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Monitoring shark species of conservation concern within the Adelaide metropolitan and Gulf St Vincent regions

C. Huveneers[1, 2], P.J. Rogers[1] and M. Drew[2]

SARDI Publication No. F2013/000716-1
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SARDI Aquatic Sciences
PO Box 120 Henley Beach SA 5022

January 2014

Final Report to the Adelaide and Mount Lofty Ranges Natural Resources Management Board

Government of South Australia
Adelaide and Mount Lofty Ranges Natural Resources Management Board

An Australian Government Initiative
National Collaborative Research Infrastructure Strategy

IMOS Integrated Marine Observing System
FACILITY 8: Australian Animal Tagging and Monitoring System (AATAMS)

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EXECUTIVE SUMMARY

Many shark species are considered particularly at risk of overexploitation because of their relatively slow life history traits and ensuing slow rebound potential. In response, the International Plan of Action for the Conservation and Management of Sharks was developed, which formed the basis of the Australian National Plan of Action for the Conservation and Management of Sharks. In South Australia, bronze whalers (*Carcharhinus brachyurus*), dusky sharks (*C. obscurus*), and white sharks (*Carcharodon carcharias*) have been identified as species of conservation concern. *Carcharhinus brachyurus* and *C. obscurus* are seasonally targeted by longline fishers within the Marine Scalefish Fishery (MSF), and by recreational and game fishers. The Ecologically Sustainable Development (ESD) Risk Assessment of the South Australian MSF concluded that the current level of take of whaler sharks within the MSF would be having severe consequences for their populations. *Carcharodon carcharias* is currently listed as Vulnerable under the IUCN Red List, and is protected under various international, federal and state legislations and treaties.

This study used acoustic telemetry to investigate the movement and residency of *C. brachyurus, C. obscurus*, and *C. carcharias,* and provide information about the spatio-temporal dynamics of *Carcharhinus* species. This study also aimed to increase our knowledge of the timing and periods of *C. carcharias* visitations and potential important habitat within the coastal Adelaide region.

Ninety-five *C. brachyurus* and 16 *C. obscurus* were captured in Northeast Gulf St Vincent (GSV) during 37 fishing trips. Fifty-five *C. brachyurus* and nine *C. obscurus* were tagged with acoustic transmitters and monitored by 57 receivers deployed along the Adelaide metropolitan coast and Northern GSV for periods ranging one to three years.

Carcharhinus brachyurus and *C. obscurus* showed some affinity to the location where they were tagged, with a detection period by the Northeast GSV receivers of about 184 and 317 days for *C. brachyurus* and *C. obscurus*, respectively. Thirty-three and 43% of *C. brachyurus* and *C. obscurus* tagged for over a year were detected within GSV for a period longer than 365 days.

The overall and detected residency indices (RI_o and RI_d) for the area covered by receivers within GSV were low for both species. No strong diel variations in the standardised number of detections or number of individual sharks detected were observed, but detections suggest greater abundance and residency in Northwest and Northeast GSV in summer to early autumn (December–April), and along the metropolitan coast in early summer (November–December), with more sporadic detections in winter. While *C. obscurus* were not detected

along the metropolitan region, similar temporal patterns were observed between *C. brachyurus* and *C. obscurus* within Northwest and Northeast GSV.

The results from the present study showed that Northeast GSV is an important area for *C. brachyurus* and *C. obscurus,* as they were detected regularly, and for up to nearly two years, by receivers deployed in that area. The small RIs, however, suggests that the tagged sharks only spent a short amount of total time within the area. The reason for these low RIs across the areas monitored is unknown, but might be linked to feeding ecology and the productivity of upper GSV. A multi-disciplinary approach, using stomach contents, stable isotope analysis, and acoustic telemetry data would provide a further understanding of the feeding ecology of these species and assess whether it drives the spatio-temporal distribution of *C. brachyurus* and *C. obscurus* in GSV.

Size-frequency distributions show that *C. brachyurus* and *C. obscurus* caught in GSV are mostly neonates and small juveniles. Yet, large juvenile and mature sharks are critical to the sustainability of fished populations. An investigation into the large-scale movements of large juvenile and mature sharks (over 2,000 mm total length) would elucidate their visitation pattern in GSV and vulnerability to fishing pressure.

Between 2007 and 2012, 169 *C. carcharias* were tagged around Australia, 141 in South Australia and 28 in Western Australia. Five of those were detected by the receivers deployed in GSV, with two white sharks detected off the Adelaide metropolitan coast and three by the Northwest or Northeast GSV receivers. The small proportion of *C. carcharias* detected suggests that most tagged sharks did not visit areas where receivers were deployed or that they did not go into GSV. None of the *C. carcharias* were, however, tagged within GSV. Sharks tagged at the Neptune Islands might not frequently visit GSV, while white sharks sighted in GSV or along the metropolitan coastline might not frequent the Neptune Islands. Tagging of white sharks within GSV is required to test whether these sharks are more likely to be detected within GSV and whether they are detected at the Neptune Islands as frequently as those tagged there.

1. INTRODUCTION

Harvesting living marine resources can impact the population levels and conservation status of target and bycatch species, and reduce the complexity of food webs and the number of trophic levels present in marine ecosystems (Pauly *et al.*, 2002). The corollary is that heavily exploited marine ecosystems can be thrown out of balance, with catastrophic implications for the rest of the species in the system (Myers *et al.*, 2007; Ruppert *et al.*, 2013). Species particularly at risk of overexploitation are those that are highly valued, slow to mature, and have sporadic or low recruitment (Musick, 1999; Frisk *et al.*, 2005; Field *et al.*, 2009b). Such characteristics are typical of sharks (Field *et al.*, 2009a), which are fished commercially and recreationally throughout the world (Walker, 1998). Recent depletion of shark populations and other top oceanic predators has raised concerns over the sustainability of global shark populations and their fisheries, as well as the stability of ocean ecosystems (Baum *et al.*, 2003; Burgess *et al.*, 2006; Clarke *et al.*, 2006; Worm *et al.*, 2013). In response, the International Plan of Action for the Conservation and Management of Sharks was developed in 1999, and in 2004 the first Australian National Plan of Action for the Conservation and Management of Sharks was released to ensure the sustainable management of Australia's shark populations into the future (Shark Assessment Group, 2004) and was subsequently reviewed between 2009 and 2012 (Bensley *et al.*, 2010; DAFF, 2012).

In Australia, sharks are caught by commercial, recreational, and traditional fishers as targeted and non-targeted catch (Field et al., 2009b). The commercial industry comprises State-, Territory- and Commonwealth-managed fisheries that catch an average of 10,733 tonnes of shark per year with a value of approximately AU$31–48 million (Bensley et al., 2010). Despite well-documented concerns about the sustainability of a range of shark populations and their potential vulnerability to fisheries, population assessments for the majority of shark species in Australia have not been conducted (Field et al., 2009b). Population assessments rely on high-quality catch and effort data, that for many species is sparse or imprecise (Walker, 1998; Field et al., 2009b). Population assessments also require information on population structure, extent of movements and migratory patterns, and residency within specific areas, to determine how the spatio-temporal dynamics of sharks affect their resilience to fisheries, and to ensure that fishing does not result in long-term population decline. Gaining information on critical habitat of sharks and improving our understanding of their movement patterns have been identified as priorities during the review of the Australian National Plan of Action (Bensley et al., 2010).

Additionally, the vulnerability of sharks within Gulf St Vincent, and more specifically within the Adelaide metropolitan region, is likely to be accentuated as a result of the increased anthropogenic effect on the ecosystem around South Australia's capital city. In South Australia, whaler sharks (*Carcharhinus* species) are of low economic value to the commercial fishing industry because of their relatively small catches compared to snapper or garfish. White sharks cannot be commercially targeted due to their protected status. These factors have resulted in these species being precluded from fisheries research programs. However, the vulnerability to overfishing due to their K-selected life history strategies (i.e., reduced fecundity, slow growth rate leading to delayed maturity, low natural mortality) led to these species being identified as having conservation and management significance.

1.1 Bronze whaler (*Carcharhinus brachyurus*) and dusky shark (*C. obscurus*)

Bronze whalers and dusky sharks have cosmopolitan distributions, but are largely restricted to coastal and continental shelf waters (Last and Stevens, 2009). Dusky sharks are among the most vulnerable and high-risk of all marine vertebrates to overexploitation (Simpfendorfer *et al.*, 2002; Romine *et al.*, 2009), and the reproductive modes of both species are more similar to marine mammals and sea turtles than to bony fishes. Their life history characteristics include slow growth rates, late sexual maturity (> 20 years), and low fecundity (reproduction every 2–3 years) (Walter and Ebert, 1991a; McCauley *et al.*, 2007; Romine et al., 2009). Both species are recognised globally as being of conservation concern; the bronze whaler is currently listed as Near Threatened on the International Union for Conservation of Nature (IUCN) Red List (Duffy and Gordon, 2003) and the dusky shark has been listed as globally Vulnerable (Musick *et al.*, 2009), due to declines in catch rates in the western North Atlantic (Musick *et al.*, 1993) and Gulf of Mexico (Baum and Myers, 2004). National and international concern for the dusky whaler shark has also led to its inclusion on the *Environment Protection and Biodiversity Conservation (EPBC) Act 1999* Priority Assessment list since 2009.

Bronze whalers and dusky sharks are caught by commercial fisheries in New South Wales (NSW), South Australia (SA) and Western Australia (WA). In South Australia, *C. brachyurus* and *C. obscurus* are seasonally targeted by longline fishers within the Marine Scalefish Fishery (MSF), with the largest percentage of the catches originating from Spencer Gulf and Gulf St Vincent (Fowler *et al.*, 2012b; Fowler *et al.*, 2013). A review funded by the Fisheries Research and Development Corporation on whaler sharks found virtually no published information with which to assess potential impacts of the bronze whaler and dusky shark catches in South Australia (Jones, 2008). More recently, the vulnerability to extinction of these species was assessed using a fuzzy logic model, ranking *C. obscurus* as the second most vulnerable species compared to six sympatric pelagic shark species, and *C. brachyurus* in the mid to lower end of the spectrum (Rogers *et al.*, 2013a). Additionally, SA currently has no species-specific management structure to ensure the sustainability of whaler shark populations or their fisheries (Jones, 2008). Catch per unit effort data from SA fisheries show a declining trend in whaler shark catch since 2000, with 2007–2008 having the lowest catch per unit effort and 2009–2010 having the highest fishing effort ever recorded (Fowler *et al.*, 2010; Rogers et al., 2013a). Out of the 15 performance indicators and limit reference points set by the Marine Scalefish Fishery to monitor secondary species, five were reached by the bronze whaler and dusky shark fishery in the 2011/12 financial year (Fowler *et al.*, 2012a). The Ecologically Sustainable Development (ESD) Risk Assessment of the South Australian MSF also concluded that the current catch level of whaler sharks within the MSF would be having severe consequences on their populations (PIRSA, 2011).

1.2 White shark (*Carcharodon carcharias*)

The white shark is a monotypic and morphologically distinctive shark species with low reproductive rebound potential. World-wide concern regarding its population status has prompted listings under the International Union for the Conservation of Nature (IUCN – Vulnerable), the Convention on International Trade in Endangered Species (CITES – Appendix I + II), and the Convention on Migratory Species (CMS – Appendix I + II), and resultant protection in a number of jurisdictions. White sharks are listed as Vulnerable under the *EPBC Act, 1999* and are fully protected in all Australian waters. However, as identified by the National Recovery Plan for White Sharks, the Australian white shark population is still threatened by interactions with commercial and recreational fishing, shark control activities (e.g., beach meshing), trade in body parts (e.g., fins), and the potential impacts of ecotourism and cage-diving operations.

Previous limited satellite tagging has shown that white sharks exhibit movements that include the Great Australian Bight and South Australian Gulfs (Bruce *et al.*, 2006). Additionally, a pilot study assessing the use of acoustic telemetry to determine alongshore movements of white sharks across Glenelg Beach detected that a white shark spent about a month off this beach with regular detections every 1–3 days. Apart from these limited data, the spatial use of the South Australian Gulfs and the waters of the Adelaide metropolitan region by white sharks is unknown. The present study provides information on the temporal occurrence of white shark visitations and potentially important habitat within the Adelaide coastal region.

2. OBJECTIVES

The aims of this study were to monitor species of conservation concern, specifically *C. brachyurus, C. obscurus*, and *C. carcharias,* in the Adelaide metropolitan region and to expand the existing acoustic telemetry array within Gulf St Vincent (GSV) (Huveneers *et al.*, 2012). Specifically, the aims were to:

- Provide information about the spatio-temporal movement and residency dynamics of *C. brachyurus* and *C. obscurus*; and
- Increase our knowledge of the timing and length of *C. carcharias* visitations within the Adelaide coastal region.

3. METHODS

3.1 Acoustic receivers array

Based on the analysis of detections obtained between April 2008 to May 2012 (Huveneers et al 2012), the acoustic array of 50 receivers was modified and extended between May–August 2012. In the metropolitan region, the curtains of four receivers off the Torrens River mouth and two receivers off Grange were removed, while seven receivers were deployed at new locations off Aldinga. In the Northeast GSV region, the monitoring of four locations was terminated and replaced by seven new locations due to a low number of detections. In the Northwest GSV region, the monitoring of three locations was terminated and replaced by six new locations. This resulted in the GSV acoustic array being expanded to 57 receivers (Figure 1). Twenty-six, 13, and 18 receivers were deployed in the metropolitan, Northeast GSV, and Northwest GSV regions, respectively. The 39 receivers deployed in the Adelaide and Mount Lofty Ranges NRM region (metropolitan and Northeast GSV areas) were deployed to monitor *C. brachyurus, C. obscurus*, and *C. carcharias*, while the 18 receivers in the Northwest GSV region were deployed through a joint project with the SARDI finfish fisheries subprogram aimed at increasing the understanding of snapper (*Pagrus auratus*) movement in Northern GSV. Receivers were coated in anti-fouling paint, and either affixed to a 1.65 m long steel post that was hammered into the substratum to at least 0.6–0.8 m depth, or affixed to a post embedded within a 70–90 cm diameter concrete-filled car tyre.

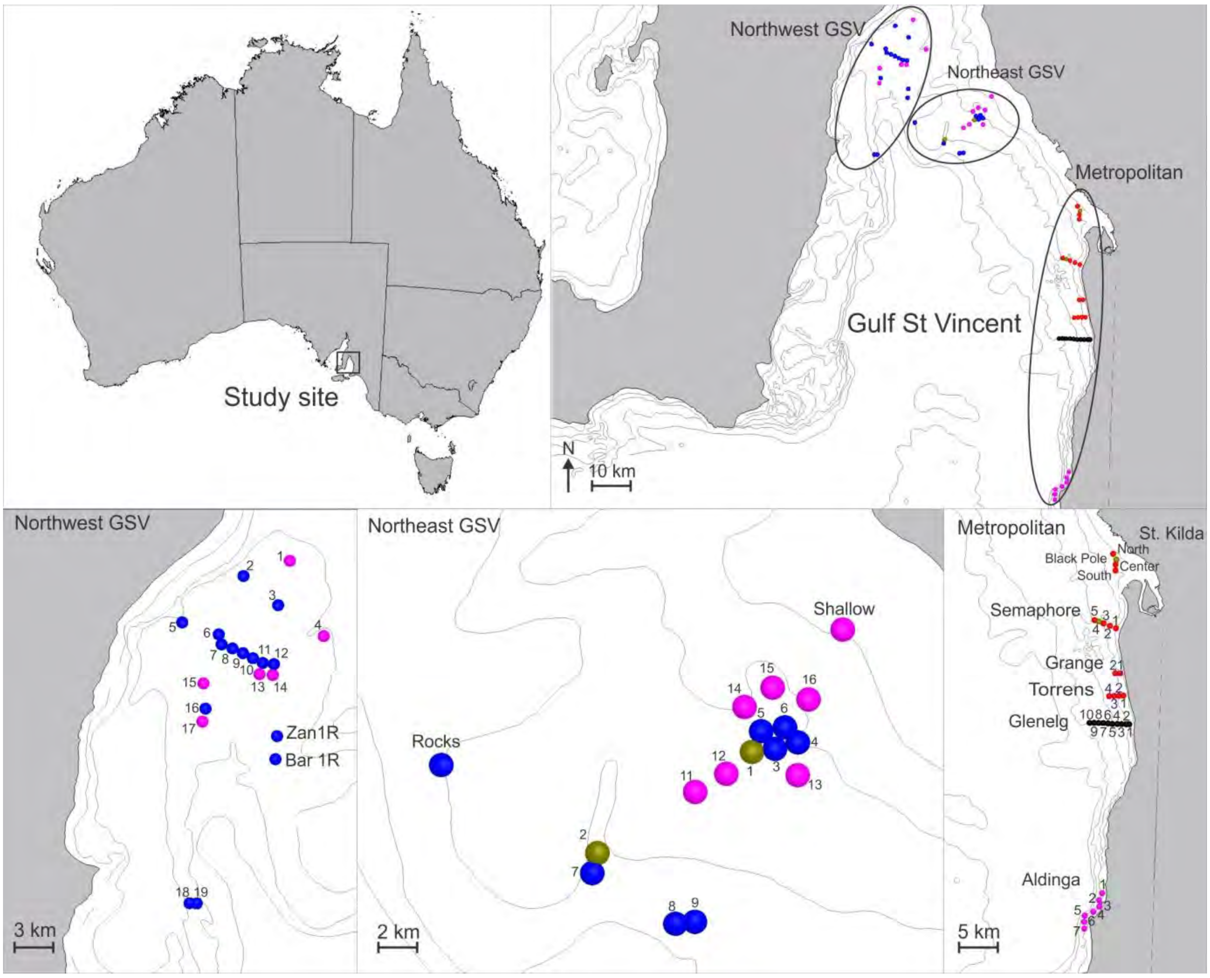

Figure 1. Locations of receivers deployed in Gulf St Vincent between 2008 and 2013. Black circles represent receivers deployed in April 2008, green circles represent receivers deployed in March 2010; red circles represent receivers deployed in December 2010, blue circles represent receivers deployed in May 2011, pink circles represent receivers deployed between May and August 2012.

Additionally, over 2,000 acoustic receivers are deployed around Australia as part of the Australian Animal Tagging and Monitoring System (AATAMS) facility, part of the Integrated Marine Observing System (IMOS), established to monitor the movements and migrations of organisms around Australia (Figure 2). The compatibility of the hardware and the collaboration across research agencies ensured that sharks tagged during the present study could be detected by these receivers, thereby extending acoustic coverage around Australia.

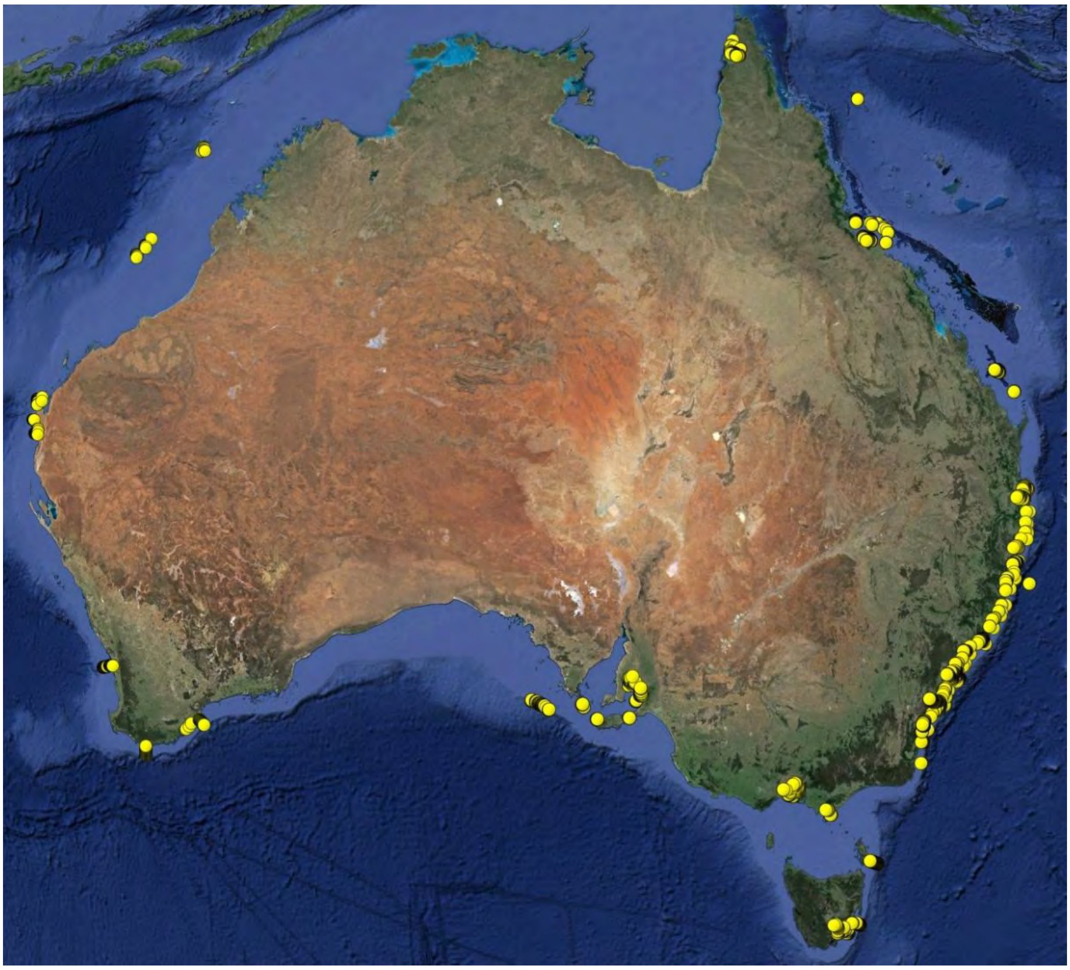

Figure 2. Locations of acoustic receivers (yellow circles) deployed in Australia as part of the Australian Animal Tagging and Monitoring System (AATAMS).

3.2 Tagging

3.2.1 Bronze whaler (Carcharhinus brachyurus) and dusky shark (C. obscurus)

Carcharhinus brachyurus and *C. obscurus* were caught using floating longlines, and rod and reel. Longlines consisted of floating rope main-lines with 1.7 mm stainless steel leaders with up to 110 16/0 stainless steel circle hooks attached to the main-line by way of a stainless steel clip. The main-line was up to 2.2 km long, anchored and marked at each terminal end with 20 to 70 cm diameter rubber floats. Hooks were spaced along the main-line at intervals of 7–12 m, with small floats every two hooks. Sharks caught off St Kilda were caught in collaboration with recreational fishers who used suspended baits under balloons using heavy tackle (30–80 lb line) and leaders of 1.5–1.7 mm nylon-coated wire attached to 12/0 or 14/0 J-style hooks.

