cost of the Eco Shark Barrier system to purchase, install and maintain is difficult to ascertain as it was in development during the Coogee Beach trial and some costs were likely to be unique to the development phase. The funding of a further 3-year trial was estimated to

cost between $150,000 per annum for a lease/maintenance arrangement with the developer and $255,000 for purchase and an estimated $70,000 per annum for maintenance (City of Cockburn 2014). There where however uncertainties noted in the ability of the Eco Shark Barrier to withstand multiple years of deployment and the potential escalating costs of cleaning of biofouling.

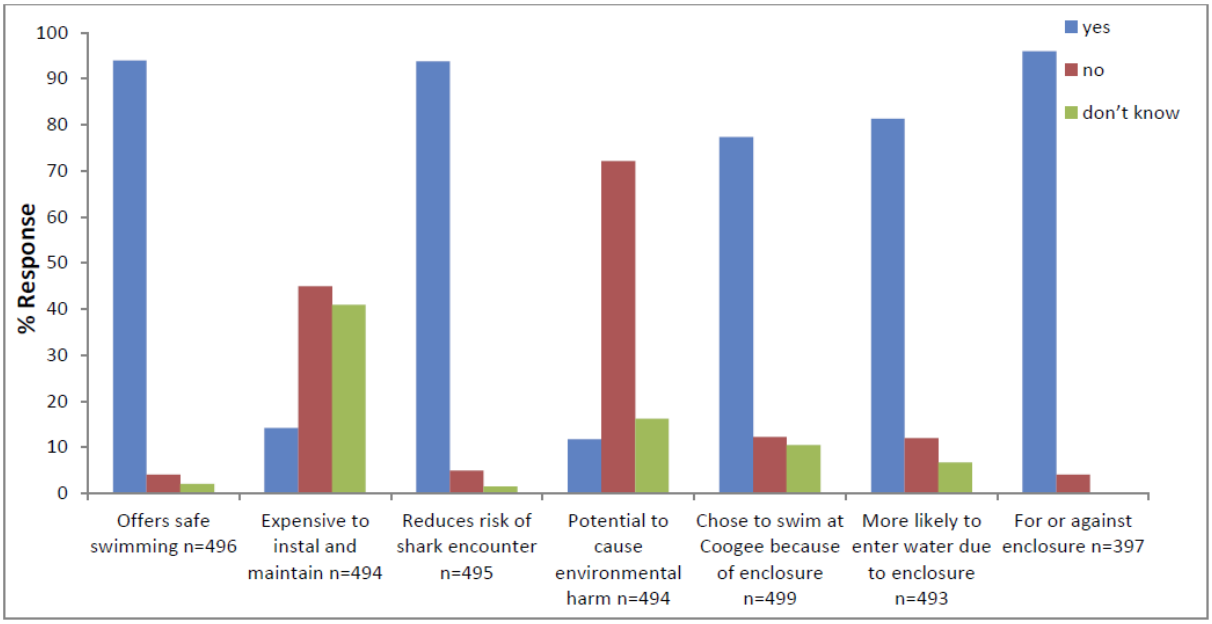


Figure A1-6 Public responses to questionnaires conducted by City of Cockburn regarding the Coogee beach enclosure