INSPIRING ACHIEVEMENT

Monitoring the presence and residency of sharks at key locations off Victor Harbor (Encounter Marine Park)

Report 2: March 2016–October 2018

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Photo: Andrew Fox

Report to the Department for Environment and Water and the City of Victor Harbor

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Disclaimer

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EXECUTIVE SUMMARY

This report provides a summary of sharks detected by acoustic receivers deployed in the Victor Harbor region in Encounter Marine Park (South Australia). It is a continuation of Munroe and Huveneers (2018), adding 12 months of acoustic monitoring for a total period of 32 months from March 2016 to October 2018. It contributes towards an assessment of the *Adequacy* (Biophysical Design Principle 3) and *Connectivity* (Biophysical Design Principle 5) of the South Australian Marine Parks network through the determination of white shark and bronze whaler visitation patterns and residency within marine parks near the Victor Harbor area.

Five VR2W acoustic receivers were deployed at key sites in the Victor Harbor region, including areas where sharks are likely to frequent naturally (Seal Island), shallow nearshore areas (Granite Island), and strategic headlands likely to be migratory paths when sharks enter the region (Kings Head, the Bluff, and Port Elliot). The receivers were deployed for a period of 32 months from March 2016 to October 2018. Sixteen months into the study period (July 2017), Oceanic Victor Pty Ltd opened a 45-m diameter aquaculture pen near Granite Island that provides people with the opportunity to swim with a range of native fish species. The monitoring period included 16 months before the pen was installed (March 2016–July 2017) and 16 months after the pen was installed (July 2017–October 2018). In addition, 71 acoustic receivers were deployed throughout the South Australian Marine Park network as a part of other monitoring programs and the Integrated Marine Observing System Animal Tracking Facility (IMOS ATF). Sites included the Neptune Islands Group (Ron and Valerie Taylor) Marine Park, the upper parts of the Encounter Marine Park, the Upper Gulf St Vincent Marine Park, and the metropolitan coast of Adelaide. Eighty-four white sharks, 55 bronze whalers, and nine dusky sharks were acoustically tagged in South Australia outside of Victor Harbor as part of separate shark monitoring projects led by or involving Flinders University. The total number of tagged sharks at liberty during the Victor Harbor monitoring period is unknown because external tags can be shed through time, and species were acoustically tagged by other agencies that could also be detected by the receivers deployed in Victor Harbor. Acoustic tracking was used to determine the number of tagged sharks that visited the monitored area in Victor Harbor, the amount of time (days) each shark spent in the area, and which receivers logged the highest number of detections. Marine Park connectivity was examined by determining the last known location of each shark prior to being detected in the Victor Harbor area.

Fifteen sharks (12 bronze whalers, 3 white sharks) were detected a total of 701 times in the Victor Harbor region over the 32-month period, including four new sharks, two bronze whalers and two white sharks, since November 2017. Data were insufficient to compare shark residency or detection patterns between years, and were therefore pooled across all years. Individuals were present in Victor Harbor for 1 to 12 days (mean ± standard deviation = 2.86 ± 3.24) and were detected on 1 to 4 receivers (1.60 ± 0.82). Sharks typically visited the Victor Harbor area only once. Two bronze whalers made two separate visits, which were approximately 12 months apart. The Granite Island receiver recorded the highest number of detections (60%) and number of days detected/shark (1.8 ± 2.9) with seven bronze whalers detected. Seal Island recorded the highest number of individuals (two white sharks and seven bronze whalers), but a relatively low proportion of the total detections (8%) and number of days detected/shark (0.75± 0.77). These findings show that bronze whalers and white sharks both use the Victor Harbor area, but that sharks stayed in the area for relatively short periods of time and primarily used the areas near Granite and Seal Island. Most detections and sharks were recorded in spring (September–November; 55.7%, six bronze whalers), followed by autumn (March–May; 34.5%, one white shark, three bronze whalers), and summer (December–February; 9.7%, two white sharks, four bronze whalers). There were no detections during winter (June–August) in any year. The small number of receivers in Victor Harbor and the lack of locally tagged sharks prevents a more thorough examination of local fine-scale movement patterns.

Six sharks detected in Victor Harbor were tagged outside of South Australia. Four of the bronze whalers were tagged in Western Australia between 2012 and 2017 near Perth and two of the white sharks were tagged in New South Wales near Ballina Bach and Lennox Head in 2016 and 2017 respectively. Of the nine remaining sharks detected in Victor Harbor, six bronze whalers were tagged in the Upper Gulf St Vincent Marine Park, and two bronze whalers and one white shark were tagged in Spencer Gulf. These data show that sharks moved between distinct areas and marine parks along the Australian coast. Victor Harbor and the Encounter Marine Park may be part of a large regional home range or migratory pathway that includes multiple South Australian marine parks. The specific importance of the Victor Harbor area to shark populations remains unclear, but the Encounter Marine Park may help to provide adequate coverage and connectivity between important shark habitats within the South Australian Marine Park network. Continued monitoring will lead to a more detailed understanding of species-specific trends in space use within and connectivity between marine parks, and help to determine if the current network is comprehensive, adequate, and supports important habitat linkages for South Australian shark populations.

1. INTRODUCTION

Marine Protected Areas (MPAs), also known as marine parks, are widely recognised as an essential tool in ocean conservation (Agardy 1994; Blyth-Skyrme *et al.* 2006; Angulo-Valdés and Hatcher 2010). By preventing damaging activities such as habitat destruction (Haddad *et al.* 2015), over-exploitation (Jackson *et al.* 2001), and pollution (Islam and Tanaka 2004), protected areas can conserve all the relevant biogeochemical processes, habitats, and species in an area. Marine parks can also provide important socio-economic benefits, such as increased tourism and employment, increased scientific capacity, and a stronger public connection to nature (Balmford *et al.* 2002; West *et al.* 2006; Apps *et al.* 2016). Well-designed and effective marine parks ultimately provide a holistic and precautionary approach to marine management that cannot necessarily be achieved using other methods.

The goals and design of any MPA are context-dependant. Nonetheless, effective conservation-oriented MPAs share a consistent set of ecological features (Edgar *et al.* 2014). South Australia's Marine Parks network explanatory document (2012) details the seven key biophysical principles that were used to establish the South Australian Marine Parks network. It highlights that effective MPAs must be *comprehensive* (Biophysical Design Principle 2; cover a full range of habitats and species), *adequate* (Biophysical Design Principle 3; be an appropriate size so as to provide sufficient protection for a given species), and must also support *connectivity and linkages* within the environment (Biophysical Design Principle 5; provide for the sharing of plants, species, and materials between sites). Marine parks designed using these core principles are more likely to provide broad and lasting protection for its plants, animals, and ecosystems (Claudet *et al.* 2008; Agardy *et al.* 2011). However, adequacy and connectivity are far more difficult to achieve for highly mobile species, such as sharks, marine mammals, or tunas (McLaren *et al.* 2015, Jones *et al*. 2018). This is because the home ranges of these species are usually much larger than the MPAs themselves, and mobile species generally use a wide assortment of distinct and distant habitats. As a result, mobile species often spend most of their time outside marine parks and remain exposed to potentially damaging human activities (Claudet *et al.* 2008; Grüss *et al.* 2011; McLaren *et al.* 2015). For example, genetic analyses and satellite tracking have shown that the shortfin mako (*Isurus oxyrinchus*) exhibits a high level of connectivity across Australian states and international boundaries (Rogers *et al*. 2015a; 2015b). Therefore, mobile species require large, well-connected MPA networks, and marine parks need to be regularly evaluated to ensure they include both the key habitats and movement paths of different mobile and vulnerable species.