Once captured, sharks over two metres were restrained alongside the boat using a small rubber sling, sharks less than two metres were brought onboard onto a foam mattress. Seawater was circulated across the gills of each shark using an external submersible bilge pump to ensure continuous oxygenation throughout the surgery. A small incision (2–4 cm) was made posterior to the pelvic fins to insert a Vemco V16-6H tag into the body cavity. The minimum and maximum time interval between each pulse transmission was set at 50 and 110 seconds, respectively. The incision was stitched using 2–3 non-continuous external sutures (3/0 Monosyn absorb violet 70 cm, needle tapercut) (Figure 3). Oxytetracycline at a dose of 20 ml/kg body weight was injected into the dorsal musculature to prevent infection, while a plastic head conventional identification tag (Hallprint™, Hindmarsh Valley) was inserted into the muscle below the first dorsal fin to aid identification in case of recapture, or capture by commercial or recreational fishers. Prior to being released, the total length (TL) of each shark was measured to the nearest 1 mm. The maturity stage of males was assessed based on the degree of clasper calcification (Walker, 2007). The state of maturity of females was determined based on the published size-at-first maturity of 2290 mm TL for *C. brachyurus* (Walter and Ebert, 1991b) and 2,200 mm fork length (FL) for *C. obscurus* (Simpfendorfer *et al.*, 1999). Two sharks were externally tagged by recreational fishers under the first dorsal fin in the dorsal musculature using a pole and stainless steel applicator. For external tagging, V16-6H tags were affixed to a stainless steel dart tag (Hallprint™, Hindmarsh Valley) using fast setting epoxy (Knead it®).

In addition, the Western Australian Department of Fisheries also internally tagged *C. brachyurus* and *C. obscurus* in WA as part of a project funded by the Fisheries Research and Development Corporation using similar methods (Project 2010/003: Spatial and temporal dynamics of Western Australia’s commercially important sharks).

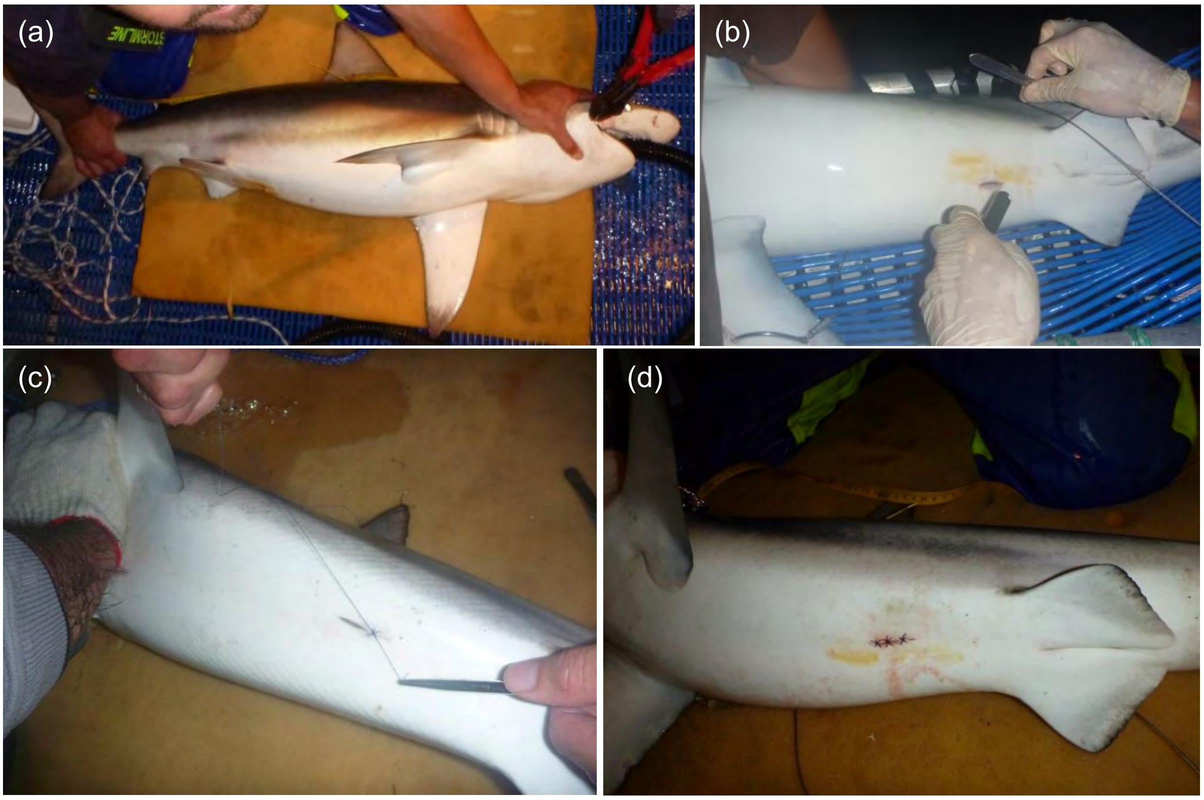

Figure 3. Internal tagging procedure of a *Carcharhinus brachyurus* showing (a) captured shark, (b) incision and tag insertion, (c) suturing, and (d) finished sutures.

3.2.2 White shark (Carcharodon carcharias)

White sharks were tagged with V16 acoustic transmitters (VEMCO Ltd., Halifax, Canada) at the Neptune Islands, South Australia and off Western Australia as part of other projects led by the Department of Fisheries, Western Australia and the Commonwealth Scientific and Industrial Research Organisation (CSIRO). In South Australia, transmitters were tethered to an umbrella or metal dart-tag head using a 10–15 cm long stainless wire trace and externally implanted in the dorsal musculature of sharks using a tagging pole when sharks were attracted close to the white shark cage-diving operation (Figure 4). In Western Australia, sharks were also tagged internally and externally using similar attachment and deployment methods, and surgical techniques.

Figure 4. External tagging of a *Carcharodon carcharias* at North Neptune Islands.

3.3 Data analysis

A Chi-square (χ^2) test was used to determine if the sex ratio of each of *C. brachyurus* and *C. obscurus* differed from unity. A two-sample Mann-Whitney test was used to test the difference in size distribution between sexes for *C. brachyurus*. This was not undertaken for *C. obscurus* because of the small sample size (n=9). Combining sexes, a Mann-Whitney test was also used to compare the size distributions of the two species.

For the analysis of presence and absence of acoustically tagged sharks, receivers were grouped into four clusters: Northeast GSV, metropolitan (receivers deployed between St Kilda and Aldinga and within 10 km of the coast), Northwest GSV, and GSV (all regions combined). Site fidelity was quantified using two residency indices (RI). The overall residency index (RI_o) was calculated by dividing the number of days a shark was present by the monitoring period (number of days between date of tagging and last download). The detected residency index (RI_d) was calculated by dividing the number of days a shark was present by the period during which sharks were detected. Sharks monitored for less than four months were removed from graphical representations and summary statistics to avoid biases due to the short monitoring period. Two residency indices, RI_d and RI_o, were used because the fate of sharks leaving the area acoustically covered by the receivers was unknown and might include: death due to post-release stress following handling and tagging, capture by recreational fishers, or emigration. Since the fate of these sharks is unknown, and these sharks might not have left the array naturally, RI_o can potentially under-estimate residency. On the other hand, RI_d does not account for sharks that naturally leave the acoustic array and might over-estimate residency. The use of both estimates of residency allows one to account for such biases, and is recommended in studies where the fate of tagged organisms is unknown. An individual was considered 'present' within the array if it was detected at least twice within a 24-hour period. This eliminated the possibility of 'false detections', which may occasionally occur when there are multiple acoustic tags present within range of an array of receivers (Pincock, 2011). A value of 0 indicated no residency and a value of 1 indicated 100% residency. Correlation between total length (TL) and RI was tested using the Spearman or Pearson correlation test, depending on whether the data was normally distributed as determined by a Shapiro-Wilk test.

3.3.1 Temporal variations in residency

The short- (daily) and long-term (monthly) temporal dynamics of shark residency were assessed by comparing the number of detections and the number of individual sharks detected within each region per hour and per month.

Acoustic detectability can be affected by environmental conditions potentially biasing the probability of detecting a tagged shark in the proximity of a receiver (Payne *et al.*, 2010; Gjelland and Hedger, 2013). The death of one shark close to one of the acoustic receivers (see Results section) allowed for temporal variation in acoustic detectability to be determined and accounted for. The tag from the dead shark (thereafter referred to as 'sentinel tag') was detected by the acoustic receiver on 635 days over two years. A diel and annual pattern was observed, with the highest number of detections occurring during daytime (8 am–6 pm) and in winter (June–August) (Figure 5).

To account for the diel and annual patterns in the number of detections, a corrected detection frequency for each hourly and monthly bin was calculated for each shark using the formula from Payne et al. (2010):

$$_{b} \quad \frac{_{b}}{}$$

Where CDF is the corrected detection frequency for each hourly or monthly bin (b), μ is the overall mean hourly or monthly detection frequency and B is the mean detection frequency in each 24-hour or 12-month bin for the sentinel tag. For each shark, the total detection frequency of each hourly or monthly bin was divided by the CDF of the corresponding hourly or monthly bin from the sentinel tag (Payne et al., 2010). The corrected hourly and monthly detection frequencies were then standardised by the total number of detections for that shark (thereafter referred to as standardised number of detections) to avoid sharks with the most detections biasing calculations of temporal variation. Although a sentinel tag was only present in proximity to one receiver, and detection probability varies between habitat and environmental conditions (How and de Lestang, 2012; Cagua *et al.*, 2013), receivers were deployed in similar habitat and were exposed to similar weather conditions. In the future, sentinel tags should be deployed in proximity to additional receivers to validate the variations in detection probability observed in this study.

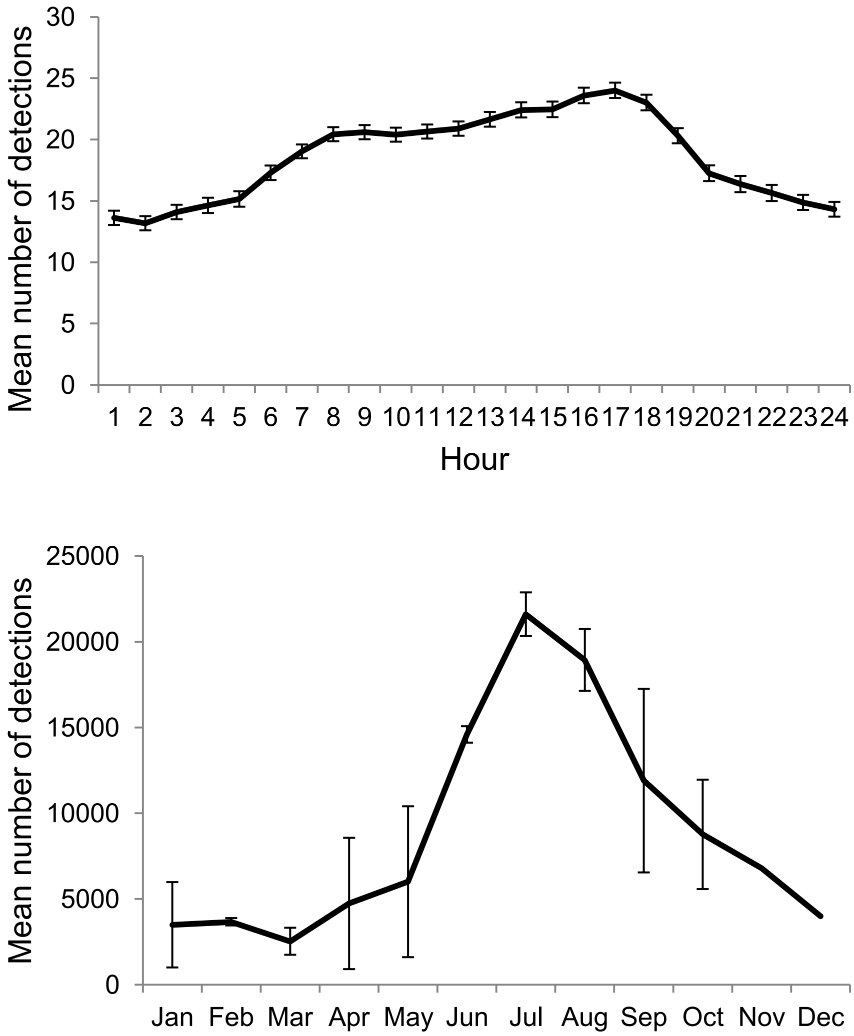

Figure 5. Mean number of detections per hour (a) and per month (b) for the sentinel tag. Error bars represents standard error across days (n = 635) and years (n = 2).

3.3.2 Spatial distribution and large-scale movements

The fine-scale distribution of sharks in GSV was assessed by comparing the number of detections and the number of individual sharks detected between stations and regions. As acoustic coverage expanded throughout the study period, receivers were not all deployed for the same period of time. The difference in deployment periods between individual receivers and total number of detections between individual sharks was accounted for by standardising the number of detections per receiver for each individual shark by the number of days the receiver was deployed and by the total number of detections.

When sharks were detected outside GSV by acoustic receivers from other organisations, the minimum distance travelled was estimated using Google Earth, and the rate of movement, was estimated by dividing the minimum distance travelled by the period between the last detection within GSV and the first detection by the receiver outside GSV.

Throughout the results, values provided are mean ± standard error.

4. RESULTS AND DISCUSSION

4.1 Tagging events

Thirty-seven field trips to capture and tag *C. brachyurus* and *C. obscurus* were conducted between October 2009 and February 2013, with all trips occurring between October and April (Table 1).

Table 1. Details of tagging trips in Gulf St Vincent to internally tag *Carcharhinus brachyurus* and *C. obscurus* with acoustic transmitters

Date	Location	Gear type	No of line set	No of hooks	No of sharks caught
30/10/2009	St Kilda	Longline	1	40	0
11/11/2009	St Kilda	Longline	1	70	0
2/12/2009	Goanna	Longline	1	80	0
31/01/2010	Northeast GSV	Longline	2	90	10
17/03/2010	Northeast GSV	Longline	2	120	0
25/10/2010	Northeast GSV	Longline	2	103	0
10/11/2010	Northeast GSV	Longline	2	103	0
24/11/2010	Northeast GSV	Longline	2	96	2
13/01/2011	Northeast GSV	Longline	1	150	7
31/01/2011	Northeast GSV	Longline	2	100	6
19/10/2011	Northeast GSV	Longline	2	104	3
26/10/2011	Black pole	Rod and reel	1	1	0
1/11/2011	Black pole	Rod and reel	1	1	0
3/11/2011	Northeast GSV	Longline	2	85	17
8/11/2011	Glanville/Black pole	Longline	1	50	1
9/11/2011	Black pole	Rod and reel	1	1	0
17/11/2011	Black pole	Longline	1	50	1
14/02/2012	Northeast GSV	Longline	1	92	11
23/02/2012	Northeast GSV	Longline	1	110	0
4/04/2012	Northeast GSV	Longline	1	100	1
16/11/2009-30/11/2010*	St Kilda	Rod and reel	3	3	5
22/11/2012	Northeast GSV	Longline	1	100	14
23/11/2012	Black Pole	Rod and reel	1	2	0
28/11/2012	Northeast GSV	Longline	1	85	7
5/12/2012	Northeast GSV	Longline	2	99	6
7/01/2013	Aldinga Reef	Longline	1	35	0
10/01/2013	Northeast GSV	Longline	1	93	1
23/01/2013	Goannas	Longline	1	85	12
6/02/2013	Northeast GSV	Longline	1	76	0
21/02/2013	Northeast GSV	Longline	1	81	9

* Eight trips were undertaken off St Kilda with recreational fishers to deploy acoustic tags.

4.2 Capture and tagging

A total of 113 *Carcharhinus* sharks were captured during 37 field trips. These were composed of 95 *C. brachyurus*, 16 *C. obscurus* and two sharks for which species could not be confirmed because they were captured and tagged by recreational fishers. The number of sharks caught per trip ranged from 0–17 (mean 3.8 ± 0.9; median 1), with no sharks caught during nine longlining trips (36% of longlining trips) (Figure 6). By-catch species included snapper (*P. auratus*), smooth rays (*Dasyatis brevicaudata*), Port Jackson sharks (*Heterodontus portusjacksoni*), and smooth hammerheads (*Sphyrna zygaena*). Sharks that were considered to be too small to be internally tagged with a V16 acoustic tag or that were not in healthy condition were tagged with a conventional identification tag and released.

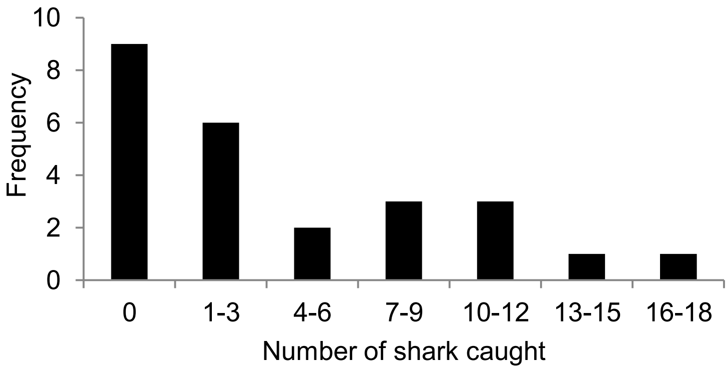

Figure 6. Histogram of the combined number of *Carcharhinus brachyurus* and *C. obscurus* caught per trip using longlines in Gulf St Vincent (25 trips total).

Gender was assessed for 107 of the 113 (95%) captured sharks with no significant deviation in the sex ratio for males to females from 1:1 for *C. brachyurus* (0.75:1, n=91, χ^2=1.86, P=0.17) or *C. obscurus* (1:1, n=16, χ^2=0.00, P=0.99). Total length was measured for 92 *C. brachyurus* and 16 *C. obscurus*, and ranged from 690–2750 mm for *C. brachyurus* and 960–1870 mm for *C. obscurus*. However, 90% of *C. brachyurus* and 75% of *C. obscurus* were <1500 mm TL (Figure 7). There was no significant difference in the size distribution between sexes for *C. brachyurus* (Mann-Whitney test: n=91, W=11600, P=0.16). Combining sexes, *C. obscurus* were larger than *C. brachyurus* (Mann-Whitney test: n=16, W=449, P=0.01) (Figure 7). Based on clasper calcification, all males were sexually immature. Based on our comparisons with published sizes-at-maturity, all females, but one 2750 mm TL *C. brachyurus*, were classified as immature.

The size-frequency distribution of *C. brachyurus* caught during this study is similar to that of whaler species (*C. brachyurus* and *C. obscurus* combined) caught by recreational fishers and conventionally tagged as part of the NSW game tagging program (Pepperell, 1990; Pepperell, 2011). *Carcharhinus brachyurus* and *C. obscurus* from this study (900 and 1050 mm TL, respectively) are, however, smaller than that of commercial catches (1200 and 1600 mm TL, respectively) (M. Drew, unpublished data; Rogers et al., 2013a). The large proportion of juvenile *C. brachyurus* and *C. obscurus* commercially caught within Spencer Gulf and GSV, and during this study, suggests that the South Australian gulfs represent ecologically significant habitats for the juvenile stages of these species (Rogers et al., 2013a). Size-frequency distributions from commercial catches (M. Drew, unpublished data; Rogers et al., 2013a) and fisheries-independent sampling (this study) also suggest that the mean size of *C. obscurus* in GSV is greater than that of *C. brachyurus*, and that large juveniles and adults of both species are less abundant.

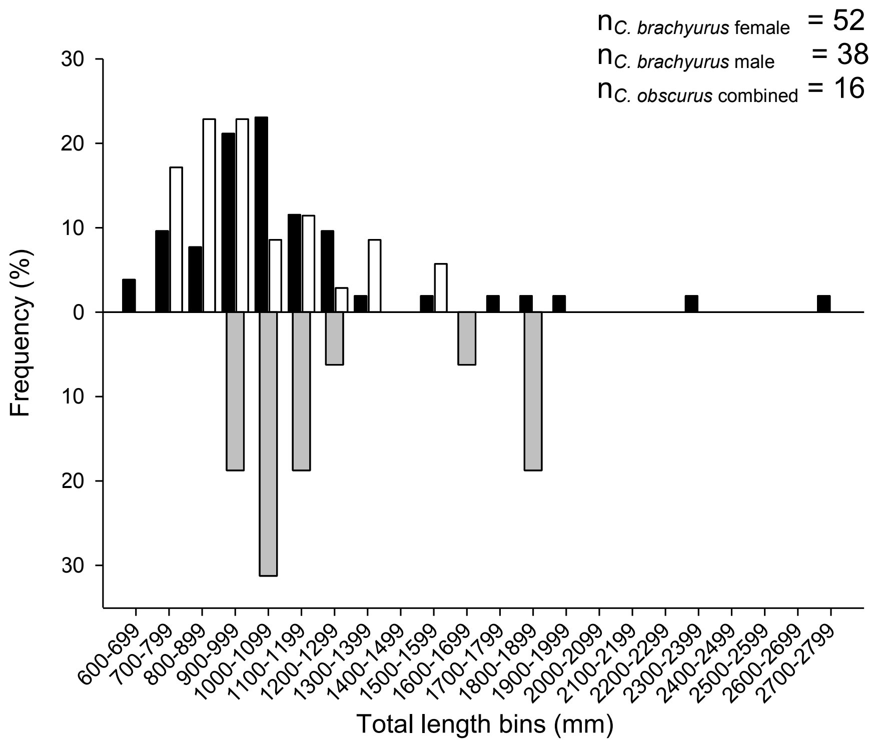

Figure 7. Size-frequency of sharks captured in Gulf St Vincent. White bars represent male *Carcharhinus brachyurus*, black bars represent female *C. brachyurus*, and gray bars represent *C. obscurus*. Male and female *C. obscurus* were combined due to small sample size.

Eighty *C. brachyurus* (32 male, 44 female, and four unknown sex) and 11 *C. obscurus* (six males and five females) were tagged with conventional identification tags. An acoustic tag was inserted in 64 of the 91 (70%) conventionally tagged sharks. Of those, 55 were *C. brachyurus* (22 males, 31 females, and two unknown) and nine were *C. obscurus* (five males and four females). All but two of the acoustically tagged sharks were tagged in the Northeast GSV region. Sharks 13 and 14 were tagged off St Kilda (Table 2).

4.3 Detections of bronze whalers and dusky sharks

Fifty-five sharks (86% of tagged sharks) were detected over the monitoring period (October 2009 to May 2013). Of these, 48 were *C. brachyurus* (87% of tagged *C. brachyurus*) and seven were *C. obscurus* (78% of tagged *C. obscurus*). The regular and near constant detection of two *C. brachyurus* (a 780 mm TL male and a 1,230 mm TL female) by only one receiver suggested that they died close to that receiver. The 780 mm male was detected 209,140 times over two years and was used as a sentinel tag to calculate the standardised detection frequency. The 1,230 mm female shark had 21,300 detections over seven months. This shark was not used as a sentinel tag because of the smaller number of detections, which was likely due to this shark dying further away from the receiver, and because of the shorter detection period (seven months vs. over two years). Removing the detections from these two presumed dead sharks, the number of acoustic detections of individual tagged sharks ranged from 2–4,443 (mean 773.8 ± 148.5 detections; median 197) (Table 2).

Table 2. Summary of detections obtained from acoustically tagged sharks in South Australian waters. 'Period monitored' represent the number of days between tagging and last download. GSV = Gulf St Vincent

Shark no	Species	TL	Sex	Season	Tagged	Period monitored	Number of detections				Number of days detected			
							All regions	Northeast GSV	Northwest GSV	Metropolitan	All regions	Northeast GSV	Northwest GSV	Metropolitan
1 [a]	*C. brachyurus*	780	Male	2009-10	31/01/2010	1206	*	*	*	*	*	*	*	*
2	*C. brachyurus*	1100	Female	2009-10	31/01/2010	1206	1535	322	29	1184	59	19	4	36
3	*C. brachyurus*	1060	Female	2009-10	31/01/2010	1206	188	156	0	32	18	13	0	5
4	*C. brachyurus*	1320	Male	2009-10	31/01/2010	1206	*	*	*	*	*	*	*	*
5	*C. brachyurus*	1230	Female	2009-10	31/01/2010	1206	119	117	0	2	6	5	0	1
6	*C. brachyurus*	1100	Female	2010-11	24/11/2010	909	*	*	*	*	*	*	*	*
7	*C. brachyurus*	1540	Male	2010-11	24/11/2010	909	921	901	20	0	47	46	1	0
8	*C. brachyurus*	740	Male	2010-11	13/01/2011	859	*	*	*	*	*	*	*	*
9	*C. brachyurus*	1140	Male	2010-11	13/01/2011	859	318	0	0	318	12	0	0	12
10 [a]	*C. brachyurus*	1230	Female	2010-11	14/01/2011	858	*	*	*	*	*	*	*	*
11	*C. brachyurus*	915	Female	2010-11	31/01/2011	841	136	78	0	58	5	3	0	2
12	*C. brachyurus*	850	Male	2010-11	31/01/2011	841	9	0	0	9	1	0	0	1
13 [b]	*C. brachyurus*	-	Unknown	2010-11	-	-	2092	1166	926	0	52	30	22	0
14 [b]	*C. brachyurus*	-	Unknown	2010-11	-	-	1206	1065	4	137	49	40	1	8
15	*C. brachyurus*	1365	Male	2011-12	19/10/2011	580	92	77	15	0	8	6	2	0
16	*C. brachyurus*	950	Male	2011-12	19/10/2011	580	1429	1429	0	0	37	37	0	0
17	*C. brachyurus*	1150	Male	2011-12	3/11/2011	565	2860	2844	16	0	77	76	1	0
18	*C. brachyurus*	1060	Female	2011-12	3/11/2011	565	95	95	0	0	3	3	0	0
19	*C. brachyurus*	1030	Female	2011-12	3/11/2011	565	921	739	125	57	54	43	8	3
20	*C. brachyurus*	920	Male	2011-12	3/11/2011	565	197	197	0	0	12	12	0	0
21	*C. brachyurus*	890	Male	2011-12	3/11/2011	565	7	7	0	0	1	1	0	0
22	*C. brachyurus*	1900	Female	2011-12	3/11/2011	565	31	10	21	0	5	3	2	0
23	*C. brachyurus*	1360	Female	2011-12	14/02/2012	462	534	505	0	29	23	22	0	1
24	*C. brachyurus*	1030	Female	2011-12	14/02/2012	462	857	734	71	52	32	26	4	3
25	*C. brachyurus*	1040	Male	2011-12	14/02/2012	462	1891	428	892	571	51	7	26	19
26	*C. brachyurus*	990	Male	2011-12	15/02/2012	461	727	107	109	511	25	1	1	23
27	*C. brachyurus*	1140	Male	2011-12	15/02/2012	461	2235	552	307	1376	36	12	6	18
28	*C. brachyurus*	950	Male	2011-12	15/02/2012	461	1425	0	1393	32	39	0	37	2
29	*C. brachyurus*	1150	Female	2011-12	4/04/2012	412	4166	4116	0	50	43	40	0	3
30	*C. brachyurus*	1210	Female	2012-13	22/11/2012	180	89	89	0	0	4	4	0	0
31	*C. brachyurus*	1730	Female	2012-13	23/11/2012	179	127	127	0	0	8	8	0	0
32	*C. brachyurus*	2320	Female	2012-13	23/11/2012	179	349	320	29	0	12	10	2	0
33	*C. brachyurus*	860	Male	2012-13	23/11/2012	179	67	67	0	0	17	17	0	0
34	*C. brachyurus*	1300	Female	2012-13	29/11/2012	173	93	93	0	0	5	5	0	0
35	*C. brachyurus*	1240	Male	2012-13	29/11/2012	173	49	49	0	0	13	13	0	0
36	*C. brachyurus*	1030	Female	2012-13	29/11/2012	173	8	8	0	0	1	1	0	0
37	*C. brachyurus*	2750	Female	2012-13	29/11/2012	173	23	23	0	0	7	7	0	0
38	*C. brachyurus*	790	Male	2012-13	29/11/2012	173	33	14	0	19	3	1	0	2

Shark no	Species	TL	Sex	Season	Tagged	Period monitored	Number of detections				Number of days detected			
							All regions	Northeast GSV	Northwest GSV	Metropolitan	All regions	Northeast GSV	Northwest GSV	Metropolitan
39	*C. brachyurus*	1220	Female	2012-13	29/11/2012	173	21	14	0	7	2	1	0	1
40	*C. brachyurus*	980	Female	2012-13	5/12/2012	167	*	*	*	*	*	*	*	*
41	*C. brachyurus*	790	Female	2012-13	5/12/2012	167	3533	2226	1300	7	58	30	27	1
42	*C. brachyurus*	1550	Male	2012-13	6/12/2012	166	2	0	2	0	1	0	1	0
43	*C. brachyurus*	1560	Female	2012-13	6/12/2012	166	11	0	11	0	1	0	1	0
44	*C. brachyurus*	880	Female	2012-13	10/01/2013	131	60	60	0	0	1	1	0	0
45	*C. brachyurus*	1190	Female	2012-13	24/01/2013	117	135	135	0	0	2	2	0	0
46	*C. brachyurus*	1040	Female	2012-13	24/01/2013	117	254	254	0	0	3	3	0	0
47	*C. brachyurus*	900	Female	2012-13	24/01/2013	117	3319	3163	8	148	32	27	1	4
48	*C. brachyurus*	920	Female	2012-13	24/01/2013	117	36	36	0	0	1	1	0	0
49	*C. brachyurus*	900	Male	2012-13	24/01/2013	117	368	74	294	0	10	4	6	0
50	*C. brachyurus*	970	Female	2012-13	24/01/2013	117	*	*	*	*	*	*	*	*
51	*C. brachyurus*	1150	Male	2012-13	21/02/2013	89	122	122	0	0	3	3	0	0
52	*C. brachyurus*	1040	Female	2012-13	22/02/2013	88	167	39	0	128	10	2	0	8
53	*C. brachyurus*	990	Female	2012-13	22/02/2013	88	4443	4166	13	264	59	55	1	4
54	*C. brachyurus*	1010	Female	2012-13	22/02/2013	88	1174	1174	0	0	31	31	0	0
55	*C. brachyurus*	850	Male	2012-13	22/02/2013	88	846	804	0	42	18	16	0	2
1	*C. obscurus*	1700	Male	2009-10	31/01/2010	1206	*	*	*	*	*	*	*	*
2	*C. obscurus*	1070	Male	2009-10	31/01/2010	1206	99	99	0	0	5	5	0	0
3	*C. obscurus*	1850	Male	2010-11	13/01/2011	859	*	*	*	*	*	*	*	*
4	*C. obscurus*	1870	Male	2010-11	14/01/2011	858	841	841	0	0	35	35	0	0
5	*C. obscurus*	1190	Female	2010-11	14/01/2011	858	903	902	1	0	57	56	1	0
6	*C. obscurus*	1190	Female	2010-11	14/01/2011	858	10	10	0	0	10	10	0	0
7	*C. obscurus*	1250	Female	2011-12	15/02/2012	461	223	219	4	0	10	9	1	0
8	*C. obscurus*	1040	Female	2012-13	22/11/2012	180	59	59	0	0	3	3	0	0
9	*C. obscurus*	1850	Male	2012-13	23/11/2012	179	1102	1086	16	0	32	30	3	0

[a] Based on the continuous detections by only one receiver, shark is considered to have died in the array.

[b] Tagging was undertaken by recreational fishers who did not record the tagging date. Hence, values could not be calculated.

* Indicates that shark was never detected.

Table 3. Residency index from tagged sharks in South Australian waters. GSV = Gulf St Vincent

	Overall residency index				Detected residency index			
Shark no	All regions	Northeast GSV	Northwest GSV	Metropolitan	All regions	Northeast GSV	Northwest GSV	Metropolitan
1 [a]	*	*	*	*	*	*	*	*
2	0.05	0.02	0	0.03	0.08	0.03	0.01	0.05
3	0.01	0.01	0	0	0.03	0.02	0	0.01
4	*	*	*	*	*	*	*	*
5	<0.01	0	<0.010	0	0.01	0.01	0	<0.01
6	*	*	*	*	*	*	*	*
7	0.05	0.05	0	0	0.06	0.06	<0.01	0
8	*	*	*	*	*	*	*	*
9	0.01	0	0	0.01	0.1	0	0	0.1
10 [a]	*	*	*	*	*	*	*	*
11	0.01	0	0	0	0.02	0.01	0	0.01
12	<0.01	0	0	<0.01	0.03	0	0	0.03
13 [b]	-	-	-	-	-	-	-	-
14 [b]	-	-	-	-	-	-	-	-
15	0.01	0.01	0	0	0.02	0.02	0.01	0
16	0.06	0.06	0	0	0.08	0.08	0	0
17	0.14	0.13	0	0	0.2	0.19	<0.01	0
18	0.01	0.01	0	0	0.3	0.3	0	0
19	0.1	0.08	0.01	0.01	0.13	0.11	0.02	0.01
20	0.02	0.02	0	0	0.15	0.15	0	0
21	<0.01	<0.01	0	0	0.5	0.5	0	0
22	0.01	0.01	0	0	0.15	0.09	0.06	0
23	0.05	0.05	0	0	0.07	0.07	0	<0.01
24	0.07	0.06	0.01	0.01	0.1	0.08	0.01	0.01
25	0.11	0.02	0.06	0.04	0.12	0.02	0.06	0.05
26	0.05	0	0	0.05	0.08	<0.01	<0.01	0.07
27	0.08	0.03	0.01	0.04	0.11	0.04	0.02	0.06
28	0.08	0	0.08	0	0.2	0	0.19	0.01
29	0.1	0.1	0	0.01	0.13	0.12	0	0.01
30	0.02	0.02	0	0	0.36	0.36	0	0
31	0.04	0.04	0	0	0.32	0.32	0	0
32	0.07	0.06	0.01	0	0.41	0.34	0.07	0
33	0.09	0.09	0	0	0.1	0.1	0	0
34	0.03	0.03	0	0	0.04	0.04	0	0
35	0.08	0.08	0	0	0.08	0.08	0	0
36	0.01	0.01	0	0	1	1	0	0
37	0.04	0.04	0	0	0.05	0.05	0	0
38	0.02	0.01	0	0.01	0.5	0.17	0	0.33
39	0.01	0.01	0	0.01	0.11	0.06	0	0.06
40	*	*	0	*	*	*	*	*
41	0.35	0.18	0.16	0.01	0.38	0.2	0.18	0.01
42	0.01	0	0.01	0	0.06	0	0.06	0
43	0.01	0	0.01	0	0.08	0	0.08	0
44	0.01	0.01	0	0	0.5	0.5	0	0
45	0.02	0.02	0	0	0.4	0.4	0	0
46	0.03	0.03	0	0	0.33	0.33	0	0
47	0.27	0.23	0.01	0.03	0.34	0.29	0.01	0.04
48	0.01	0.01	0	0	0.5	0.5	0	0
49	0.09	0.03	0.05	0	0.22	0.09	0.13	0
50	*	*	*	*	*	*	*	*
51	0.03	0.03	0	0	0.6	0.6	0	0
52	0.11	0.02	0	0.09	0.19	0.04	0	0.15
53	0.67	0.62	0.01	0.05	0.7	0.65	0.01	0.05
54	0.35	0.35	0	0	0.47	0.47	0	0
55	0.2	0.18	0	0.02	0.31	0.28	0	0.03
1	*	*	*	*	*	*	*	*
2	<0.01	<0.01	0	0	0.05	0.05	0	0
3	*	*	*	*	*	*	*	*
4	0.04	0.04	0	0	0.05	0.05	0	0
5	0.07	0.07	0	0	0.08	0.08	<0.01	0
6	0.01	0.01	0	0	0.02	0.02	0	0
7	0.02	0.02	0	0	0.32	0.29	0.03	0
8	0.02	0.02	0	0	0.11	0.11	0	0
9	0.18	0.17	0.02	0	0.49	0.46	0.05	0

[a] Based on the continuous detections by only one receiver, shark is considered to have died in the array.
[b] Tagging was undertaken by recreational fishers who did not record the tagging date. Hence, values could not be calculated.
* Indicates that shark was never detected.

4.4 Residency

Except for more frequent detections directly after tagging, the overall daily detections of *C. brachyurus* and *C. obscurus* across all regions showed no clear temporal pattern through the monitoring period. Most detections were obtained by the receivers deployed in Northeast GSV, with most sharks also detected by either or both the Northwest GSV and metropolitan receivers (Figure 8).

Carcharhinus brachyurus and *C. obscurus* were detected by the receivers deployed in GSV for an average period of 184 ± 31 days (range 1–726 days) and 317 ± 125 days (range 28–712 days), respectively. The tagged sharks showed some affinity to the location where they were tagged, Northeast GSV, with a similar detection period (183 ± 34 days, range 1–726 days and 317 ±125 days, range 28–712 for *C. brachyurus* and *C. obscurus*, respectively). Thirty-three percent and 43% of *C. brachyurus* and *C. obscurus* tagged for more than a year were detected within GSV for a period longer than 365 days. Four of the 14 *C. brachyurus* and two of the seven *C. obscurus* tagged for longer than two years were detected within GSV for more than 630 days.

During the monitored period, RI_o within the area covered by GSV receivers was very low, averaging 0.05 ± 0.01 (range 0–0.35) and 0.049 ± 0.024 (range 0–0.18) for *C. brachyurus* and *C. obscurus*, respectively (Table 3, Figure 9). There was no significant relationship between RI_o and total length (Pearson's correlation: *C. brachyurus*: r=-0.16 t_{34}=-0.91; P=0.37; *C. obscurus*: r= 0.67; t_5=2.04; P=0.1) (Figure 9). The two highest RIs (*C. obscurus* no 9 and *C. brachyurus* no 41) were obtained for sharks tagged during the 2012–13 season, which is likely due to the smaller number of days monitored compared to sharks tagged in earlier tagging seasons. The detected residency index was higher, averaging 0.18 ± 0.03 (range 0.01–1.00) and 0.16 ± 0.07 (range 0.02–0.49) for *C. brachyurus* and *C. obscurus*, respectively (Table 3). The RI_d was higher than RI_o because some sharks were only detected for short periods directly after tagging (e.g., shark 22, 38, and 39).

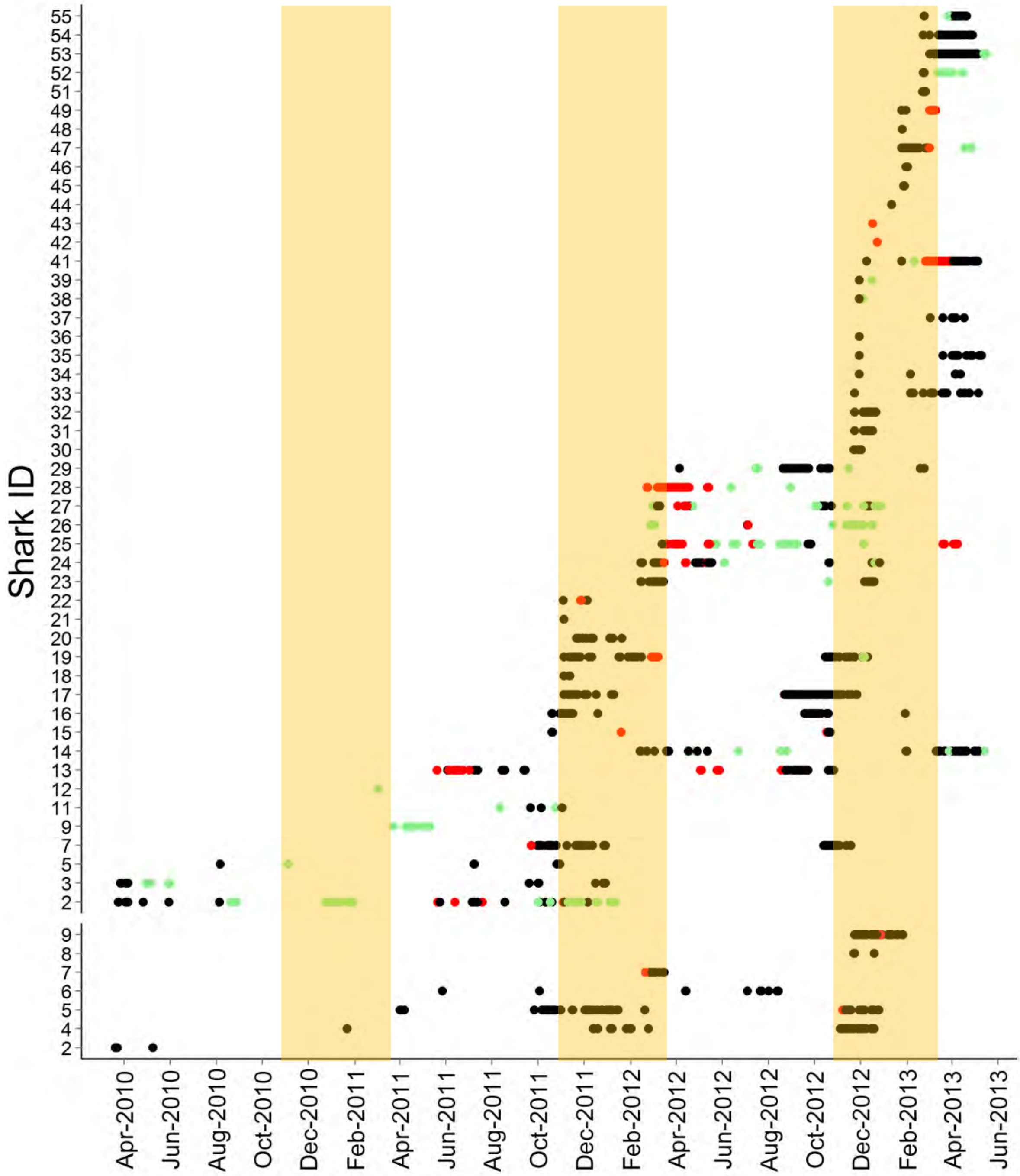

Figure 8. Daily detections of *Carcharhinus brachyurus* and *C. obscurus* in Gulf St Vincent. Red represents Northwest GSV receivers; black Northeast GSV receivers, and green Metropolitan receivers. Bottom sharks (2–9) are *C. obscurus*, top sharks (Shark ID 2–55) are *C. brachyurus*. Sharks that were never detected are not represented. Orange shaded areas represent warm summer months (November–March).

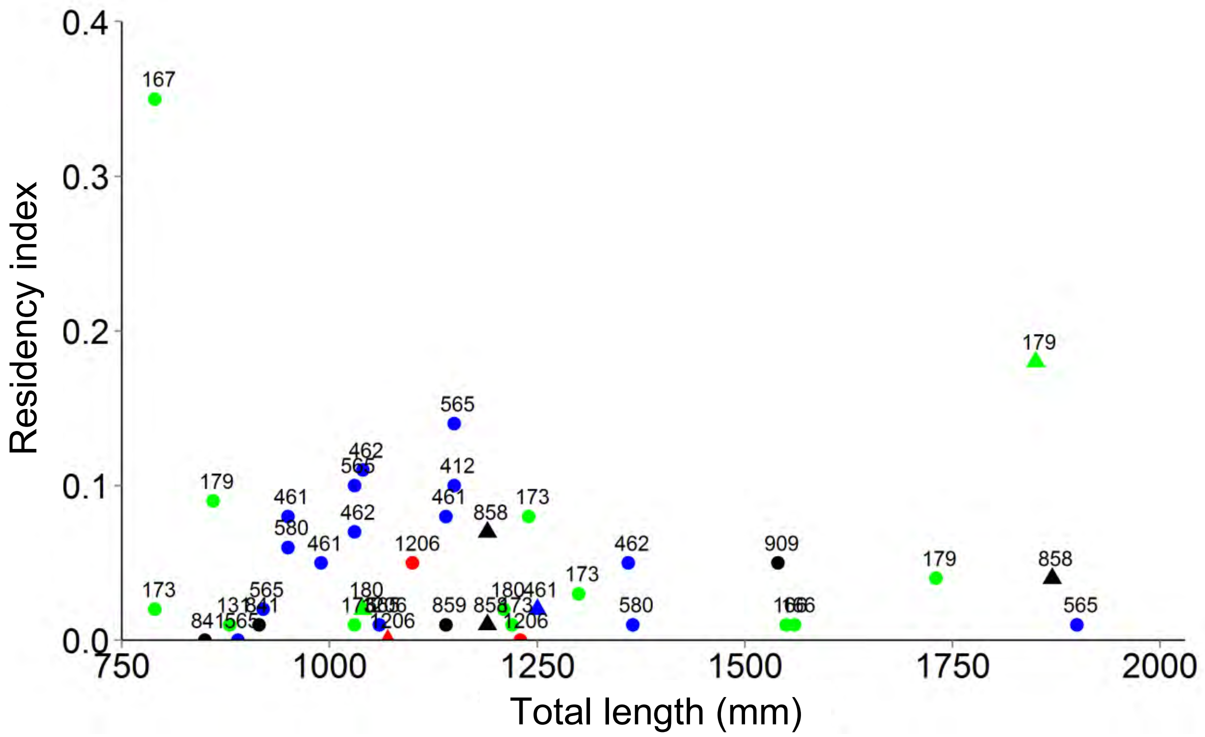

Figure 9. Overall residency index of *Carcharhinus brachyurus* (circles) and *C. obscurus* (triangles) against total length (mm). Number above symbols represents the number of days between tagging and last detection (period monitored). Sharks monitored for less than four months are not shown to avoid biases due to the short monitoring period. Sharks tagged during different tagging seasons are represented in different colours. Black represents 2009-2010; red 2010-11; blue 2011-12; green 2012-13.