Sharks are highly mobile aquatic predators that exert top-down control on marine food webs (Heupel *et al.* 2014). Sharks help to maintain healthy marine ecosystems by limiting prey population size and altering prey behaviour, which in-turn reduces competition between preys and preserves species biodiversity (Heithaus *et al.* 2008). However, sharks across the globe are experiencing unprecedented levels of population decline. Approximately 25% of all chondrichthyan fishes (sharks, rays, and chimaeras) are at elevated risk of extinction, primarily due to overfishing and habitat destruction (Dulvy *et al.* 2014). Large and well-connected MPA networks can provide effective protection from these critical threats (Dulvy 2006; Garla *et al.* 2006). For example, Knip *et al.* (2012) used an array of acoustic receivers to examine the movement and space use of two tropical coastal shark species, juvenile pigeye (*Carcharhinus amboinensis*) and adult spottail (*Carcharhinus sorrah*), within two MPAs in the Great Barrier Reef Marine Park, Australia. The authors found that sharks used large areas inside the MPAs over relatively long periods of time, indicating the MPAs could have substantial conservation benefits for these populations. Moreover, a recent assessment of species connectivity within the South Australian Marine Parks network (Jones *et al*. 2018) indicated that sharks should be a high priority "exemplar" group for future MPA research because of their high mobility, unique life history (large-bodied, low reproductive rate, and late to mature), and significant trophic role. Knip *et al.* (2012), and other studies like it (Garla *et al.* 2006; Dewar *et al.* 2008; Espinoza *et al.* 2014), also demonstrate that acoustic monitoring is a highly efficient way to evaluate and improve MPAs for shark species. Jones *et al*. 2018 similarly recommended using telemetry and other tracking techniques to examine "whole of network" connectivity for mobile species that use the SA MPA network.

Limited acoustic monitoring within the South Australian Marine Parks network has already helped to identify important shark habitat. Fifty-five bronze whalers (*Carcharhinus brachyurus*) and nine dusky sharks (*C. obscurus*) were tagged with acoustic transmitters in Gulf St Vincent between 2010 and 2013 as part of a study monitoring shark species of conservation concern within the Adelaide metropolitan and Gulf St Vincent regions (Huveneers *et al.* 2014a; 2014b). Twenty white sharks have and continue to be tagged yearly at the Neptune Islands group (Ron and Valerie Taylor) Marine Park since 2013 as part of the white shark cage-diving industry monitoring. Many of these sharks have been detected in several South Australian marine parks, including in the Neptune Islands group Marine Park, the upper parts of the Encounter Marine Park (e.g., Aldinga Reef Sanctuary Zone), and the Upper Gulf St Vincent Marine Park (e.g., Zanoni Sanctuary Zone; see Huveneers *et al*. 2014a; 2014b; Rogers *et al*. 2014; Rogers and Huveneers 2016; Huveneers and Lloyd 2017 for more details about residency and detections within these locations). These studies strongly indicate that the Gulf St Vincent and the Neptune Islands are essential habitat for a variety of shark species. For example, the Gulf St Vincent is likely a key nursery ground for juvenile bronze whalers (Rogers *et al.* 2013). However, the relative importance of other marine parks within the South Australian network to shark populations is poorly understood. It is currently unclear if the South Australia Marine Park network provides comprehensive and adequate protection, or if it supports important habitat linkages, for South Australian shark populations.

Victor Harbor is located on the south coast of the Fleurieu Peninsula, approximately 80 km from Adelaide. It is the largest population centre on the peninsula and is a popular tourist destination, especially during summer. Victor Harbor sits within the Encounter Marine Park, which extends off the coast of southern Adelaide within Gulf St Vincent, to the exposed Coorong coast. The park itself is one of the largest marine parks in South Australian waters (3,119 km^2) and is considered a vital component of South Australia's Marine Park network. The Victor Harbor region and the southern range of the Encounter Marine Park is home to wide range of diverse habitats including reefs, high-energy dissipative beaches, and wetlands (Encounter Marine Park Management Plan, 2012). The park also provides a significant link between the Gulf St Vincent and the southern coast. Given its potential importance to South Australian sharks, the local economy, and the wider Marine Park network, shark movement patterns within the Victor Harbor area needs to be examined to ensure that the park is providing sufficient protection for regional populations. In 2016, acoustic receivers were deployed in Victor Harbor to establish the Victor Harbor shark monitoring program. Munroe and Huveneers (2018) used passive acoustic telemetry to evaluate the presence and residency of sharks at key locations within the Victor Harbor region from March 2016 to November 2017. Initial results indicated that the Victor Harbor area within the Encounter Marine Park provide coverage and connectivity between important shark habitats within the South Australian Marine Park network and, for some sharks, may be a part of large regional home range or migratory pathway that includes multiple parks. However, Munroe and Huveneers (2018) also highlighted the importance of continued, long-term monitoring in Encounter Marine Park to examine species-specific trends in space use and connectivity to determine if the current network is comprehensive, adequate, and supports important habitat linkages for South Australian shark populations.

1.2 *Aims and objectives*

The primary aim of this report was to use passive acoustic telemetry to evaluate the presence and residency of sharks at key locations within the Victor Harbor region. This work was a continuation of the original evaluation and report produced by Munroe and Huveneers (2018), adding 12 months of acoustic monitoring for a total monitoring period of 32 months from March 2016 to October 2018. Overall, the deployment of receivers in Victor Harbor will contribute to DEW Monitoring, Evaluation and Reporting program by assisting in assessing the *Adequacy* of the South Australian Marine Parks network (Biophysical Design Principle 3) through the determination of white shark and bronze whaler visitation patterns and residency within marine parks and sanctuary zones. This project will also contribute to assessing the level of *Connectivity* between marine parks where receivers are deployed (Biophysical Design Principle 5).