Comparing between regions, the RI_o was highest in Northeast GSV (0.034 ± 0.007, maximum: 0.180 and 0.047 ± 0.02, maximum: 0.170 for *C. brachyurus* and *C. obscurus*, respectively) for all sharks but two *C. brachyurus* (a 95 cm TL male and a 104 cm TL male). The second highest RI_o was for the Northwest GSV region (0.01 ± 0.005, maximum: 0.16 and 0.003 ± 0.003, maximum: 0.02 for *C. brachyurus* and *C. obscurus*, respectively), which also was the region where the two male *C. brachyurus* listed above spent most of their time. One 79 cm TL female spent an equal amount of time between Northeast and Northwest GSV (Figure 10). Fifteen *C. brachyurus* were detected in the metropolitan region, but they did not spend a large amount of time there, as shown by the low RI_o (0.006 ± 0.002, maximum: 0.050). No *C. obscurus* were detected in the metropolitan region. Although the number of receivers deployed was not equal across regions, it was unlikely to bias the relative RI between regions, as the region with the most receivers was the metropolitan region which also had the lowest RI.

Overall, the RI values in each region and for all regions combined suggest that while the detection period of *C. brachyurus* and *C. obscurus* was relatively long, they were not detected on many days during this period.

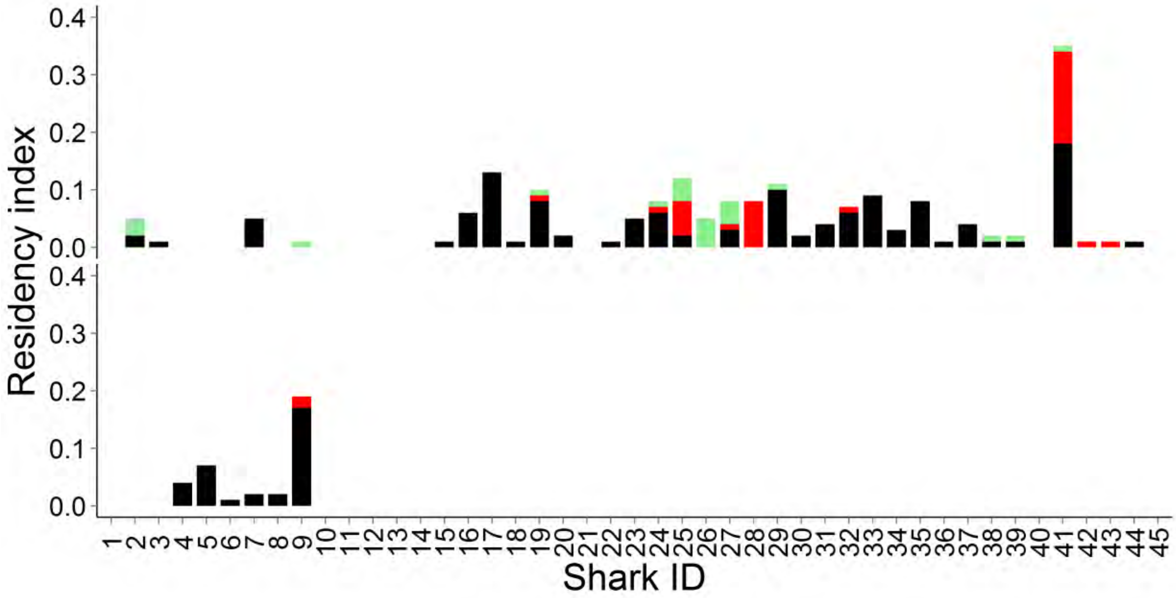

Figure 10. Overall residency index of *Carcharhinus brachyurus* (top) and *C. obscurus* (bottom) for each of the three regions monitored. Sharks monitored for less than four months are not shown to avoid biases due to short monitoring period. Red represents Northwest GSV; black represents Northeast GSV; and green represents the metropolitan region.

The results showed that GSV is likely to be an important area for *C. brachyurus* and *C. obscurus* as they were detected regularly and for up to nearly two years by receivers deployed in that area. The low residency index, however, suggests that whaler sharks only spend a short amount of total time within the acoustically covered area. The number of detections is also relatively small in comparison to the residency of closely related tropical Carcharhinidae species around reefs (Chapman *et al.*, 2005; Field *et al.*, 2011; Speed *et al.*, 2011).

4.5 Temporal variation in residency

4.5.1 Diel variation

Overall, there were no differences in the standardised number of detections and total number of individual sharks between hours of the day for either species or within any region (Figure 11, Figure 12). More individual sharks were detected in the Northeast GSV region compared to the Northwest GSV and metropolitan regions. This might have been biased by tagging having predominantly taken place in the Northeast region. The diel pattern in the standardised number of detections was variable between sharks, with modal peaks observed during the day for some sharks and higher number of detections at night for others. Modal peaks at either or both nighttime and daytime were present for sharks with the most detections, with less detections during sunrise and sunset (Appendix 1).

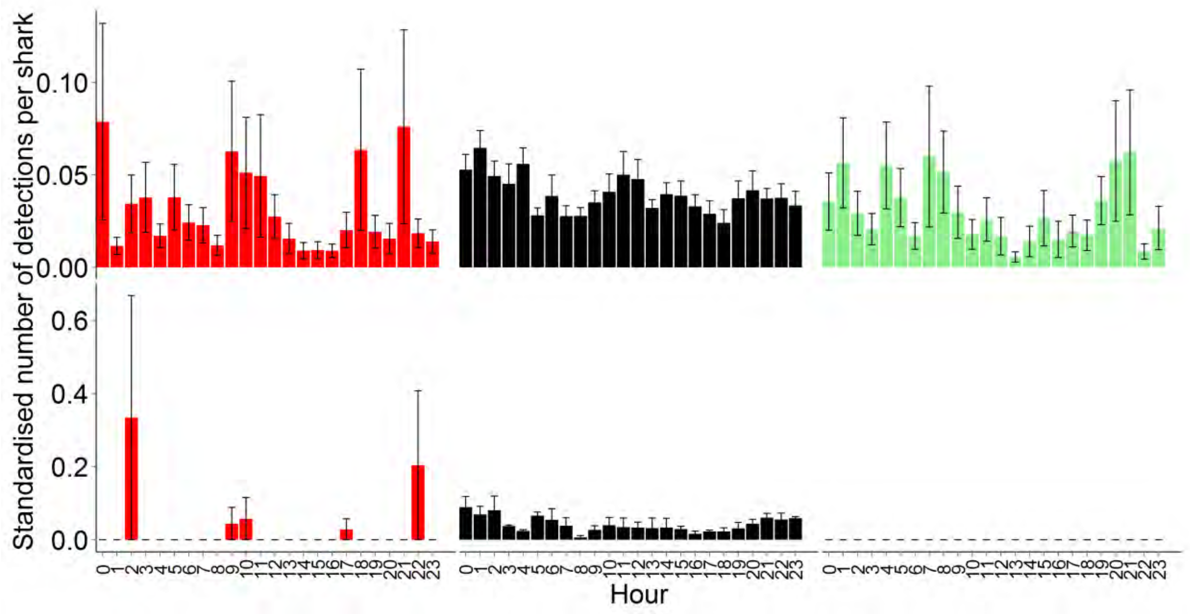

Figure 11. Mean standardised number of detections per hour of *Carcharhinus brachyurus* (top) and *C. obscurus* (bottom) for each of the three regions monitored. Red represents Northwest GSV; black Northeast GSV; and green the metropolitan region. Error bars represent standard error across sharks.

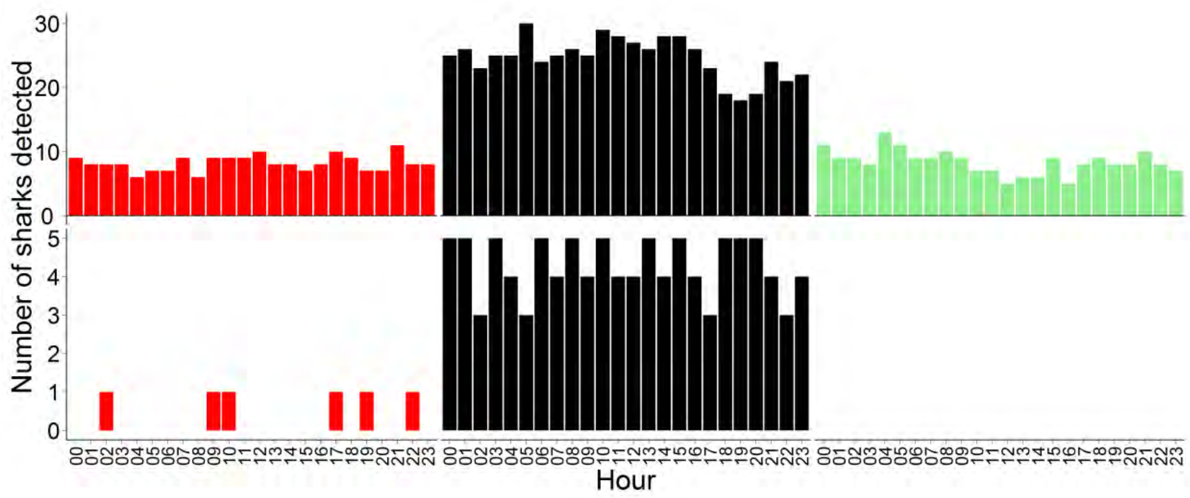

Figure 12. Total number of *Carcharhinus brachyurus* (top) and *C. obscurus* (bottom) detected per hour within each of the three regions monitored. Red represents Northwest GSV; black Northeast GSV; and green the metropolitan region.

4.5.2 Monthly variations

In both species, the standardised number of detections was different between months (Figure 13, Appendix 2). For *C. brachyurus*, detection frequency was highest during summer months (December–April). Regional differences were observed, with peaks in standardised number of detections in March–April in Northwest and Northeast GSV, and in December in the metropolitan region. *Carcharhinus obscurus* were detected the most in November–December in Northwest and Northeast GSV, but were not detected in the metropolitan region. The patterns of high activity around the summer months were also supported by the total number of individual sharks detected per month, with the largest number of *C. brachyurus* detected from October–April in Northeast GSV, and March–May around Northwest GSV (Figure 14). The pattern of higher detection in summer was less pronounced off the metropolitan region because of a low number of sharks detected in January–February

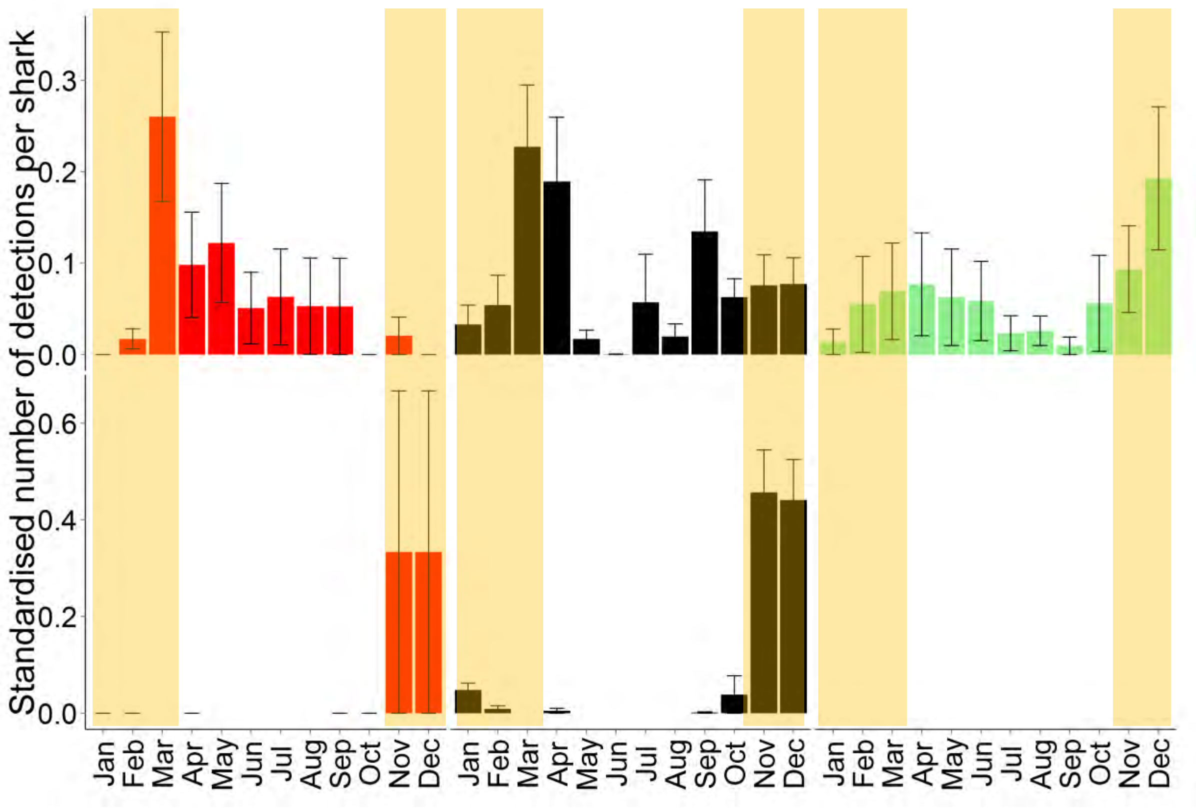

Figure 13. Mean standardised number of detections per month of *Carcharhinus brachyurus* (top) and *C. obscurus* (bottom) for each of the three regions monitored. Red represents Northwest GSV; black Northeast GSV; and green the metropolitan region. Error bars represent standard error across sharks. Orange shaded areas represent warm summer months (November–March).

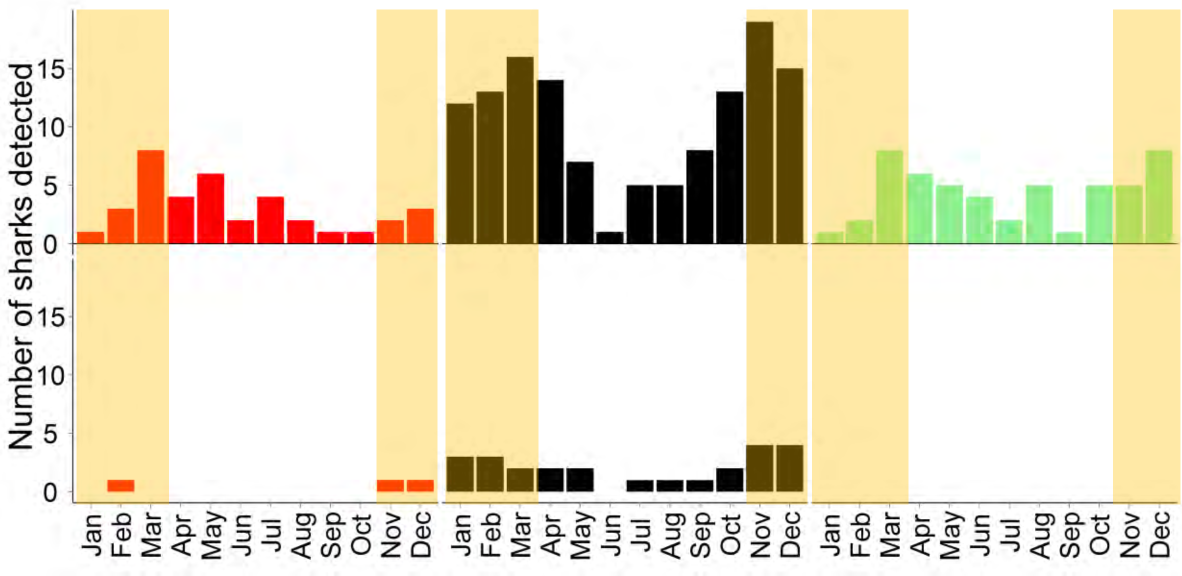

Figure 14. Total number of *Carcharhinus brachyurus* (top) and *C. obscurus* (bottom) detected per month within each of the three regions monitored. Red represents the Northwest GSV region; black Northeast GSV region; and green the metropolitan region. Orange shaded areas represent warm summer months (November–March).

4.6 Fine-scale spatial distribution

In both species, spatial distribution was variable between sharks (Appendix 3), and also between regions and stations, with the highest number of detections by the Northeast GSV receivers (Figure 15). For *C. brachyurus*, the highest number of detections was at NW GSV 16, NE GSV 12 and 16, and Semaphore 4 and 5, within the Northwest GSV, Northeast GSV, and metropolitan regions, respectively (Figure 15). *Carcharhinus obscurus* were never detected by the metropolitan receivers and rarely detected by the receivers in Northwest GSV. The standardised number of detections in Northeast GSV was three times higher at the Northeast GSV 11 and 12 stations than at other receivers (Figure 15).

The number of individual sharks detected at each station mostly reflected the patterns observed by the standardised number of detections, with more *C. brachyurus* and *C. obscurus* detected in Northeast GSV than in the other two regions (Figure 16). Although no *C. obscurus* were detected in the metropolitan region, about the same number of *C. brachyurus* were detected in Northwest GSV and the metropolitan region. Within Northeast GSV, the stations detecting the most individual sharks were Northeast GSV 1–6 and 11–16, and included the stations detecting the most standardised detections (Northeast GSV 11, 12 and 16). The more homogeneously distributed number of sharks across stations compared to the number of detection suggests that the higher number of detections was mostly due to a small number of sharks and confirms the high variability in the number of detections per station between sharks (Appendix 3). The Aldinga receivers did not detect many individual sharks or tag transmissions.

Sharks that were tagged around Northeast GSV were subsequently detected more frequently in the region compared to the Northwest GSV or metropolitan regions. Many of the detections along the metropolitan region were by receivers deployed close to natural or artificial reef systems (e.g., Semaphore Reef, Glenelg Tyre Reef), where reef fish are likely to be more abundant than in the surrounding area (Shepherd and Baker, 2008). Considering that all but one of the tagged sharks were immature, it is likely that the movement and residency of these sharks was driven by prey availability. This suggests the Northeast GSV region might have higher abundance of suitable prey for juvenile *C. brachyurus* and *C. obscurus* than the Northwest GSV and metropolitan regions, and that the natural and artificial reefs where *C. brachyurus* were most detected represented the area with the highest abundance of suitable prey compared to the adjacent areas monitored by the other receivers. The apparent preference for the Northeast GSV might have also been biased by all but two sharks having been tagged in that region. Future studies should attempt to tag sharks in other regions to determine whether such sharks would be detected in Northeast GSV as much as those tagged within that region. The Aldinga receivers were deployed around a natural reef which has been a reserve since 1971, and where fish diversity and abundance would be expected to be higher than its surrounding or unprotected reef. Yet, the number of detections and sharks recorded were low. This might be due to the Aldinga receivers being located ~ 30 km further south than all other receivers. *Carcharhinus brachyurus* and *C. obscurus* are, however, known to be able to travel long distances and outside GSV (see 4.8) and the reason for the observed low number of detections off Aldinga is unknown.

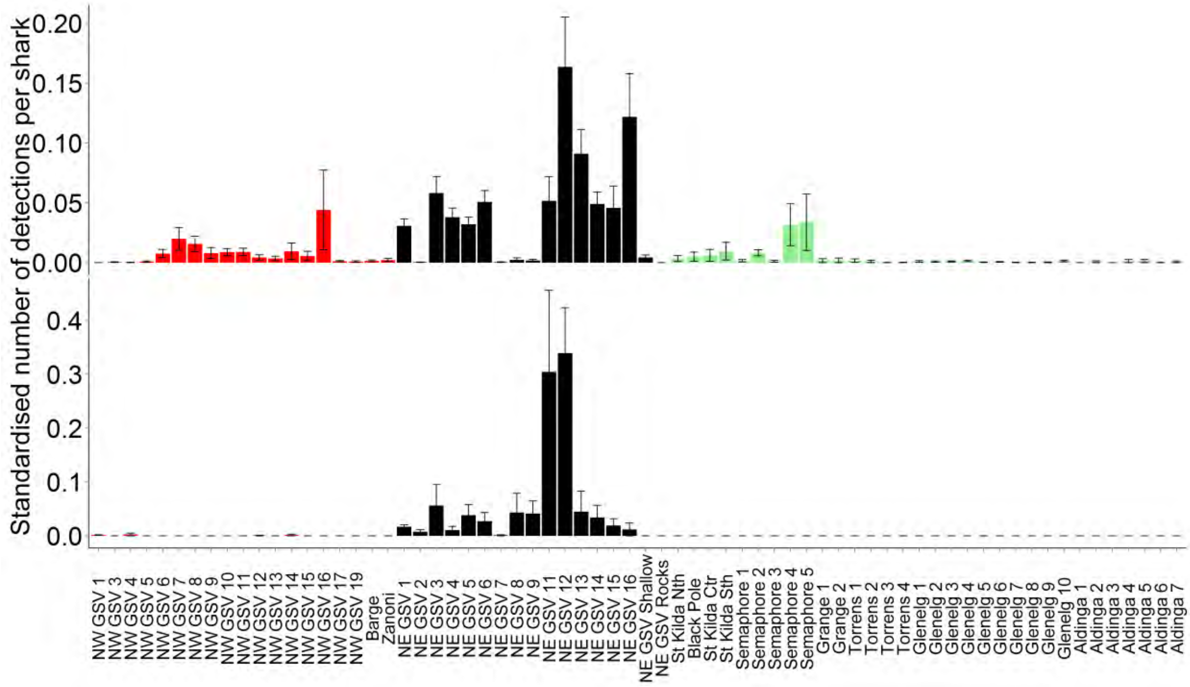

Figure 15. Mean standardised number of detections per station of *Carcharhinus brachyurus* (top) and *C. obscurus* (bottom) for each of the three regions monitored. Red represents the Northwest GSV region; black Northeast GSV region; and green the metropolitan region. Error bars represent standard error across sharks.