Over 1,000 acoustic receivers are also deployed throughout Australia and the receivers deployed off Victor Harbor will contribute to the national network of acoustic receivers managed by the Integrated Marine Observing System Animal Tracking Facility (IMOS ATF). These receivers can be used to determine shark connectivity with other regions around Australia, including areas protected through the National Representative System of Marine Protected Areas (NRSMPA). For example, bronze whalers and dusky sharks tagged in South Australia have been detected in Victoria (Corner Inlet) and Western Australia (off Perth) (Huveneers *et al*. 2014b), while white sharks tagged at the Neptune Islands have been detected across their distribution from Ningaloo Reef, Western Australia to the Great Barrier Reef, Queensland (McAuley *et al.*, 2017; Bruce and Bradford; unpublished data). Ultimately, the Victor Harbor monitoring program will contribute to nation–wide evaluations of animal movement patterns.

2. METHODS

2.1 Study site and receiver deployments

Five VR2W (Vemco Ltd., Halifax, Canada) acoustic receivers were deployed at key sites in the Victor Harbor region including areas where sharks are likely to frequent naturally (Seal Island), shallow nearshore areas (Granite Island), and strategic headlands likely to be migratory paths when sharks enter the Victor Harbor region, i.e. Kings Head, the Bluff, and Port Elliot (Fig. 1). Receivers were coated in anti-fouling paint and affixed to a 1.65 m long steel post that was hammered into the substratum to at least 0.6–0.8 m depth. The receivers were deployed for a period of 32 months from March 2016 to October 2018. Sixteen months into the study period (July 2017), a new wildlife tourism opportunity for people to swim with a range of native fish species opened near Granite Island. The Oceanic Victor operations consists of a 45 m diameter aquaculture pen which hosts less than 5 tonnes of Southern Bluefin tuna that are fed a minimum of 5% body weight per day (when weather permits) to meet metabolic demands. Therefore, the monitoring period included 16 months before the pen was installed (March 2016–July 2017) and 16 months after the pen was installed (July 2017–October 2018). In addition, 71 acoustic receivers were deployed throughout the regional marine park network as a part of other monitoring programs (see Huveneers *et al.* 2014a; 2014b; Rogers *et al.* 2014; Rogers and Huveneers 2016; Huveneers and Lloyd 2017). Sites included the Neptune Islands Group (Ron and Valerie Taylor) Marine Park, the upper parts of the Encounter Marine Park (e.g., Aldinga Reef Sanctuary Zone), the Upper Gulf St Vincent Marine Park (e.g., Zanoni Sanctuary Zone), and the metropolitan coast of Adelaide (Fig. 2).

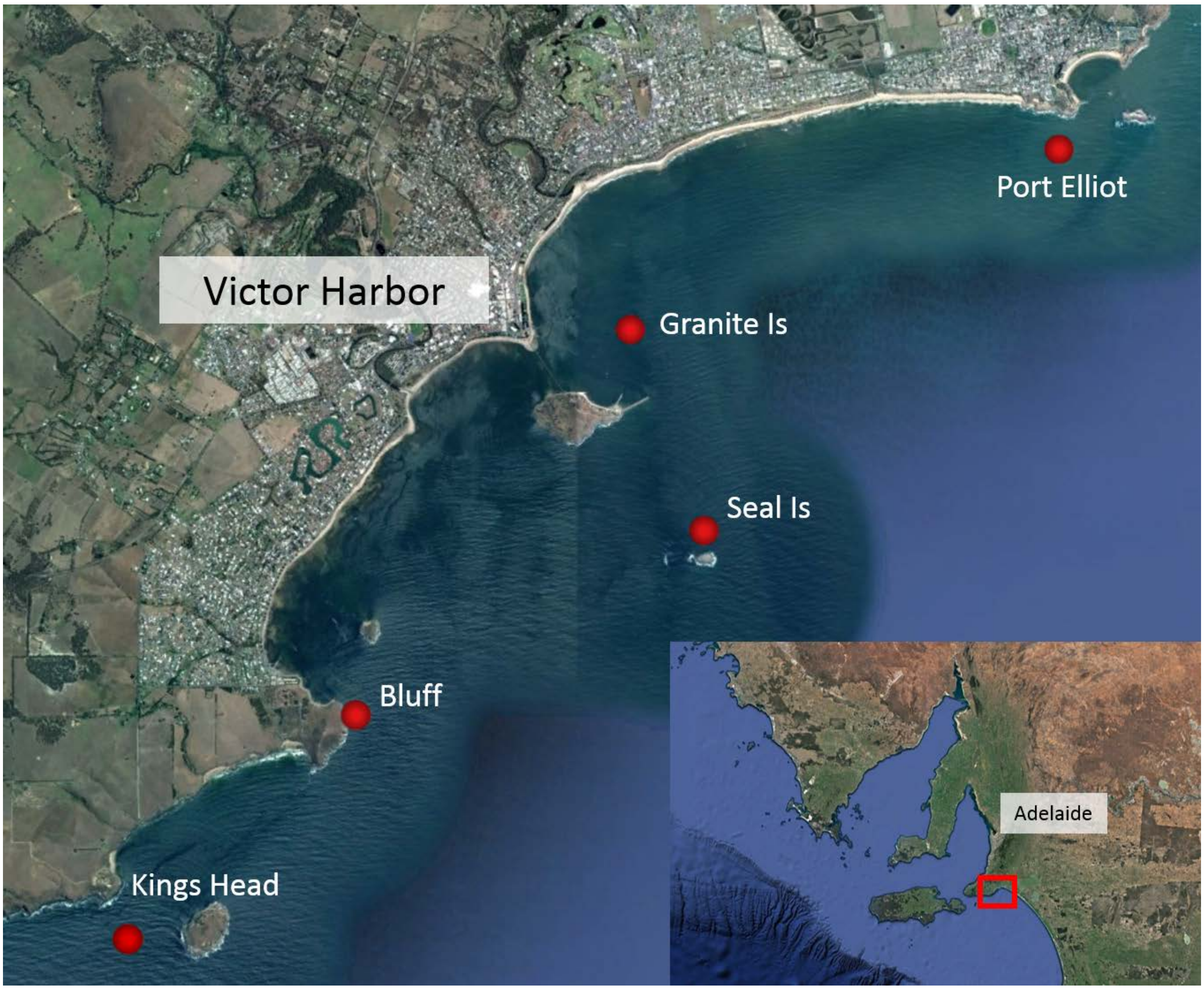

Figure 1. Map of acoustic receivers locations within the Victor Harbor region.