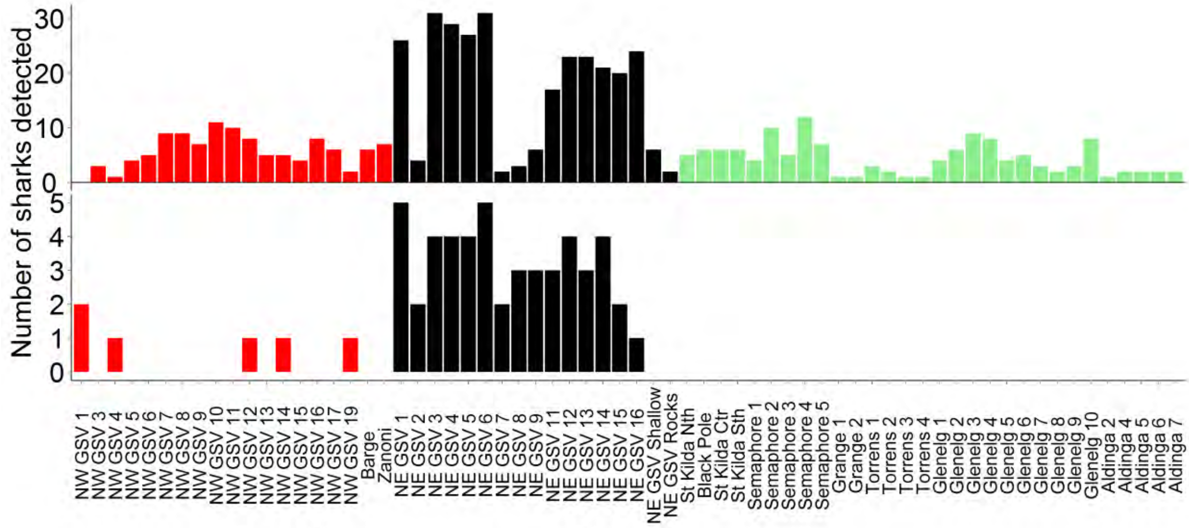

Figure 16. Total number of *Carcharhinus brachyurus* (top) and *C. obscurus* (bottom) detected per station within each of the three regions monitored. Red represents the Northwest GSV region; black Northeast GSV region; and green the metropolitan region.

4.7 Spatio-temporal distribution

Different temporal distribution patterns of *C. brachyurus* can be observed between regions. Sharks were more regularly detected in Northeast GSV than in Northwest GSV and the metropolitan region (Figure 17). In Northeast GSV, detections were obtained throughout the year. There were, however, periods during which sharks were not detected. Form mid-May to mid-August 2012, *C. brachyurus* were only detected on a few days in early July, but were otherwise absent from Northeast GSV. Another gap in detections was also observed around December 2012 and January 2013 during which sharks were detected very sporadically (Figure 17). The reasons for the periods with no or limited detections is currently unknown and could be related to environmental conditions (e.g., heavy storms) affecting shark distribution or detection probability, or to sharks being attracted to an adjacent area. Since the two periods of low detections did not occur at a similar time of the year, it is unlikely that such a mass exodus is related to seasonal prey behaviour. In Northwest GSV, most detections were concentrated in May–June 2011, March–May 2012, and March–May 2013. The lack of detections prior to May 2011 was due to receivers being deployed in Northwest GSV for the first time in May 2011. Detections off the metropolitan region were more sporadic, with most detections on the northern part of the array (from Grange to St Kilda) occurring in November through to February, while detections from the Torrens River mouth to Glenelg occurred mostly April to August. Seasonality at the Aldinga receivers could not be determined because they were deployed for 12 months only, and detections were relatively sparse (Figure 18, Figure 19).

Detections of *C. obscurus* in Northwest GSV were too low to assess seasonality. In Northeast GSV, *C. obscurus* were consistently detected from November to February in 2012 and 2013, concurring with the seasonality observed from the number of individual sharks detected (Figure 19).

The temporal variation of detections by GSV receivers coincides with the peak in commercial catches (Jones, 2008), suggesting a higher abundance of whaler sharks during the warm summer months. Whaler sharks were previously thought to leave the South Australian Gulfs during the winter months (Jones, 2008). *Carcharhinus brachyurus* and to some level *C. obscurus*, however, were still detected throughout winter, albeit to a lesser extent, indicating that at least some individuals remain within GSV. The reduced catches during winter in the commercial fishery might be related to a combination of lower abundance, sharks feeding less frequently, and reduced fishing effort.

Seasonal migration of whaler sharks (specifically *C. brachyurus*) has previously been documented in another Australian state and other countries. Off New South Wales, *C. brachyurus* are present during Spring–Autumn between September and May, with peak abundance between February and April (Krogh, 1994). In Argentina and New Zealand, *C. brachyurus* are only found in coastal waters during summer (Cox and Francis, 1997; Lucifora *et al*., 2002). Off South Africa, *C. brachyurus* are abundant in the warm waters off KwaZulu-Natal during winter. Their numbers decline dramatically in spring and summer (Cliff and Dudley, 1992), when they move to cooler Cape waters (Smale, 1991). Similarly in the Southwest Atlantic, *C. brachyurus* are most common in warm-temperate waters during cool months. These migratory patterns are likely to be related to water temperature (Cliff and Dudley, 1992) and prey availability, and should be further investigated to improve our understanding of the drivers underpinning the movements of these species.

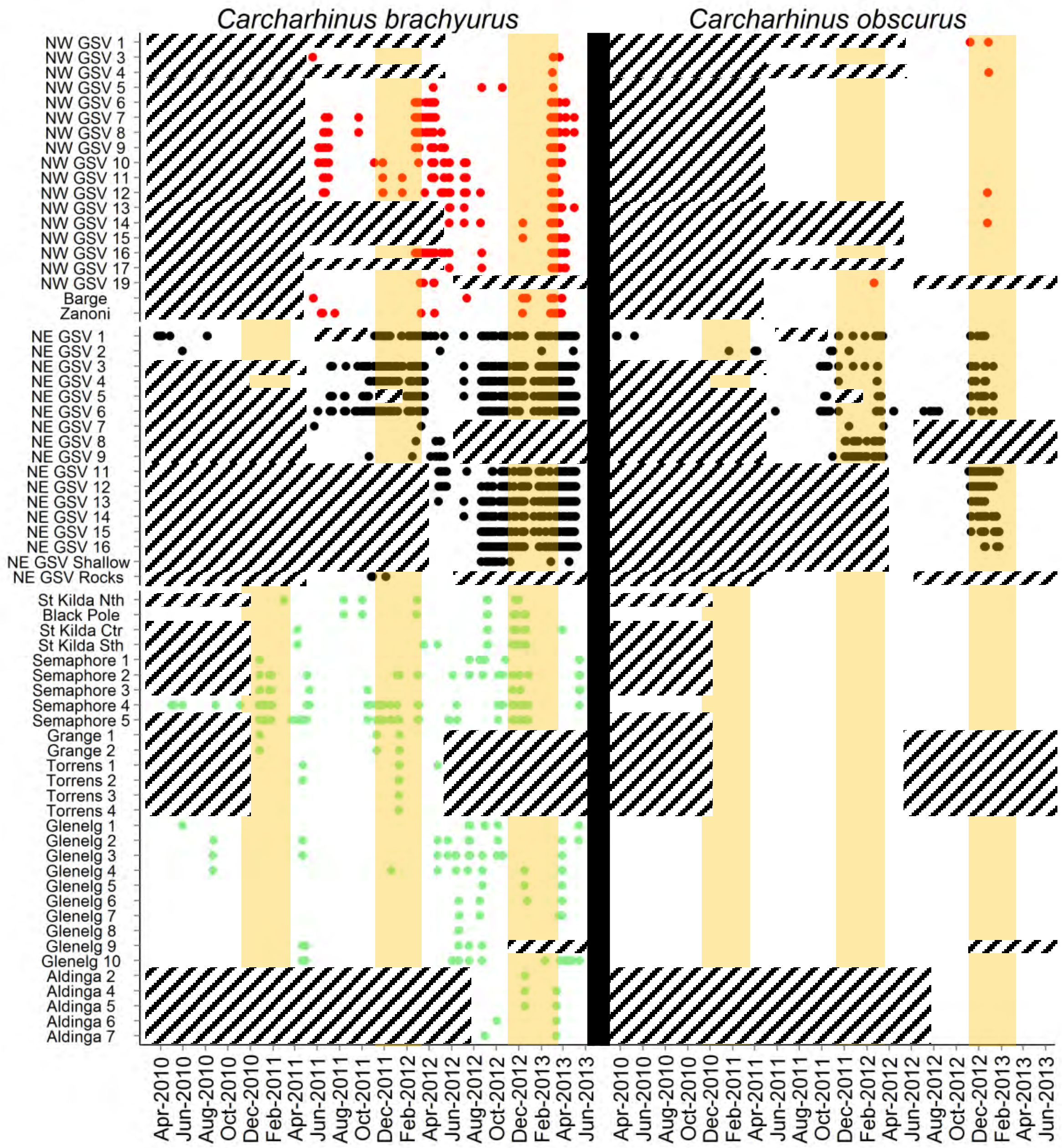

Figure 17. Daily detections of *Carcharhinus brachyurus* and *C. obscurus* in Gulf St Vincent by stations and regions. Red represents Northwest GSV stations (top section); black Northeast GSV stations (middle section), and green the metropolitan station (bottom section).Orange shaded areas represent warm summer months (November–March). Striped boxes are periods when receivers were not deployed, malfunctioned, or removed.

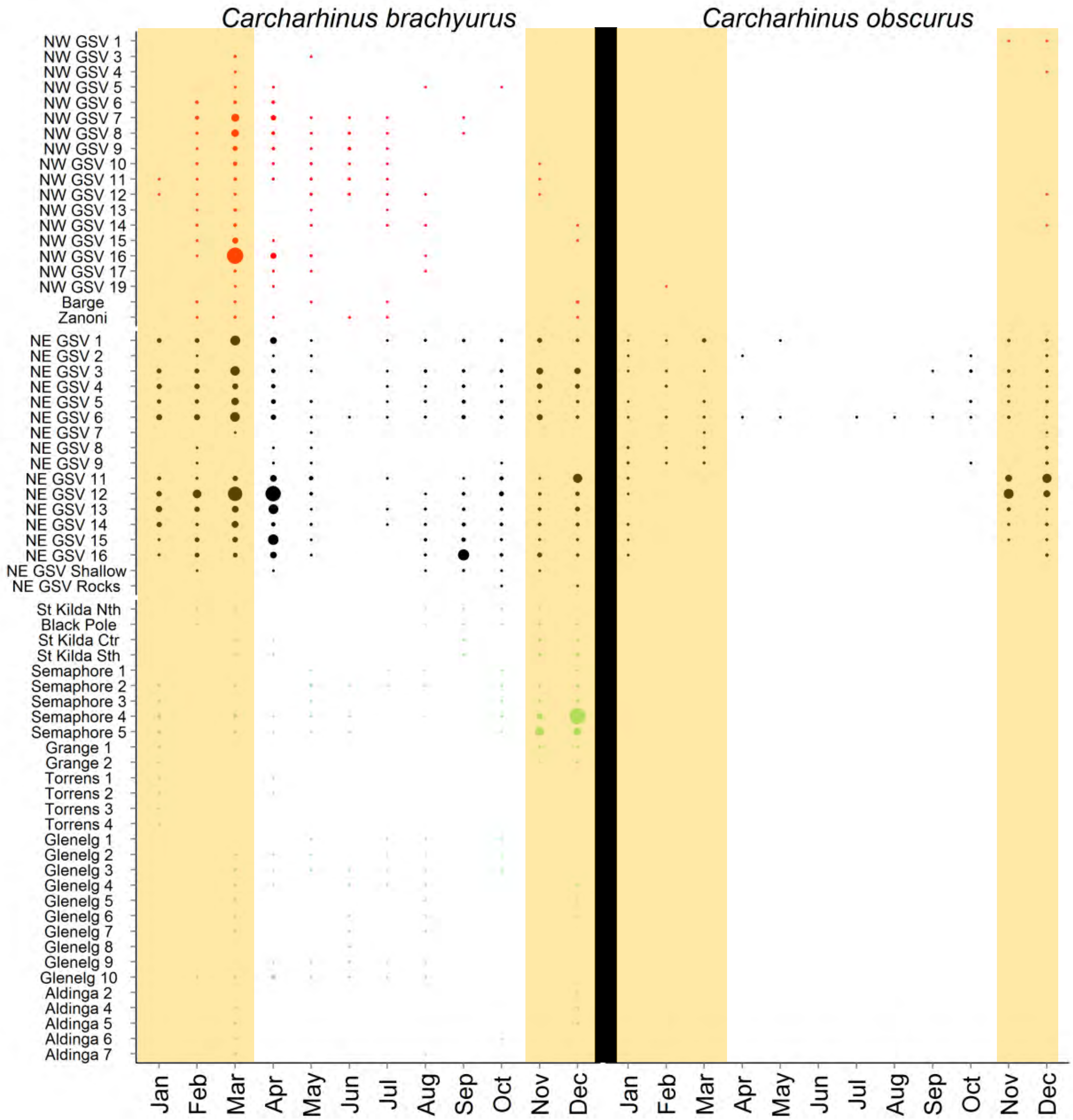

Figure 18. Overall corrected number of detections of *Carcharhinus brachyurus* and *C. obscurus* in Gulf St Vincent (GSV) by stations and months. Red represents Northwest GSV stations (top section); black Northeast GSV stations (middle section), and green the metropolitan station (bottom section). Size of the circles represents the number of detections with the largest circle being 3,000. Orange shaded areas represent warm summer months (November–March).

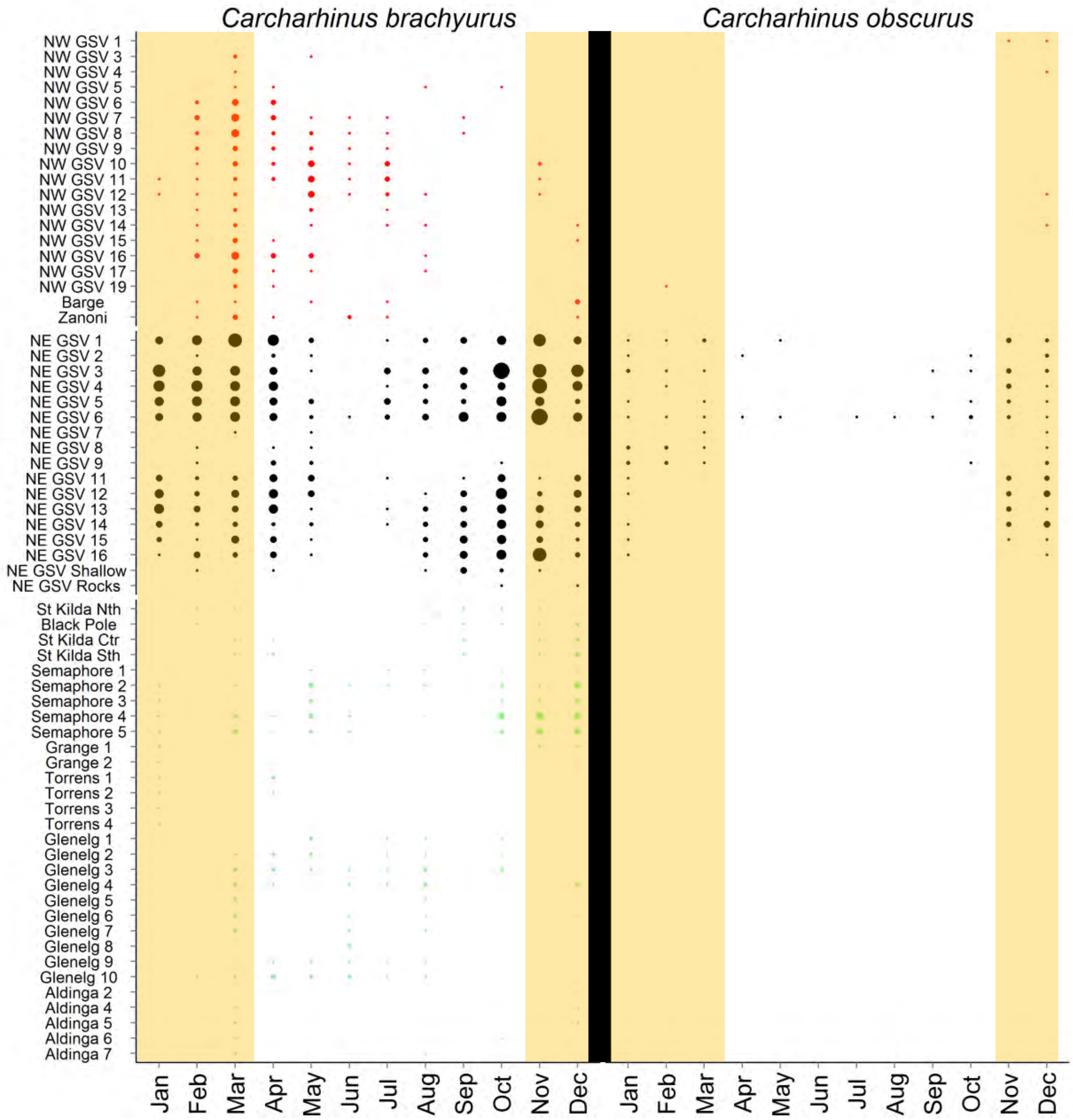

Figure 19. Overall number of individual *Carcharhinus brachyurus* and *C. obscurus* detected per month in Gulf St Vincent (GSV) by stations. Red represents Northwest GSV stations (top section); black Northeast GSV stations (middle section), and green the metropolitan station (bottom section). Size of the circles represents the number of detections with the largest circle being 12 sharks. Orange shaded areas represent warm summer months (November–March).

The number of individual sharks detected per hour, and the standardised number of detections per hour did not vary greatly between stations. In the Northeast GSV region, there was a small difference in the distribution of the number of detections. All stations had a higher number of detections during night time (20:00 to 6:00), but stations Northeast GSV 12–16 had a higher number of detections in late morning and around midday than stations

Northeast GSV 1–6 (Figure 20). The number of sharks detected was, however, homogeneously distributed across all stations (Figure 21).

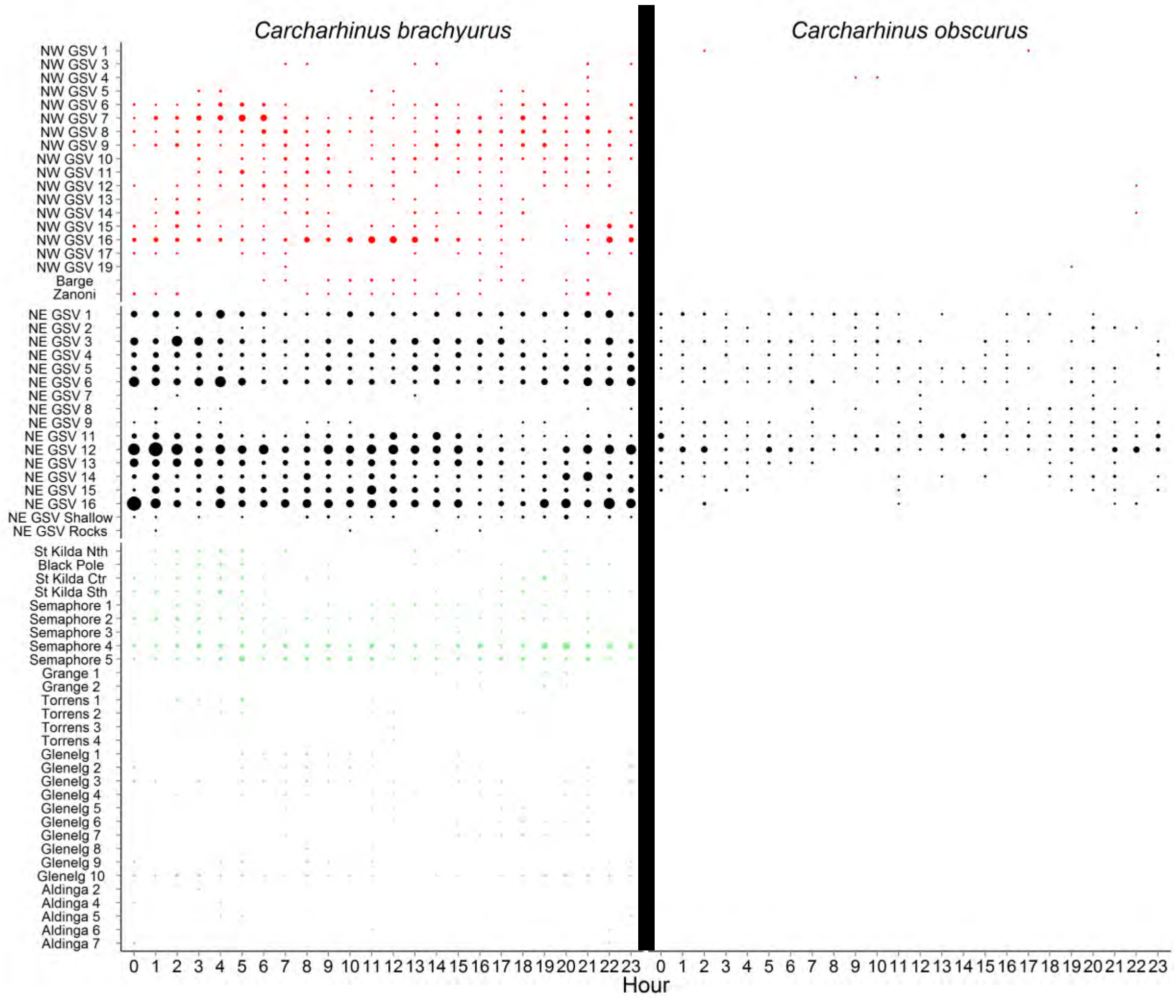

Figure 20. Overall corrected number of detections of *Carcharhinus brachyurus* and *C. obscurus* in Gulf St Vincent (GSV) by stations and hours. Red represents Northwest GSV stations (top section); black Northeast GSV stations (middle section), and green the metropolitan station (bottom section). Size of the circles represents the number of detections with the largest circle being 350.