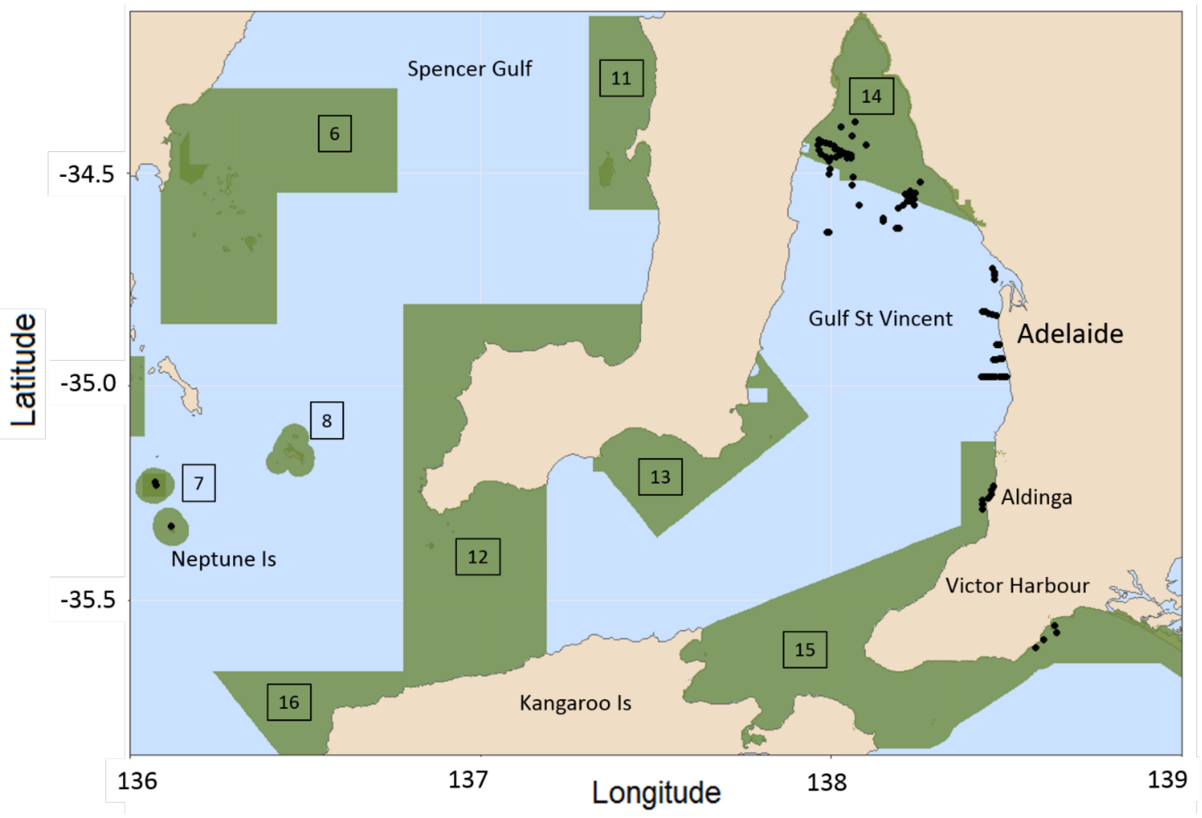

Figure 2. Acoustic receiver locations (black circles) near Adelaide, South Australia. Green areas indicate (6) Sir Joseph Banks Group Marine Park, (7) Neptune Islands Group Marine Park, (8) Gambier Islands Group Marine Park, (11) Eastern Spencer Gulf, (12) Southern Spencer Gulf Marine Park, (13) Lower Yorke Peninsula, (14) Upper Gulf St Vincent Marine Park, (15) Encounter Marine Park, and (16) Western Kangaroo Island Marine Park.

The acoustic receivers detected electronic pulses produced by acoustic transmitters or "tags" that were attached to (Fig. 3) or surgically implanted into sharks (Fig. 4; Huveneers et al. 2014a; Huveneers and Lloyd 2017). Each tag emits a unique numerical code that allows for the identification of individuals. When a tagged shark swam within the detection range of a receiver (~500 meters; Huveneers *et al.* 2016), the receiver recorded the date and time the shark was in the area. Sharks were not tagged within the Victor Harbor region. However, white sharks, bronze whalers, and dusky sharks have been acoustically tagged in Southern Australia as part of several unrelated projects:

1) Fifty-five bronze whalers and nine dusky sharks (*C. obscurus*) were internally tagged in Gulf St Vincent between 2010 and 2013 as part of a study monitoring whaler sharks in the Adelaide metropolitan and Gulf St Vincent regions (Huveneers *et al.* 2014a; 2014b);

2) Thirty bronze whalers were externally tagged in Spencer Gulf as part of a Fisheries and Research Development Corporation (FRDC) project;

3) Fifty-three bronze whalers were internally tagged in WA as part of another FRDC project (Braccini *et al.* 2017);

4) Eighty-four whites sharks were externally tagged between September 2013 and May 2018 as part of the monitoring of the white shark cage-diving industry (Rogers *et al*. 2014; Rogers and Huveneers 2016; Huveneers and Lloyd 2017);

5) 305 white sharks were externally, internally, or double tagged by the Western Australian Department of Primary Industries and Regional Development and colleagues as part of their shark attack mitigation program (McAuley *et al.* 2017; S. Mountford pers. comm.); and

6) 346 white sharks were externally or internally tagged between August 2015 and January 2019 by the New South Wales Department of Primary Industries as part of their shark management strategy (P. Butcher pers. comm.).

It is important to note that the total number of tagged white sharks and bronze whalers at liberty during the Victor Harbor monitoring period is unknown because external tags can be shed through time. For example, white sharks tagged by the Western Australian Department of Primary Industries and Regional Development were fitted with tags between 20 December 2007 and 30 December 2015 and many external tags would have either run out of battery or shed. As a result, it is not possible to ascertain the percentage of tagged sharks detected during the study period.

Figure 3. Example of a white shark (*Carcharodon carcharias*) tagged with acoustic transmitters below the dorsal fin.

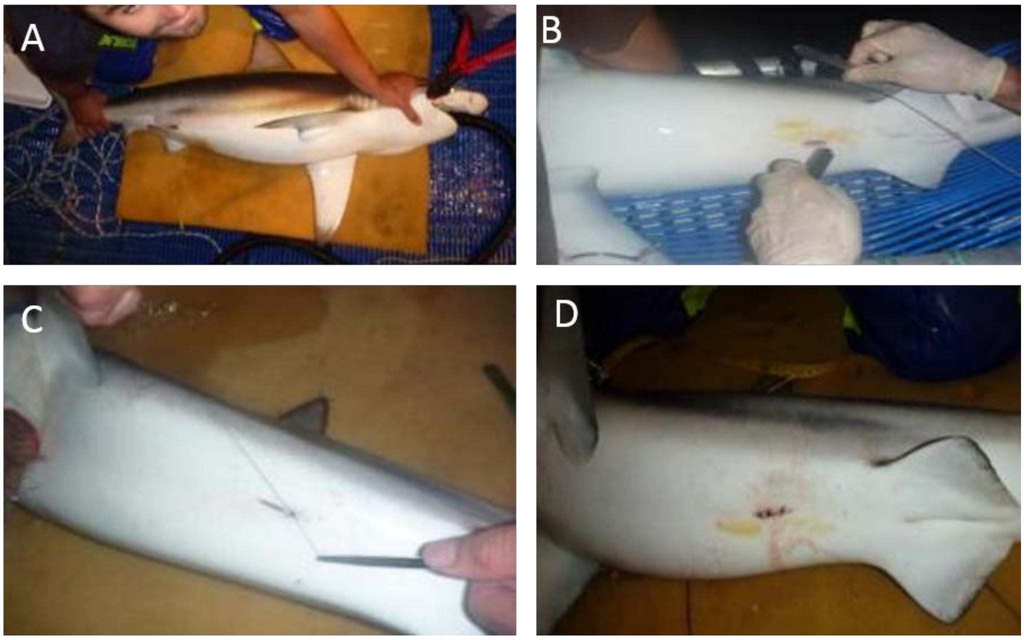

Figure 4. Internal tagging procedure of a bronze whaler (*Carcharhinus brachyurus)* showing (a) captured shark, (b) incision and tag insertion, (c) suturing, and (d) finished sutures.