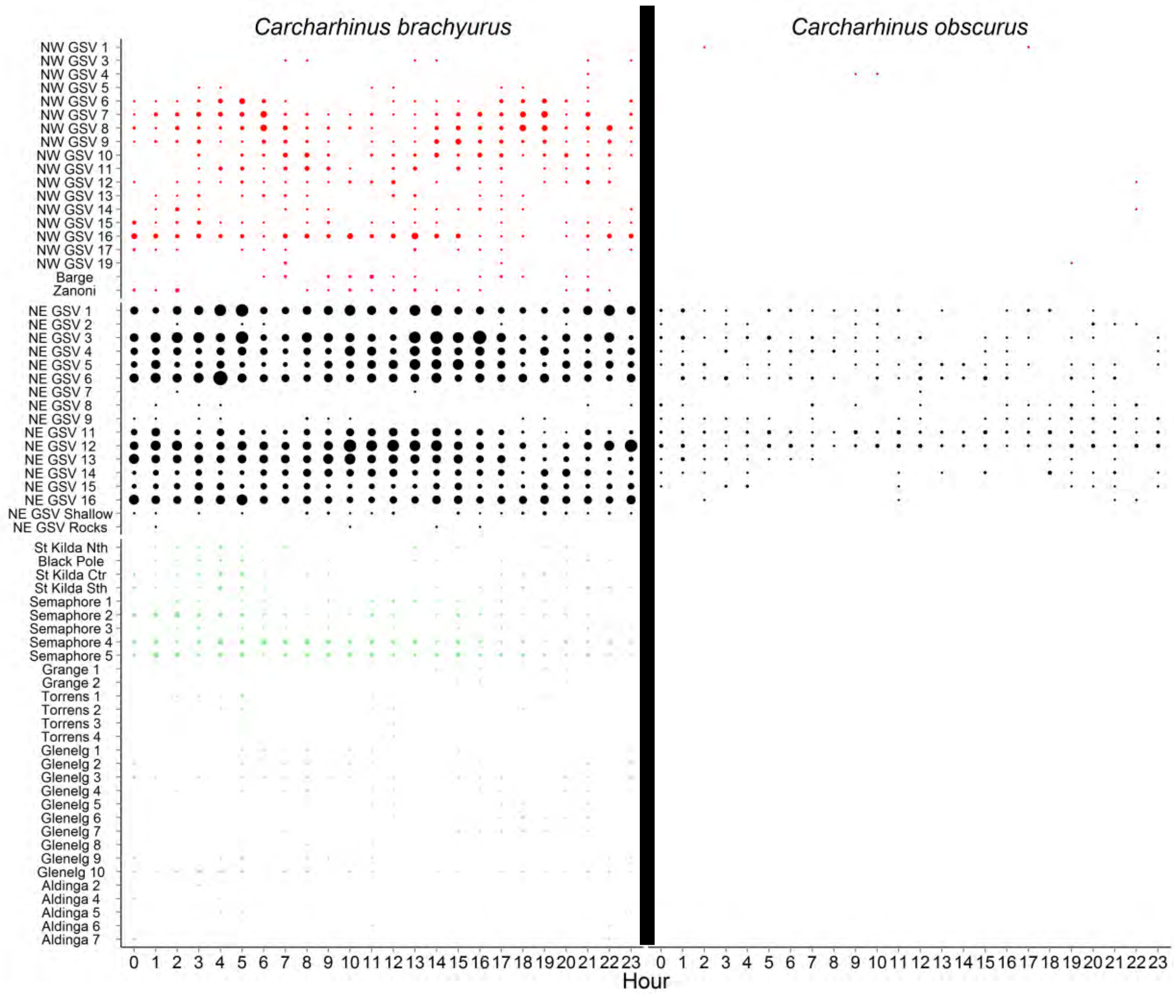

Figure 21. Overall number of individual *Carcharhinus brachyurus* and *C. obscurus* detected per hour in Gulf St Vincent by stations. Red represents Northwest GSV stations (top section); black Northeast GSV stations (middle section), and green the metropolitan station (bottom section). Size of the circles represents the number of detections with the largest circle being 16 sharks.

4.8 Large-scale movements

4.8.1 Bronze whalers and dusky sharks tagged in South Australia

Four of the 64 tagged sharks (6.2%) were detected by receivers deployed as part of other projects (Figure 22). A 1,250 mm TL female *C. obscurus* tagged on the 15th of February 2012 was last detected in GSV by a receiver deployed in the Northeast region on the 16th of March 2012, and was next detected on the 23rd of March 2012 off Dangerous Reef, Spencer Gulf. This represented a minimum distance travelled of 245 km in 6 days and a rate of movement of 40 km day^{-1}. A 1,900 mm TL female *C. brachyurus* tagged on the 3rd of November 2011 was last detected in GSV on the 5th of November 2011, and was next detected on the 15th of March 2012 off Corner Inlet, Victoria. This represented a minimum distance travelled of 1,050 km in 102 days and a rate of movement of 10.3 km day^{-1} over 3 months. A 1,850 mm TL male *C. obscurus* tagged on 13th of January 2011 was detected on two separate days (26/9/2012 and 2/10/2012) in 70 m about 24 km off Bald Island, WA, 622 days after tagging. This shark was never detected by the receivers deployed in GSV. Another *C. obscurus* male of similar size, 1,870 mm TL, tagged on the 14th of January 2011 was last detected in GSV on the 24th of February 2012, and was next detected by receivers off Hamelin Bay, Western Australia on the 16th of September 2012. This represented a minimum travelled distance of 2,400 km in 182 days and a daily movement rate of 13.2 km. This shark was detected off Hamelin Bay for 23 days and returned to GSV by the 4th of November 2012 in 49 days, representing a sustained minimum rate of movement of 49.0 km day^{-1}.

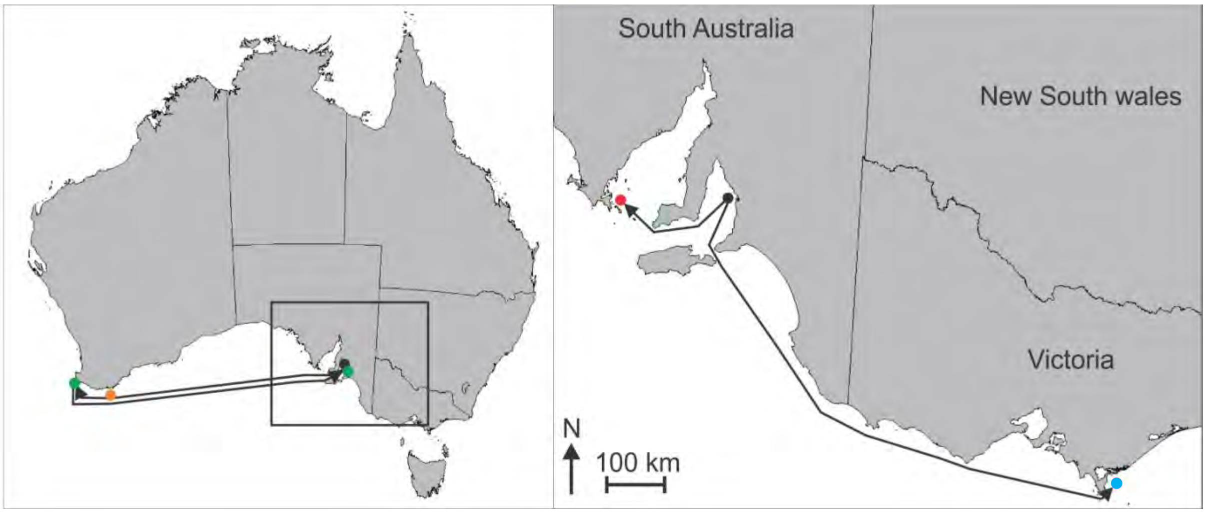

Figure 22. Map showing the movements of a 1,250 mm TL female *C. obscurus* (red dot), a 1,900 mm TL female *C. brachyurus* (blue dot), a 1,870 mm TL male *Carcharhinus obscurus* (green dot), and a 1,850 mm TL male *C. obscurus* (orange dot) detected outside of Gulf St Vincent.

4.8.2 Bronze whalers and dusky sharks tagged in Western Australia

Through FRDC project 2010/008, the WA Department of Fisheries internally tagged 29 *C. brachyurus* and 78 *C. obscurus* at various locations along the WA coastline. One 2,300 mm fork length *C. brachyurus* tagged on the 26th of April 2012 was detected 452 times between 12/10/2012 and 12/11/2012 by a total of 17 receivers deployed in Northeast GSV and the metropolitan regions.

Large-scale movement of *C. brachyurus* and *C. obscurus* is not uncommon. A previous study assessing the movements of whaler sharks in southern Australia based on data from the NSW game fish tagging program showed that four out of the 40 recaptured sharks (10%) were recaptured more than 1,000 km from the tagging location (Rogers et al., 2013a).

Carcharhinus obscurus have been found to travel up to 2,736 km between Spencer Gulf, South Australia and Mid West Western Australia (Rogers *et al.*, 2013b). Similar large-scale movements have been observed in other countries with distances of up to 1,374 km recorded in South Africa (Dudley *et al.*, 2005; Hussey *et al.*, 2009), and 3,800 km in the Northwest Atlantic (Kohler *et al.*, 1998). *Carcharhinus brachyurus* were shown to move long distances along the South African continental coastline (Cliff and Dudley, 1992). The lack of *C. brachyurus* population genetic structure between Australia and New Zealand across the Tasman Sea (Benavides *et al.*, 2011a) and between the *C. obscurus* populations from the east and west Australian coasts (Benavides *et al.*, 2011b) also supports that these whaler shark species are capable of large-scale movements.

4.9 Detections of white sharks

Between 2007 and 2012, 169 *C. carcharias* were tagged around Australia. One hundred and fourteen *C. carcharias* were tagged as part of the WA shark monitoring network, with 86 tagged in SA and 28 in WA. Fifty-five *C. carcharias* were also tagged in SA for a study assessing the residency of white sharks at the Neptune Islands and a study identifying critical residency and aggregation habitats of white sharks. Ten of the 86 sharks tagged in WA were internally and externally tagged. Of the 169 tagged sharks, five tagged at the Neptune Islands were detected in GSV by a total of 15 receivers. White sharks were detected for 16, 1, 1, 2, and 1 day, with the number of receivers that detected each *C. carcharias* ranging from 1–10. One shark was detected 272 times during 16 days between the 13th of August 2008 and the 10th of September 2008 by the ten receivers deployed off Glenelg Beach. The other four *C. carcharias* had 1–10 detections at receivers deployed off the Zanoni wreck, Northeast GSV, and Northwest GSV (Figure 23). The South Australian shark sighting log (PIRSA, 2013) and data from satellite transmitters (Bruce et al., 2006) suggest that *C. carcharias* can visit GSV throughout the year. However, the highest proportion of sightings within GSV has historically been in spring–summer (PIRSA, 2013), partly overlapping with *C. carcharias* detections from the present study being only in July–October.

Carcharodon carcharias have also been acoustically tagged off Port Stephens, New South Wales, and off New Zealand by scientists from CSIRO and in a collaboration between the Department of Conservation, New Zealand and the National Institute of Water and Atmospheric Research, respectively. None of these sharks were detected by the GSV array receivers.

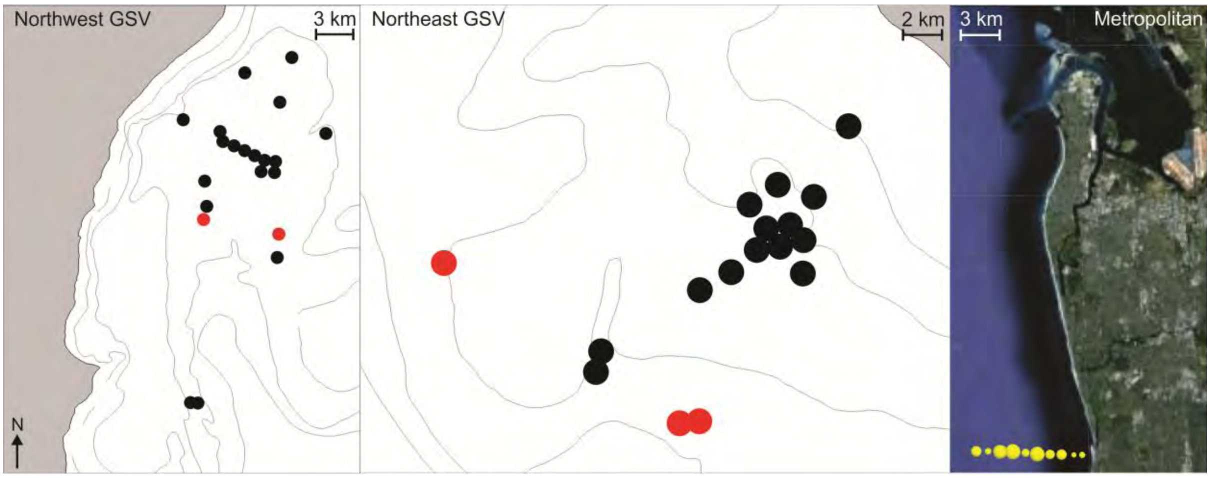

Figure 23. White shark (*Carcharodon carcharias*) detections in Gulf St Vincent. Red and black circles are receivers that detected and did not detect white sharks, respectively. Right panel shows the number of detections of a single white shark off Glenelg Beach between the 13th of August 2008 and the 10th of September 2008. Size of yellow circles represents the number of detections by the receivers, smallest circle is nine detections, largest circle is 47 detections.

4.10 Additional detections

The receivers deployed as part of this study also detected other species tagged through different projects.

A total of 53 snapper were tagged as part of a study investigating their movement and residence times. Over 400,000 detections from 46 of the tagged snapper were obtained between May 2011 and May 2013 on 35 of the receivers, including receivers from the Northwest GSV, Northeast GSV, and metropolitan regions. Further information about the first 29 snapper tagged can be obtained from Fowler *et al.* (2012c).

This study initiated the South Australian acoustic monitoring network, which has already shown benefit to several other studies and has been incorporated within the Australian Animal Tagging and Monitoring System (AATAMS), part of the Integrated Marine Observing System (IMOS). The detections of other organisms (i.e., *P. auratus*) obtained by the receivers deployed for this study have been provided to the relevant research groups. Additional detections of the whaler sharks tagged as part of this study were also obtained from other receivers highlighting the benefits of sharing detections between studies, and of the AATAMS network.

5. CONCLUSION AND FUTURE STUDIES

This study investigated the small-scale movements and residency patterns of *C. brachyurus* and *C. obscurus* in GSV and showed that while sporadic detections from individual sharks within GSV were obtained for periods up to two years, both species were mobile and did not constantly remain within the tagging location or monitored areas. Large-scale movements by individual sharks of both species were also able to be documented through the compatibility of acoustic receivers across projects led by other organisations.

Size-frequency distributions in this and previous studies have shown that *C. brachyurus* and *C. obscurus* caught in GSV are mostly neonates and small juveniles. Large juveniles and adults are, however, targeted by recreational and game fishers in the region (Rogers et al., 2013a), and also caught by commercial fishers. Since the fishing gear used is able to catch sharks over 2000 mm TL, it is unknown whether the low catch rate of such sharks in this study is linked to frequent movements into deeper waters outside the gulfs, to a small population of large individuals due to the inherent lower abundance of mature animals within natural populations, to anthropogenic effects (e.g., fishing), or to a combination of these factors. Larger sharks are critical to the sustainability of fished populations as sensitivity analyses shows that some shark populations are most susceptible to the exploitation of large juvenile and mature sharks (Cortés, 2002). This has specifically been demonstrated in *C. obscurus,* with a stochastic demographic model showing that even low fishing mortality of *C. obscurus* over 10 years old would result in a 55% probability of declining stock (McCauley et al., 2007). An investigation into the large-scale movements of large juvenile and adult *C. brachyurus* and *C. obscurus* (over 2,000 mm TL) would elucidate their movement patterns and vulnerability to the various Commonwealth and State fisheries, including the MSF, and other industries such as aquaculture (Rogers et al., 2013b).

In terms of neonates and small juveniles, this study enabled assessment of spatio-temporal variation in the detection patterns of *C. brachyurus* and *C. obscurus* and showed an increased use of GSV during warmer months, especially the Northeast GSV region. This pattern was consistent with the two *C. obscurus* that travelled to WA being detected in the cooler months of September–October. This study has been undertaken for 3.2 years (albeit with a limited number of receivers for the first 15 month of the study), and seasonal patterns are only starting to become discernable. Detections were, however, obtained at some stations throughout most of the year and a longer-term study of 7–10 years is recommended to validate or refute the seasonality observed. Although a long-term acoustic telemetry study would clarify some of the observed patterns, data from acoustic telemetry alone will not enable a full assessment of habitat use and understanding of the factors which might be driving the distribution and movements of this species because of the inability to acoustically cover a large enough proportion of each habitat. An insight into the factors that underpin the spatio-temporal distribution of *C. brachyurus* and *C. obscurus* will be beneficial to better interpret results from this study. Considering that all but one tagged shark were immature, the feeding ecology of these sharks is likely to be driving some of the residency and seasonality observed (Rogers *et al.*, 2012). Such knowledge can be acquired by obtaining a better understanding of *C. brachyurus* and *C. obscurus* diet and prey origins (i.e., type of prey and ecosystems where prey were captured). This can be achieved through a multi-disciplinary approach, using stomach contents, stable isotope analysis, and acoustic telemetry data in an advanced modeling framework to quantify the ecological role of *C. brachyurus* and *C. obscurus*. Such data would provide an ecological assessment of these Near Threatened and Vulnerable species through the understanding of the drivers underpinning residency and movements within the metropolitan region and the South Australian Gulfs and would assist regional fisheries management plans.

A small proportion of white sharks tagged outside GSV were detected by the receivers deployed in GSV. Although the receivers acoustically covered a small fraction of GSV, they were strategically deployed at locations where white sharks have historically been sighted (Bruce et al., 2006; PIRSA, 2013), and where the probability of detections was considered highest. The small number of *C. carcharias* detected indicates that most tagged sharks did not visit areas where receivers were deployed or possibly did not go into GSV at all. None of the *C. carcharias* were, however, tagged within GSV, with 79% tagged at the Neptune Islands. Individual white sharks might have different movement patterns based on previous experience and foraging success at particular locations and the sharks tagged at the Neptune Islands might not frequently visit GSV, although data suggests that some do (this study; Bruce et al., 2006). White sharks sighted in GSV or along the metropolitan coastline might be sharks that do not frequent the Neptune Islands, hence the lack of tagged sharks detected by our array. Tagging of white sharks within GSV is required to test whether these sharks are more likely to be detected within GSV and whether they are detected at the Neptune Islands as frequently as those tagged there. Given the broad-scale patterns of movements of this species this would need to be done in combination with receivers across the gulf mouth.

This acoustic telemetry study of *C. brachyurus*, *C. obscurus*, and *C. carcharias* provides an improved understanding of the spatio-temporal dynamics and residency patterns of these species in the study area. Results indicate that the northern parts of GSV, and the metropolitan region, are frequently visited by these species but that residency is limited. The factors driving residency and visitation periods, and the movements of adult *C. brachyurus* and *C. obscurus,* need to be investigated to complement our current knowledge of neonate and juvenile movement dynamics.

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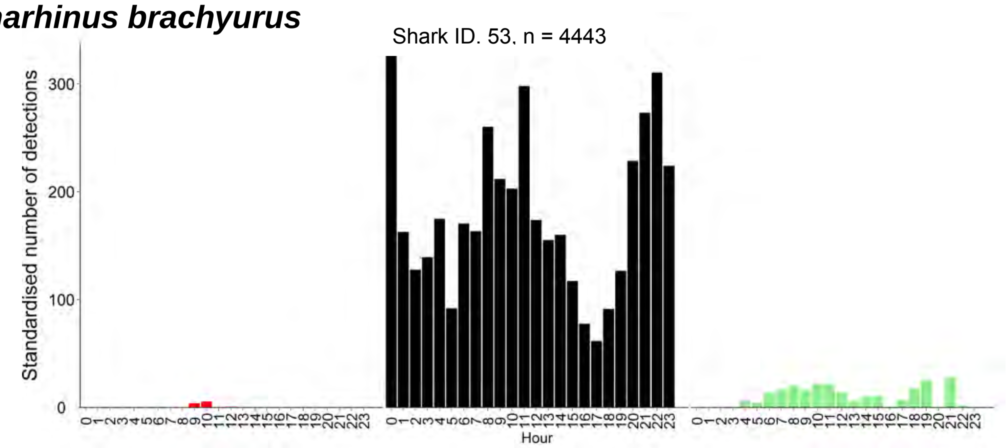
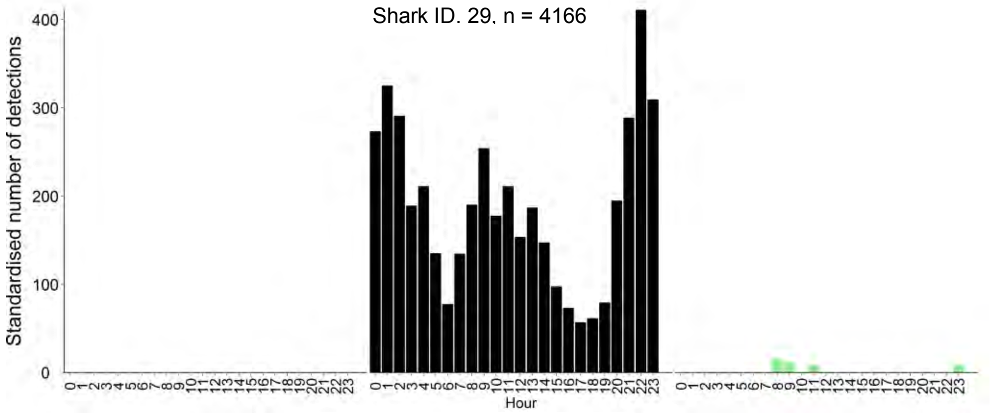
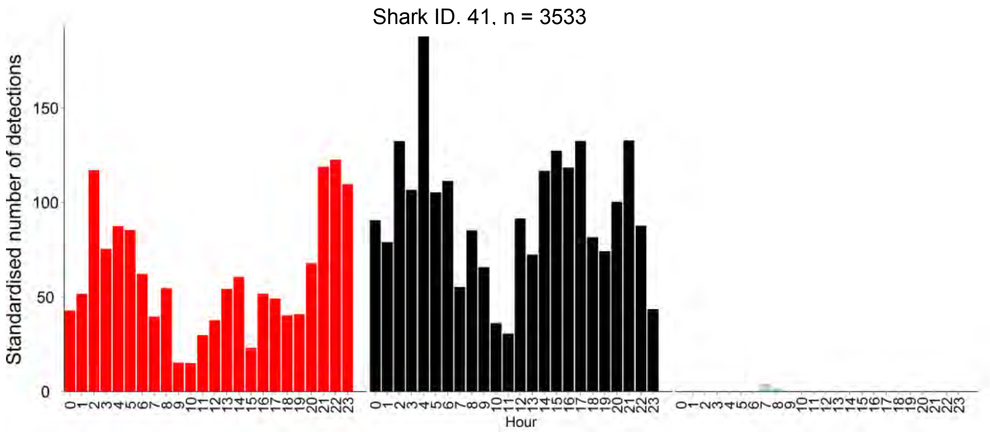
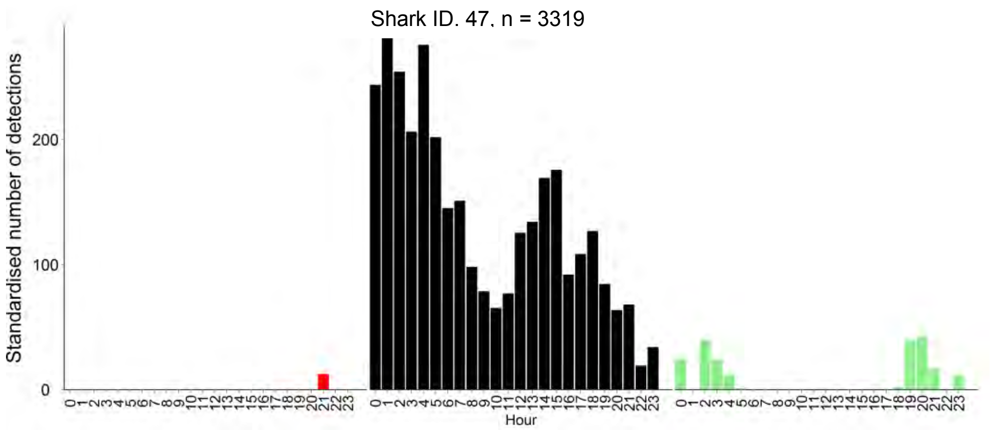
APPENDIX 1: Standardised number of detections per hour for Northwest GSV (red), Northeast GSV (black), and the metropolitan region (green)