2.2 Data analysis

Acoustic detections were used to determine the number of tagged sharks that were present in the Victor Harbor region during the monitoring period. Detection data were then used to determine the amount of time (days) each shark spent in the area, and which receivers recorded the highest number of detections, unique individuals, and mean number of days detected/shark. Sharks were considered present on any given day within the area or at a specific receiver if the receiver recorded a single detection. A minimum of two detections per day is usually required for a shark to be considered present to eliminate false detections (Simpfendorfer *et al.* 2015). However, false detections most often occur as a result of overlapping acoustic transmissions from co-occurring sharks. False detections were considered highly unlikely in Victor Harbor given the low number of tagged sharks that were present in the area during the monitoring period. Marine park connectivity was examined by determining the last known location of each shark prior to entering the Victor Harbor area. The last known location of each shark was assigned using detections from acoustic receivers outside of Victor Harbor.

4. RESULTS AND DISCUSSION

The receiver deployed off Port Elliot could not be recovered due to the location being exposed to large swell and ensuing sand movement, likely resulting in the receiver being buried. The receiver was not replaced. Residency and detection patterns were determined using the four remaining receivers. From March 2016 to October 2018, 15 sharks (12 bronze whalers, three white sharks) were detected a total of 701 times in the Victor Harbor region (Table 1), including four new sharks, two bronze whalers and two white sharks, since November 2017 (Munroe and Huveneers 2018). Data were insufficient to compare shark residency or detection patterns between years, and was therefore combined across years. Sharks were present in Victor Harbor for a cumulative total of 43 days, or approximately 4.2% of the total monitoring period. Individuals were present in Victor Harbor for 1 to 12 days (mean ± standard deviation = 2.86 ± 3.24) and were detected on 1 to 4 receivers (1.60 ± 0.82; Fig. 5). Sharks typically visited the Victor Harbor area only once. Two bronze whalers made two separate visits, which were approximately 12 months apart. Most detections were recorded at the Granite Island receiver (60%), followed by the Bluff (30%), Seal Island (8%), and Kings Head (< 1%) receivers. The Granite Island receiver also recorded the highest mean number of days detected/shark (1.8 ± 2.9), followed by the Bluff (1.0± 2.7), Seal Island (0.75± 0.77), and Kings Head (0.37 ± 1.0) receivers (Fig. 6). The Seal Island receiver recorded the highest number of unique individuals (two white sharks, seven bronze whalers). The Granite Island receiver recorded seven individuals (all bronze whalers). The Bluff receiver recorded five individuals (two white sharks, three bronze whalers), and the Kings Head receiver recorded three individuals (all bronze whalers). The high percentage of detections at the Bluff was dominated by a single shark (30894 bronze whaler), while detections at Granite and Seal Island were the result of multiple sharks using these areas across the monitoring period.

Table 1. Summary of acoustically tagged shark biological and detection data in the Victor Harbor area. Column headings are as follows: Tag identification number (Shark ID), fork length (FL), total length (TL), tag location (State), date of first and last detection in Victor Harbor (First Detection, Last detection), days present (# Days), and number of receivers that detected each shark (# Rec).

Shark ID	Species	Sex	FL (cm)	TL (cm)	Date Tagged	State	First Detection	Last Detection	# Days	# Rec
17327	*C. carcharias*	Male		330	1/12/2016	SA	24/04/2017	25/04/2017	2	1
16453	*C. carcharias*	Female		230	17/07/2017	NSW	03/02/2018	18/02/2018	4	2
20450	*C. carcharias*	Male		306	05/07/2016	NSW	24/01/2018	24/01/2018	1	1
33189	*C. brachyurus*	Female	75	90	24/01/2013	SA	10/09/2017	11/09/2017	2	1
33190	*C. brachyurus*	Female		92	24/01/2013	SA	09/01/2018	09/01/2018	1	2
33183	*C. brachyurus*	Female	129	156	6/12/2012	SA	26/12/2016	12/03/2018	2	2
23293	*C. brachyurus*	Female	150		07/02/2015	SA	14/10/2016	14/10/2016	1	1
52646	*C. brachyurus*	Female		232	23/11/2012	SA	10/10/2016	10/10/2016	1	1
30717	*C. brachyurus*	Male	91	115	3/11/2011	SA	14/10/2016	15/10/2016	2	2
52639	*C. brachyurus*	Male	94	114	15/02/2012	SA	29/09/2017	7/10/2017	9	1
23294	*C. brachyurus*	Male	203		07/02/2015	SA	11/01/2017	11/01/2017	1	1
30894	*C. brachyurus*	Female	210		2/10/2014	WA	2/05/2016	14/05/2016	12	4
31003	*C. brachyurus*	Female	230		17/10/2012	WA	23/02/2017	14/02/2018	2	2
31000	*C. brachyurus*	Female	232		18/10/2012	WA	10/05/2017	10/05/2017	2	2
27698	*C. brachyurus*	Female	262		17/10/2013	WA	20/10/2018	20/10/2018	1	1

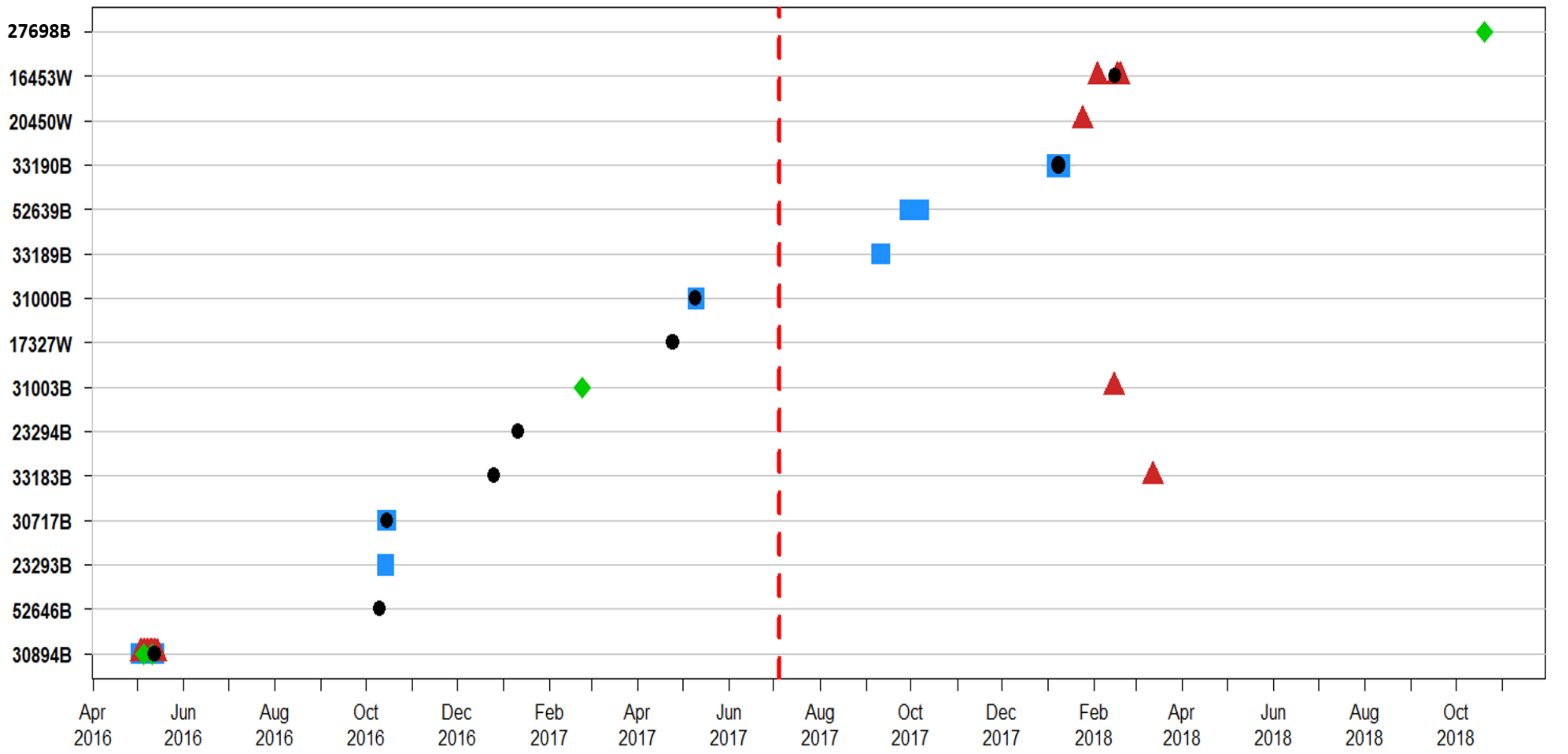

Figure 5. Daily presence of sharks (indicated by tag identification number) in the Victor Harbor region. Each point indicates a day a shark detected at the Granite Island (blue squares), Seal Island (black circles), Bluff (red triangles), and Kings Head (green diamonds) receivers. The red dotted line denotes the date the Oceanic Victor pen was installed. Letters in the tag identification number denote bronze whalers (B; *C. brachyurus*) and white sharks (W; *C. carcharias*), respectively.

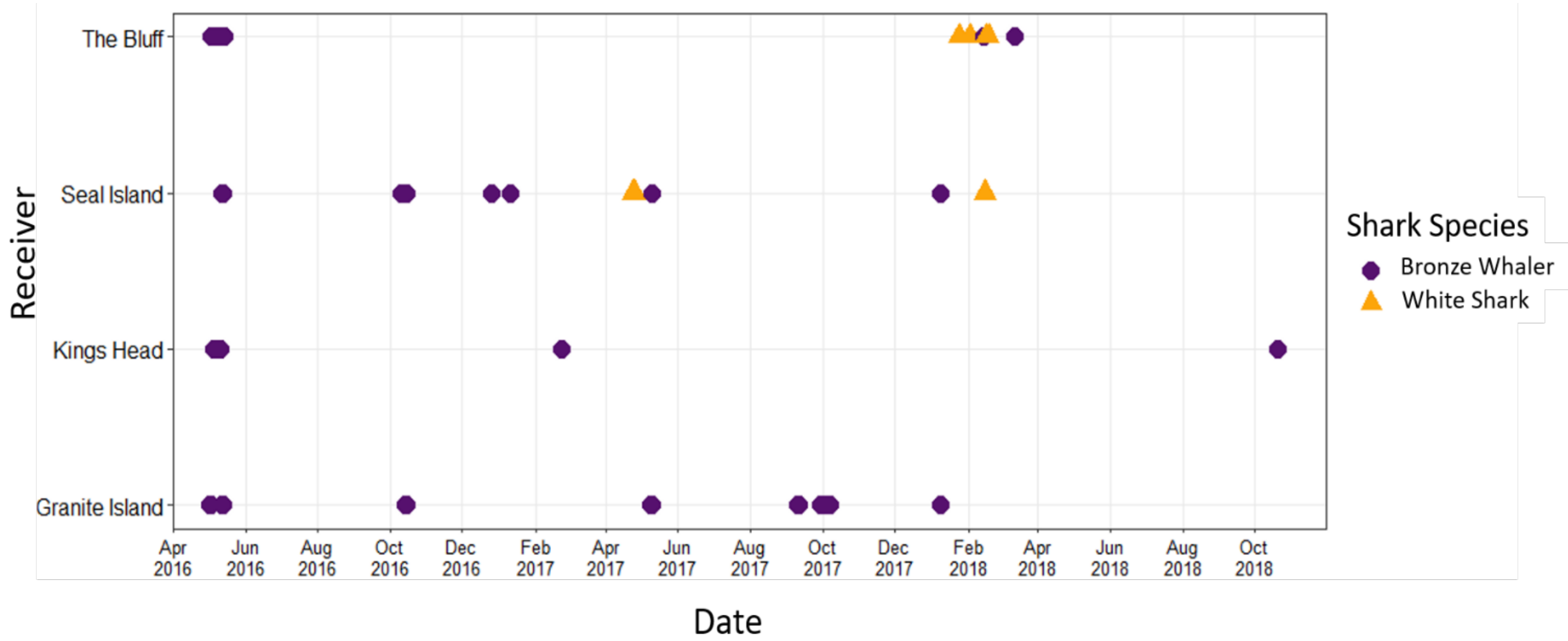

Figure 6. Daily presence of bronze whalers and white sharks at each receiver in the Victor Harbor region. Each point indicates a day a shark detected. White sharks where only detected at the Bluff and Seal island receivers. There were no detections during winter (June–August) in any year.

Collectively, these findings show that bronze whalers and white sharks both use the Victor Harbor area, but that sharks stayed in the area for relatively short periods of time and primarily used the areas near Granite and Seal Island. However, not all sharks followed this trend. A female bronze whaler (tag 30894) was detected at all four acoustic receivers and remained in Victor Harbor for 12 days, indicating that some individuals can roam throughout the area for relatively long periods of time. These results are consistent with the 2018 evaluation of shark movement in Victor Harbor (Munroe and Huveneers 2018).