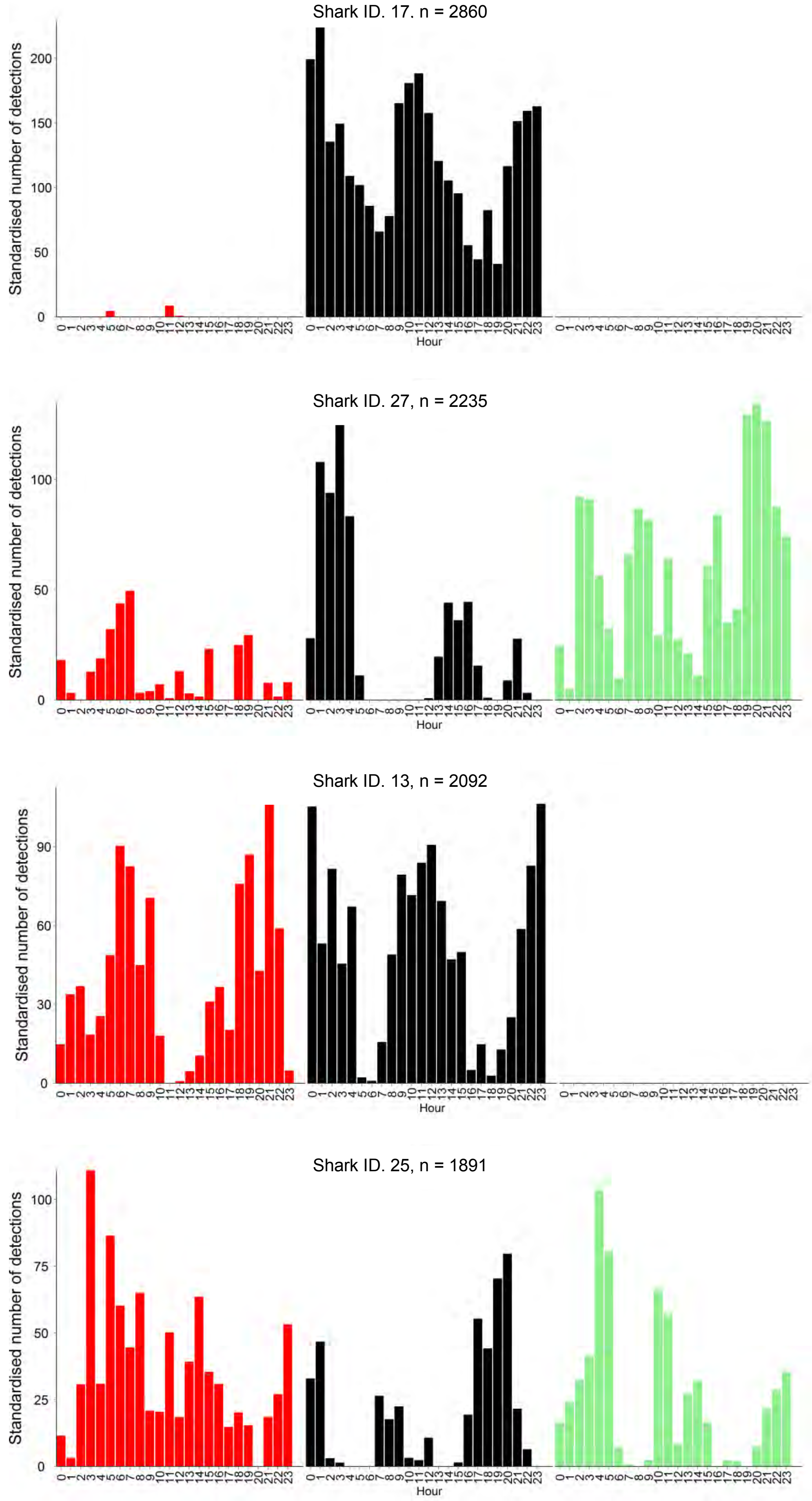
Carcharhinus brachyurus

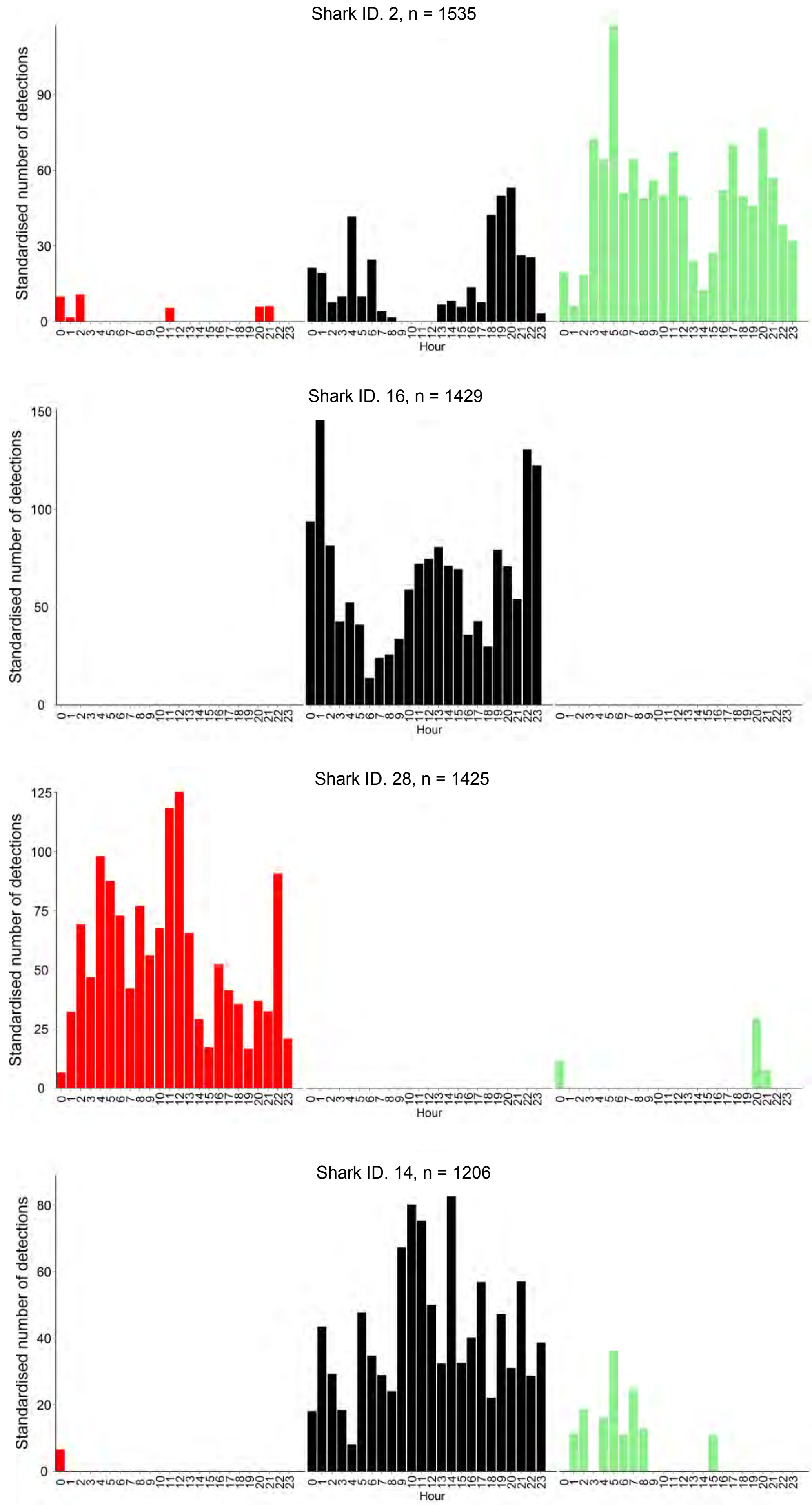


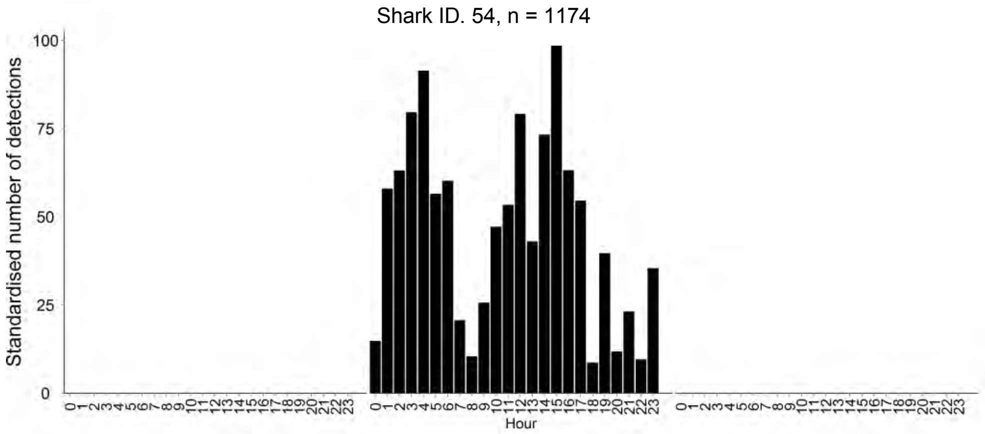







Shark ID. 17. n = 2860
Standardised number of detections
Hour
Shark ID. 27, n = 2235
Standardised number of detections
Hour
Shark ID. 13, n = 2092
Standardised number of detections
Hour
Shark ID. 25, n = 1891
Standardised number of detections
Hour


Shark ID. 2, n = 1535
Standardised number of detections
Hour
Shark ID. 16, n = 1429
Standardised number of detections
Hour
Shark ID. 28, n = 1425
Standardised number of detections
Hour
Shark ID. 14, n = 1206
Standardised number of detections
Hour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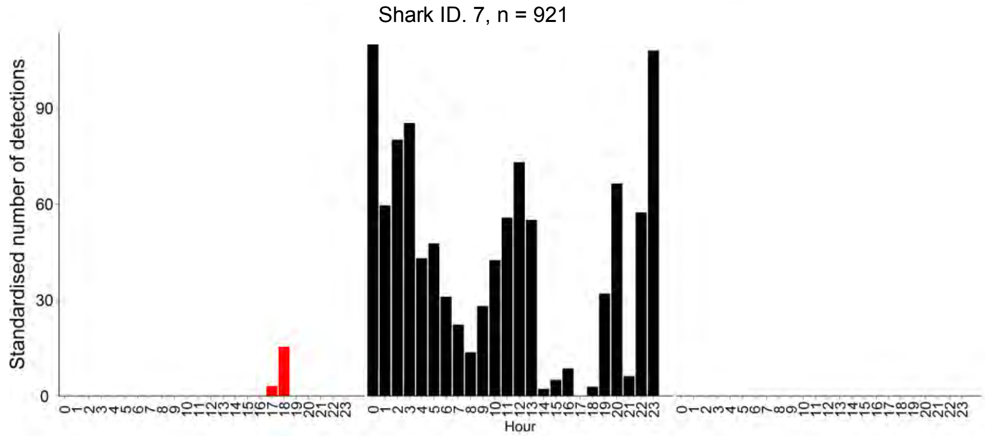
25
50
75
100
Hour


Shark ID. 7, n = 921
Standardised number of detections
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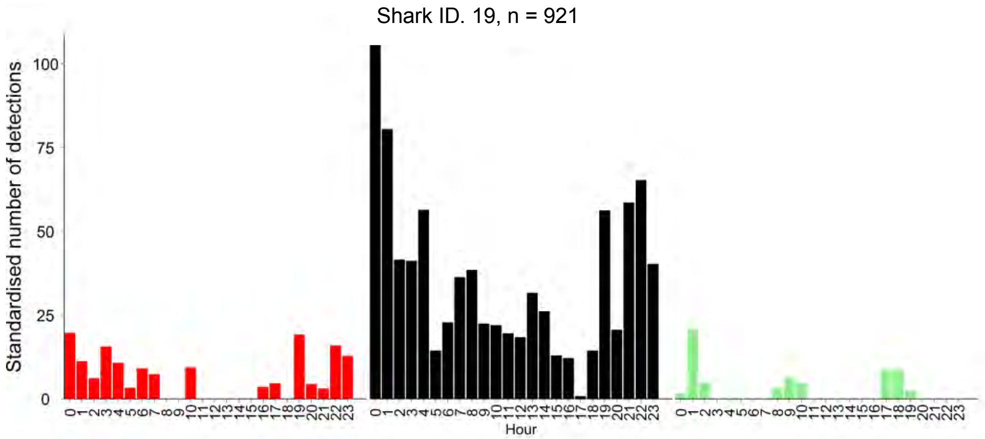
30
60
90
Hour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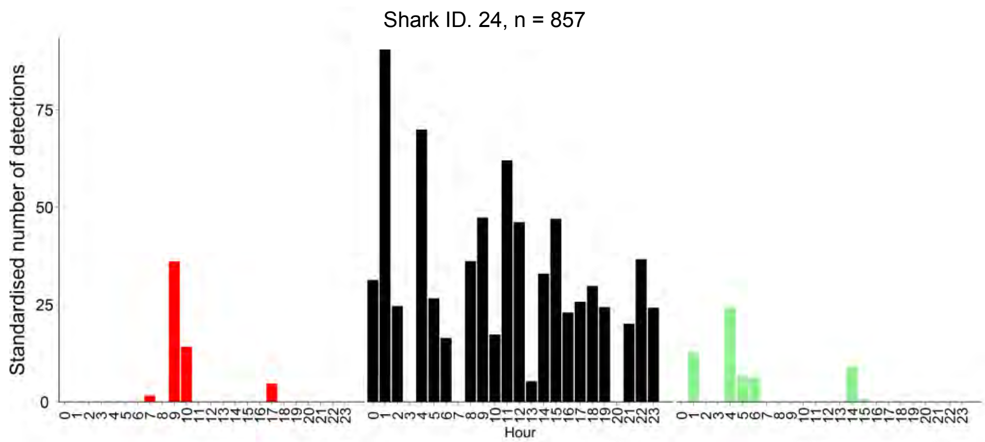
25
50
75
100
Hour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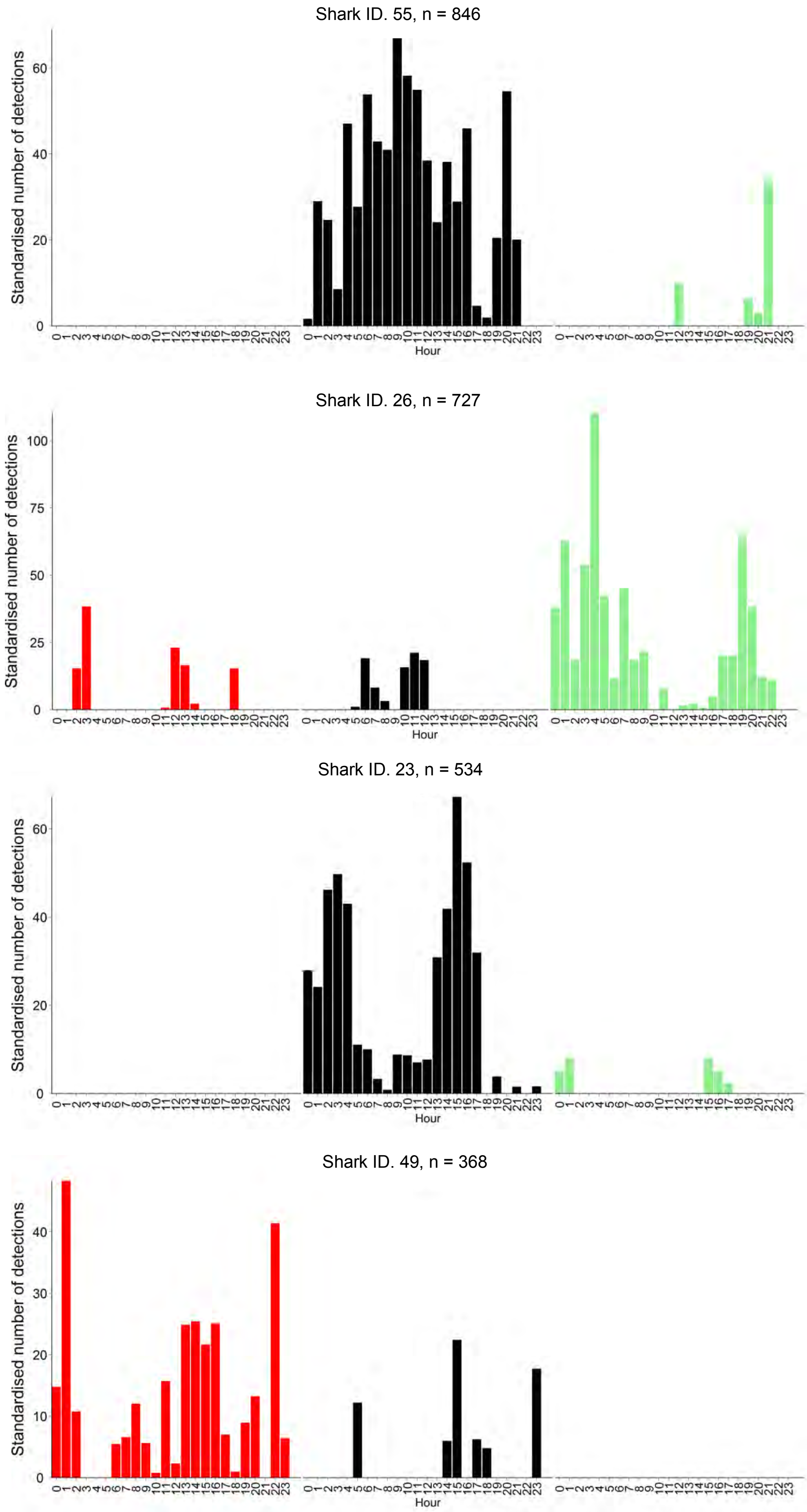
0
25
50
75
Hour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Shark ID. 26, n = 727
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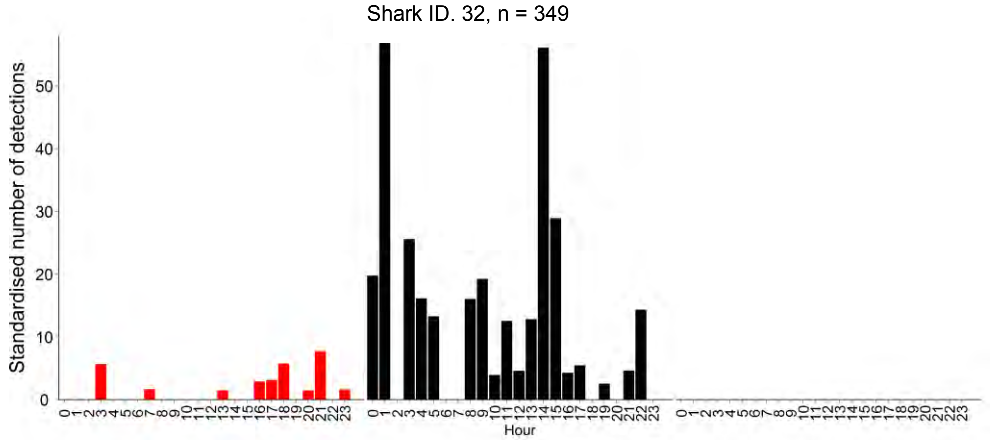
Standardised number of detections
Hour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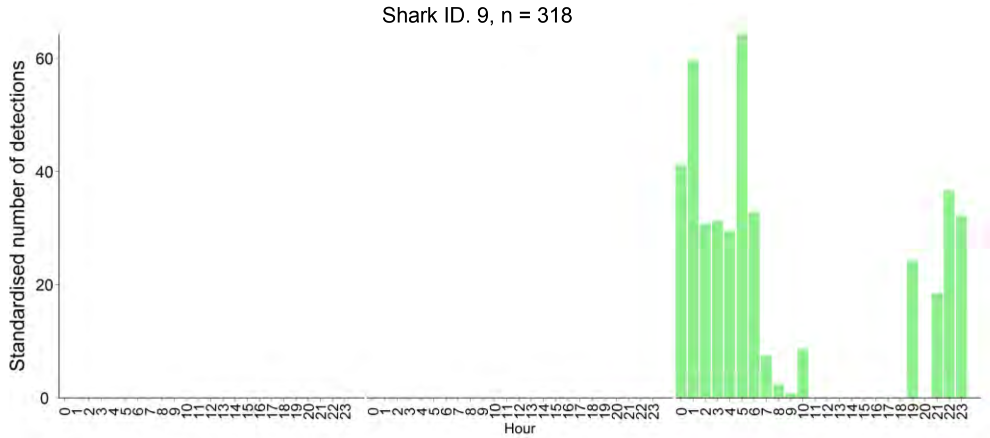
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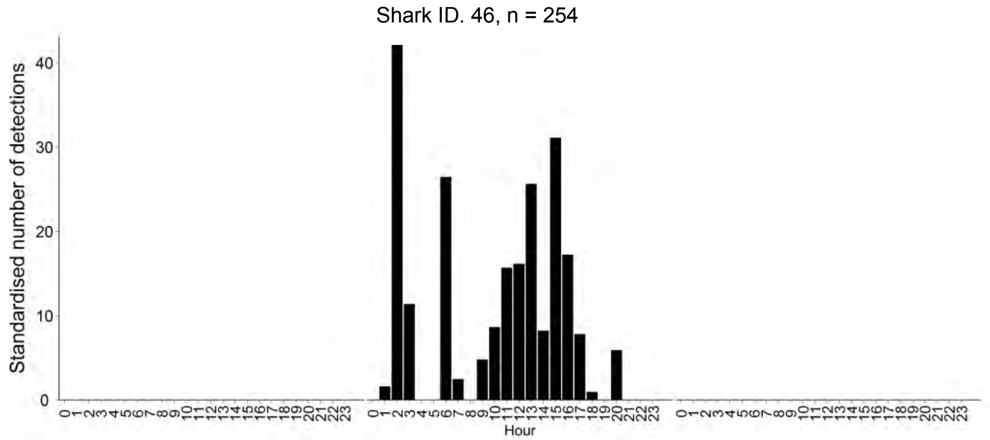
Hour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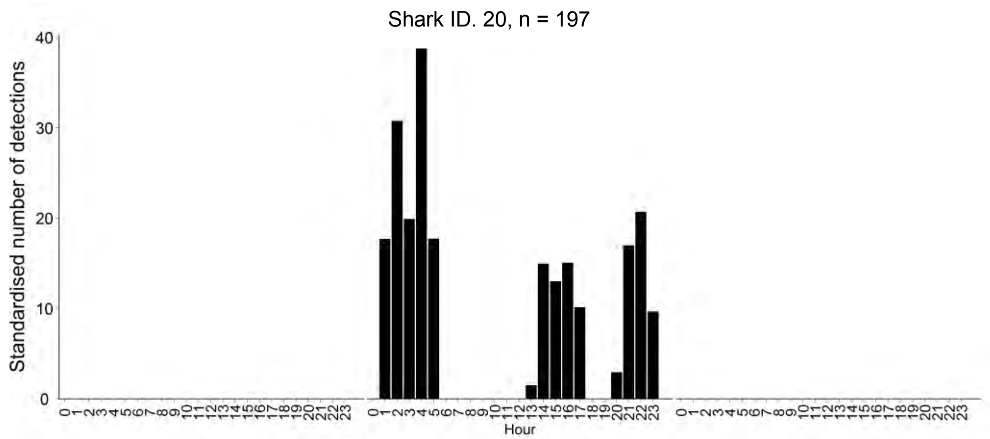
Hour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Standardised number of detections
Hour