The majority of detections were recorded in spring (September–November; 55.7%), followed by autumn (March–May; 34.5%), and summer (December–February; 9.7%) (Fig. 7). There were no detections during winter (June–August) in any year. The majority of sharks were detected in spring (six bronze whalers), and despite the relatively low number of detections, an equal number of sharks were detected in the summer (two white sharks, four bronze whalers). Aside for winter, the fewest sharks were detected in autumn (one white shark, three bronze whalers). Bronze whalers are typically most abundant in inshore areas during the spring and summer months (Smale 1991, Cappo 1992; Cliff and Dudley 1992, Chiaramonte 1998; Huveneers *et al.* 2014a; 2014b). Adult female bronze whalers often enter shallow inshore habitats in spring to breed. However, there is currently no evidence to suggest that Victor Harbor is a significant nursery ground for juvenile bronze whalers. It is also important to note that the small number of receivers in Victor Harbor prevents a thorough examination of local fine-scale movement patterns.

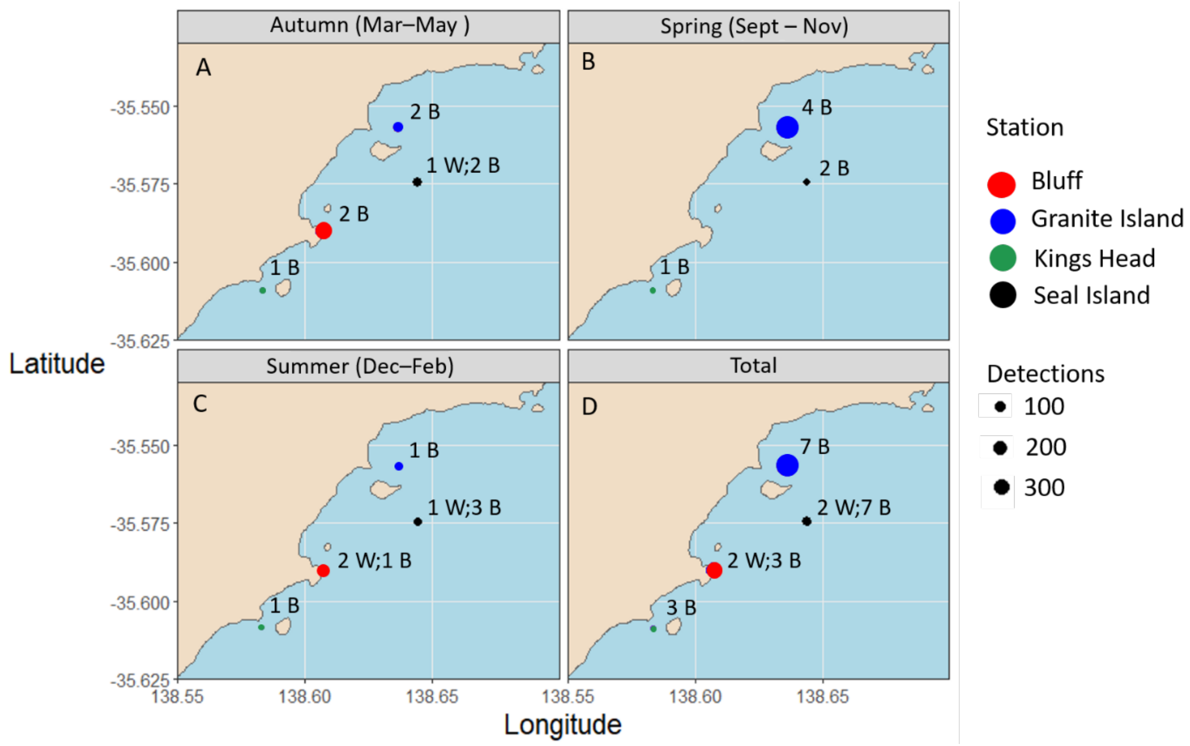

Figure 7. **(A–C)** Spatial and seasonal distribution of shark detections at Victor Harbor acoustic receivers. Circles denote receiver location and the size of the circle denotes the number of detections at each site (i.e. 100, 200, 300). Numbers denote the number of unique sharks from each species detected at each receiver (B; bronze whaler and W; white shark). There were no detections during the winter months. (D) Spatial distribution of the total number of detections over the entire monitoring period.

Since the number of months with acoustic monitoring is equal before and after the installation of the Oceanic Victor pen, the number of sharks detected within Victor Harbor and by the Granite Island receiver can be compared. Approximately half (52%) of the sharks recorded in Victor Harbor were detected before the Oceanic Victor pen was installed. Out of the seven sharks detected by the Granite Island receiver, four were detected before the pen was installed. There was a 70% increase in the number of detections at Granite Island after the pen was installed, but 40% of the days that sharks were detected at the Granite Island receiver were recorded before the pen was installed. Cumulatively, these findings do not suggest that residency or frequency of visits around Granite Island has increased since the installation of the Oceanic Victor pen. Our results are consistent with a previous study that indicated fish-pens have a negligible effect on the residency patterns of large, transitory sharks (Papastamatiou *et al*. 2010). However, Papastamatiou *et al*. (2010) also found fish-pens may aggregate local shark populations. There is considerable uncertainty regarding the level of whaler shark interaction with fish-pens in South Australian waters (Jones 2008); therefore monitoring locally tagged sharks is necessary to provide a greater understanding of how the Oceanic Victor pen may affect shark movement and residency in the Victor Harbor area.

Six sharks detected in Victor Harbor were tagged outside of South Australian waters. Four of the bronze whalers detected were tagged in Western Australia between 2012 and 2017 near Perth. These sharks were subsequently detected off Garden Island and Smiths Beach in Western Australia before being detected in Victor Harbor (Fig 8A). One bronze whaler (31003) undertook multiple trips between Western Australia and South Australia. Shark 31003 was originally tagged in Western Australia in 2012, was then detected in Victor Harbor in February 2017, was again detected in Western Australia in January 2018, and was finally detected in Victor Harbor in February 2018. Shark 31003 was detected at different receivers in each year (Kings Head and The Bluff). Two of the white sharks detected in Victor Harbor were tagged in New South Wales near Ballina Bach and Lennox Head in 2016 and 2017 before reaching Victor Harbor in January and February 2018 respectively.

Six bronze whalers were originally tagged in the Upper Gulf St Vincent Marine Park and were subsequently detected by receivers in the Upper Gulf St Vincent Marine Park, the metropolitan Adelaide coast, and within Aldinga Sanctuary Zone in the Encounter Marine Park, before arriving in Victor Harbor (Fig. 8B; Table 2). One bronze whaler (33183) that was tagged in the Gulf St Vincent was detected in Victor Harbor in multiple years (December 2016 & March 2018) at different receivers (Seal Island and The Bluff). The two remaining bronze whalers were originally tagged in the Spencer Gulf, but no acoustic data outside Victor Harbor are currently available for these individuals. One white shark was last detected within the Neptune Islands Group Marine Park in January 2017 before visiting the Victor Harbor area in April 2017.

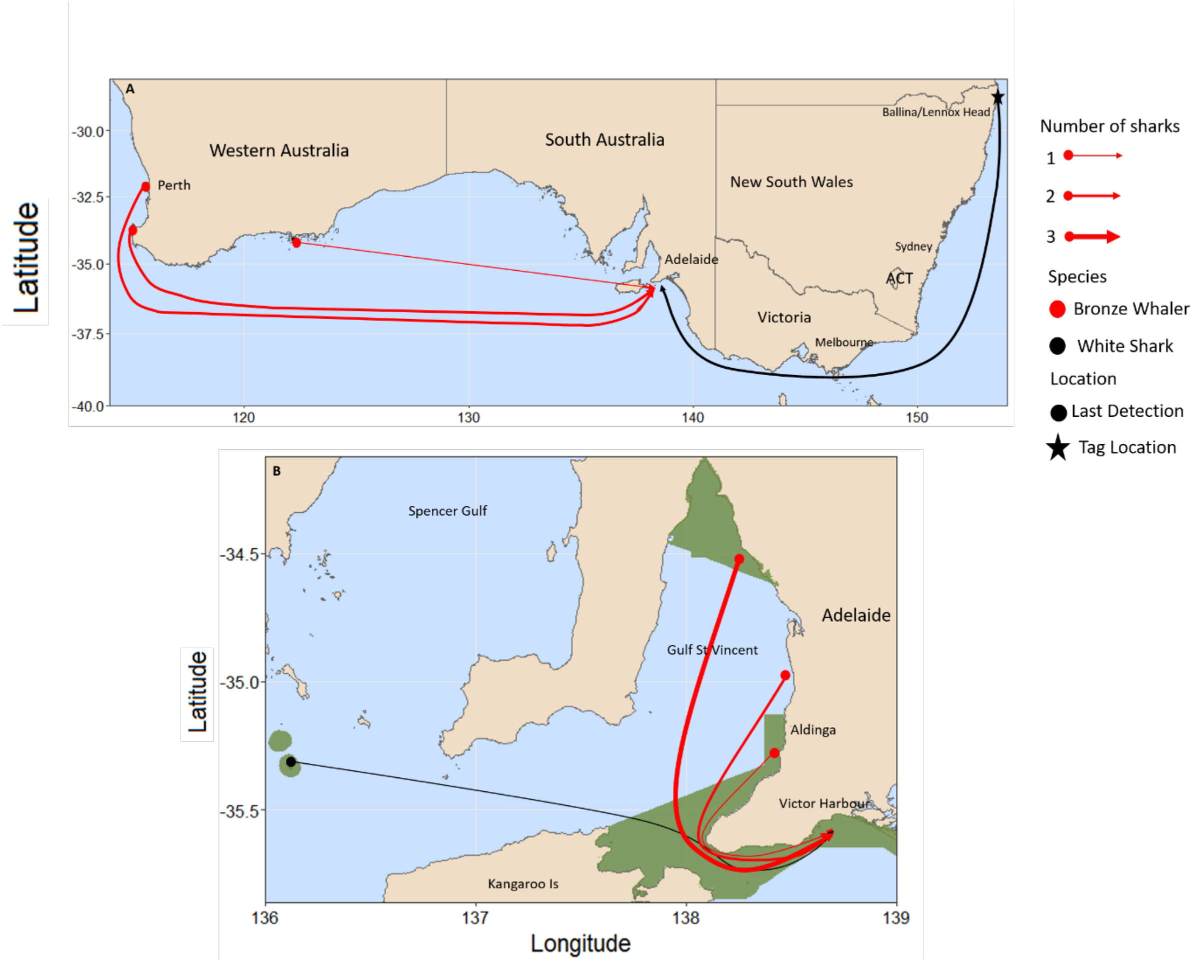

Figure 8. (A) Last known detection of bronze whales and tagging location of white sharks tagged outside of South Australian waters. (B) Last known detections of sharks tagged in South Australia. Arrows indicate the likely general direction of travel, but are not validated movement paths. Arrow thickness indicates the number of sharks traveling to Victor Harbor from a given area. Green areas are South Australian Marine Parks that contain acoustic receivers and were linked by shark movement.

Table 2. Summary of shark detection patterns in the South Australian Marine Parks network. Shark ID is the transmitter identification number, State is the Australian state where the shark was initially tagged, *n* is number of South Australian Marine Parks in which a shark was detected, and Marine Park are the specific parks in which the sharks were detected.

Shark ID	**Species**	**State**	***n***	**Marine Park**
17327	*C. carcharias*	SA	2	Neptune Islands, Encounter (Victor Harbor)
16453	*C. carcharias*	NSW	1	Encounter (Victor Harbor)
20450	*C. carcharias*	NSW	1	Encounter (Victor Harbor)
33189	*C. brachyurus*	SA	2	Upper Gulf St Vincent, Encounter (Victor Harbor)
33190	*C. brachyurus*	SA	1	Encounter (Victor Harbor)
33183	*C. brachyurus*	SA	2	Upper Gulf St Vincent, Encounter (Victor Harbor)
23293	*C. brachyurus*	SA	1	Encounter (Victor Harbor)
52646	*C. brachyurus*	SA	3	Upper Gulf St Vincent, Encounter (Aldinga, Victor Harbor)
30717	*C. brachyurus*	SA	2	Upper Gulf St Vincent, Encounter (Victor Harbor)
52639	*C. brachyurus*	SA	3	Upper Gulf St Vincent, Encounter (Aldinga, Victor Harbor)
23294	*C. brachyurus*	SA	1	Encounter (Victor Harbor)
30894	*C. brachyurus*	WA	1	Encounter (Victor Harbor)
31003	*C. brachyurus*	WA	1	Encounter (Victor Harbor)
31000	*C. brachyurus*	WA	1	Encounter (Victor Harbor)
27698	*C. brachyurus*	WA	1	Encounter (Victor Harbor)

These data show that sharks moved between distinct areas and marine parks along the Australian coast. These results are consistent with previous tag-recapture, telemetry, and elemental chemistry analysis of bronze whaler sharks that provided strong evidence of shark connectivity across SA regions (Goldsworthy *et al*. 2010; Rogers *et al*. 2013; Izzo *et al*. 2016). Moreover, these data also suggest that, for some sharks, Victor Harbor may be a part of large regional home range or migratory pathway that includes multiple parks and distinct regions. The specific importance of the Victor Harbor area to regional shark populations remains unclear, but the results of this report suggest the Encounter Marine Park contributes to providing coverage and connectivity between shark habitats within the South Australian Marine Park network and across Australia. Continued monitoring will lead to a more detailed understanding of species-specific trends in marine park shark space use and connectivity, and help to determine if the current network is comprehensive, adequate, and supports important habitat linkages for South Australian shark populations.

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