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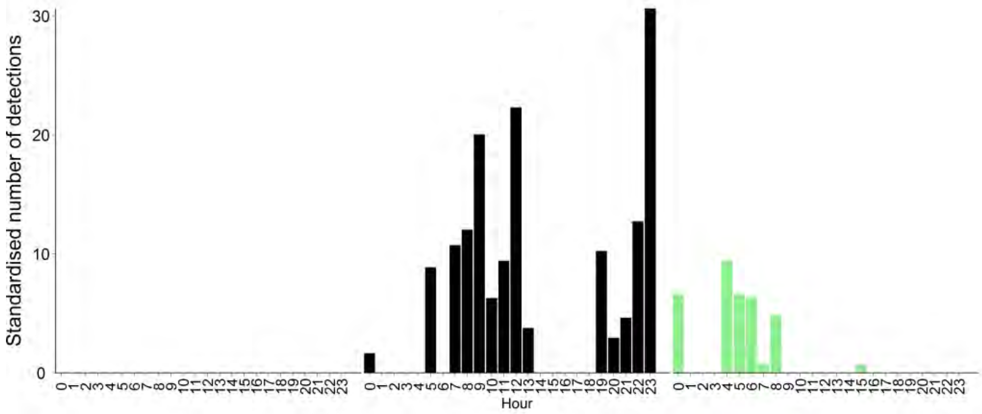

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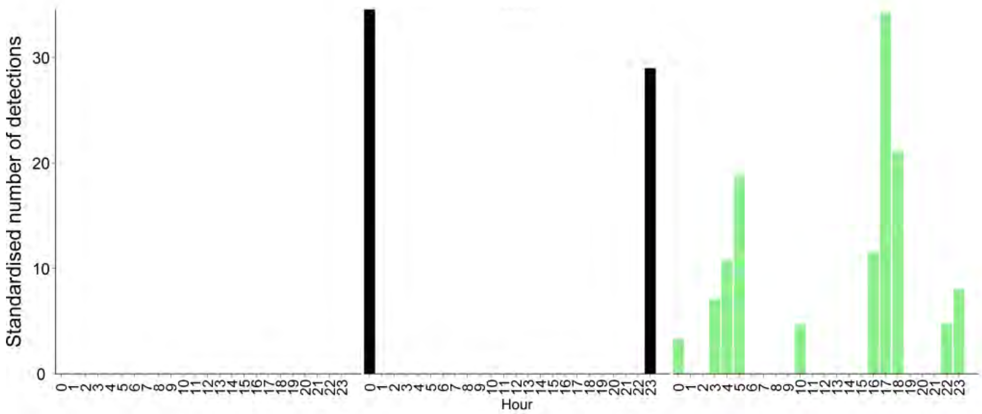

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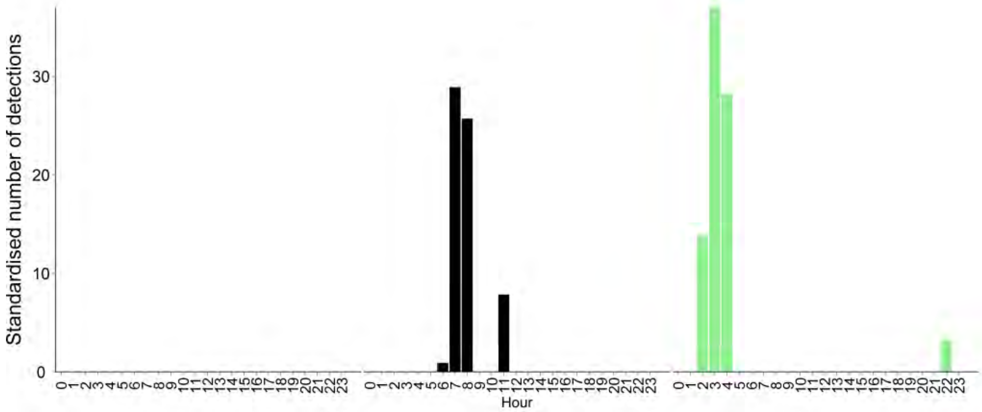

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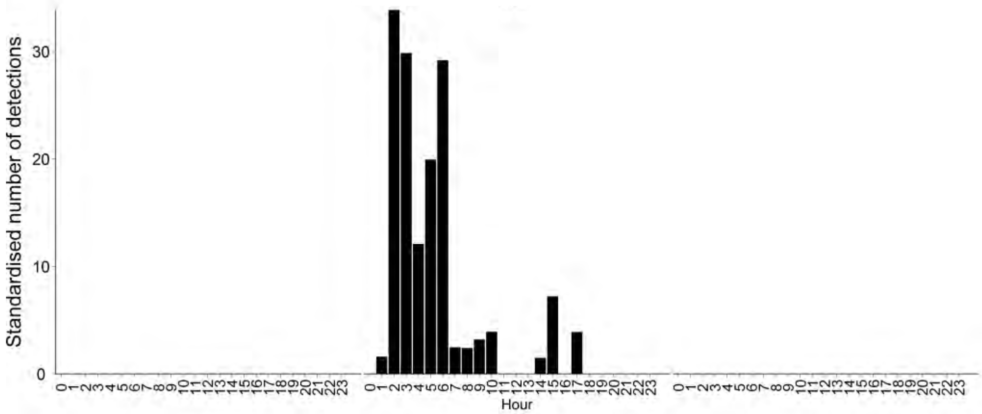

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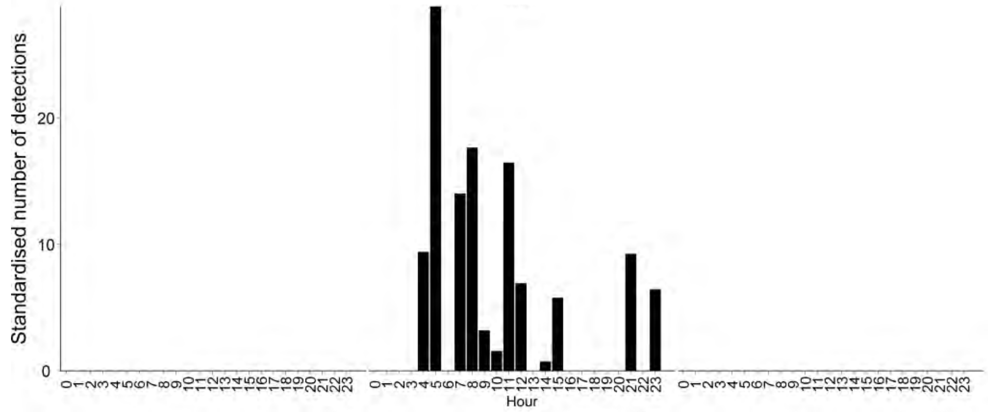

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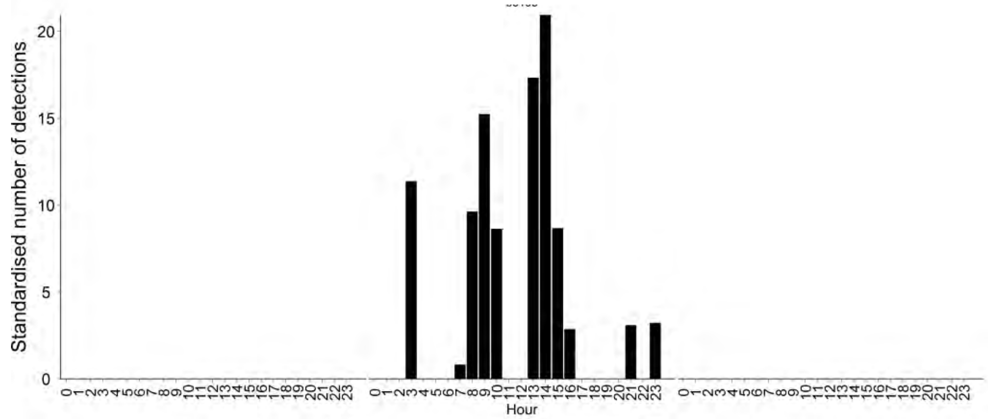

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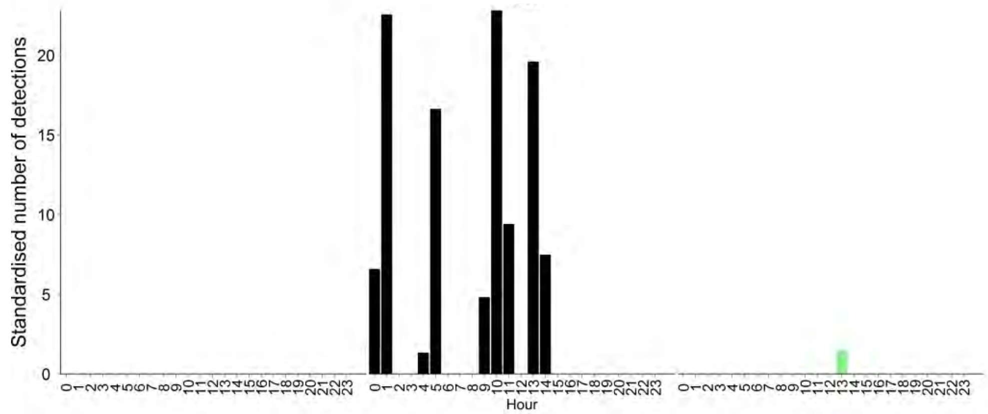

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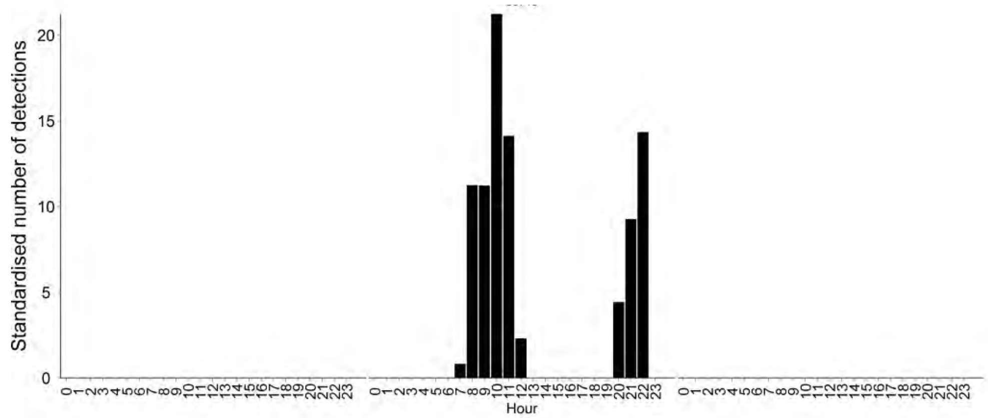

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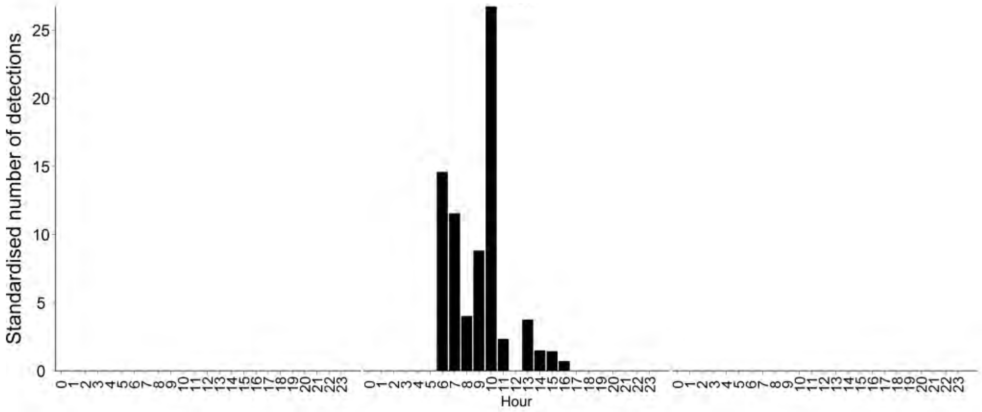

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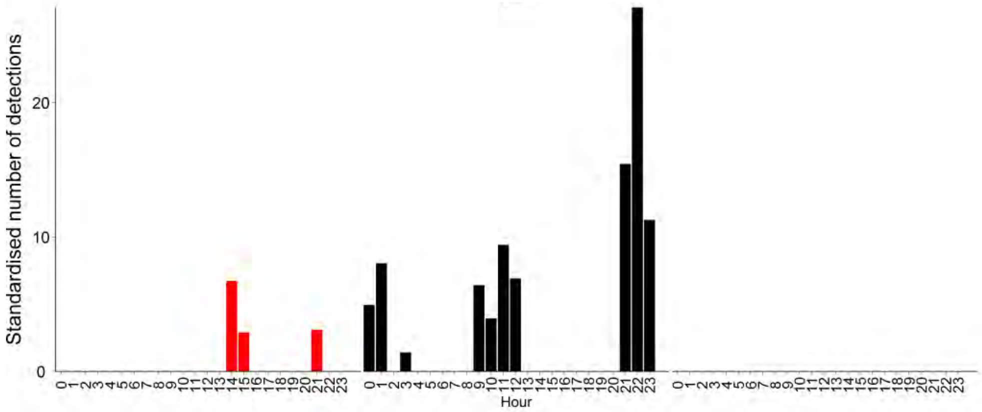

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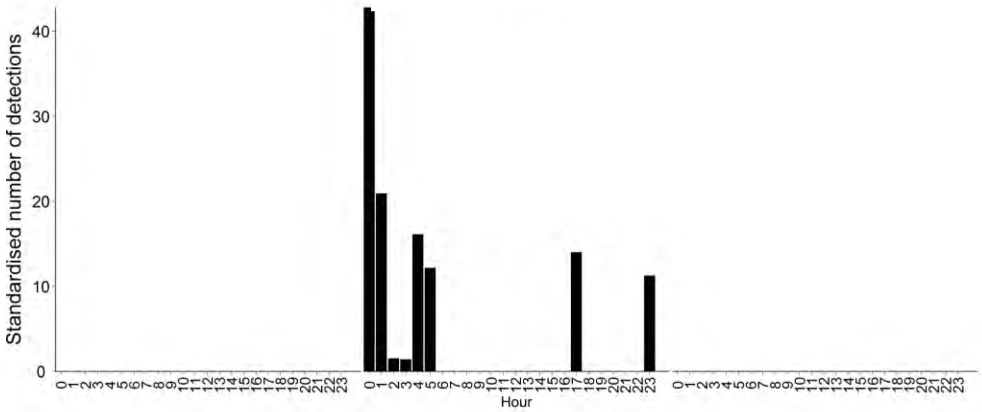

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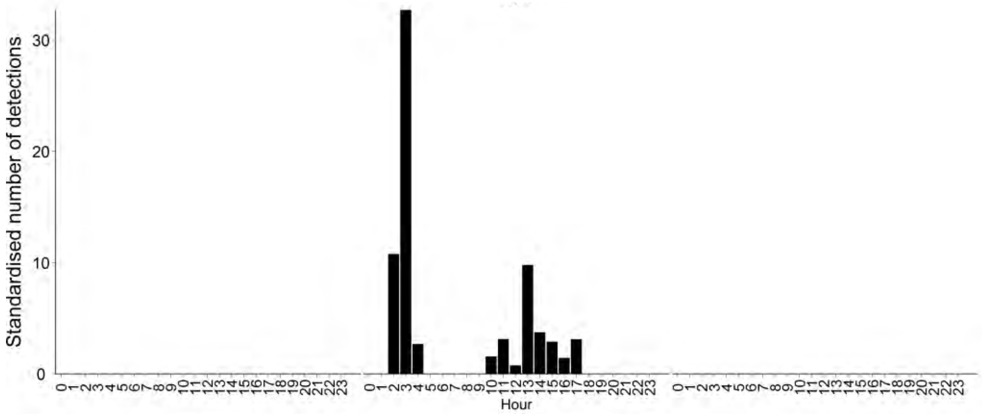

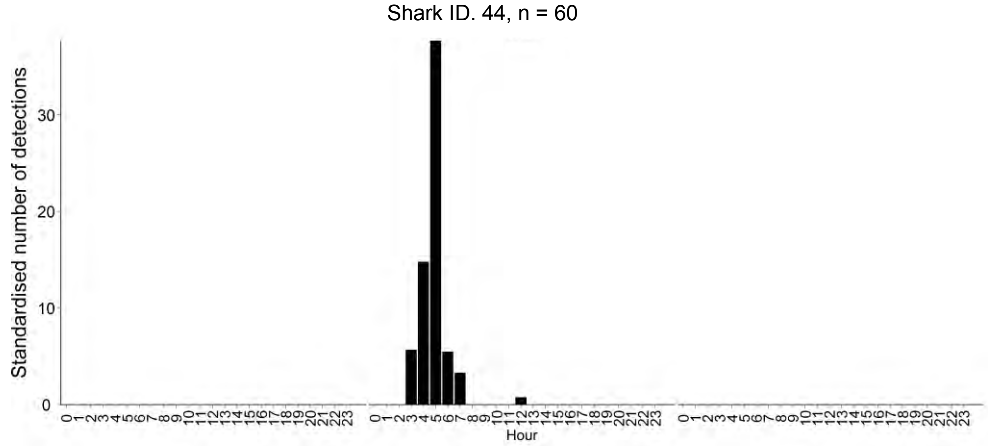
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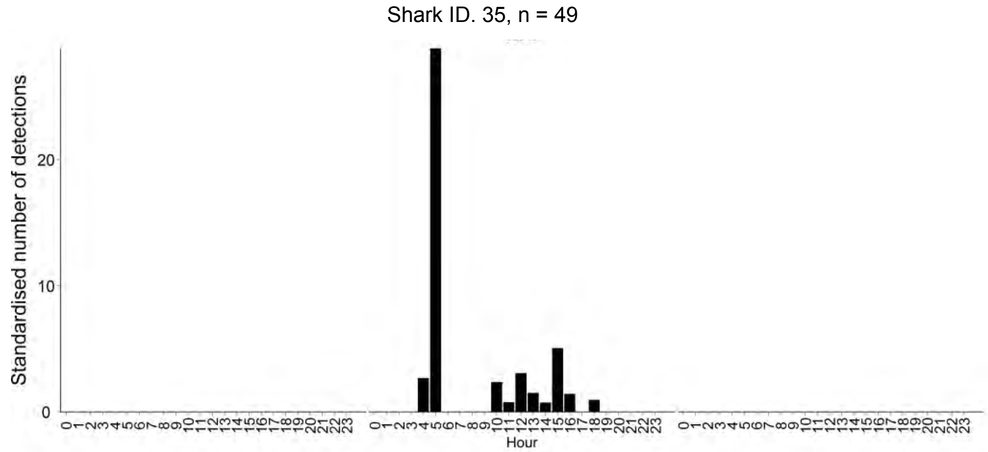
Standardised number of detections
0
10
20
30
Hour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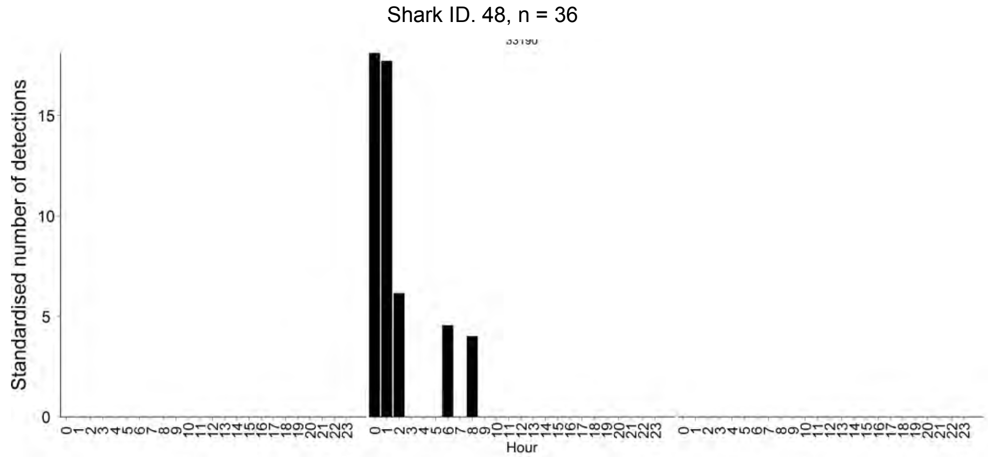
10
20
Hour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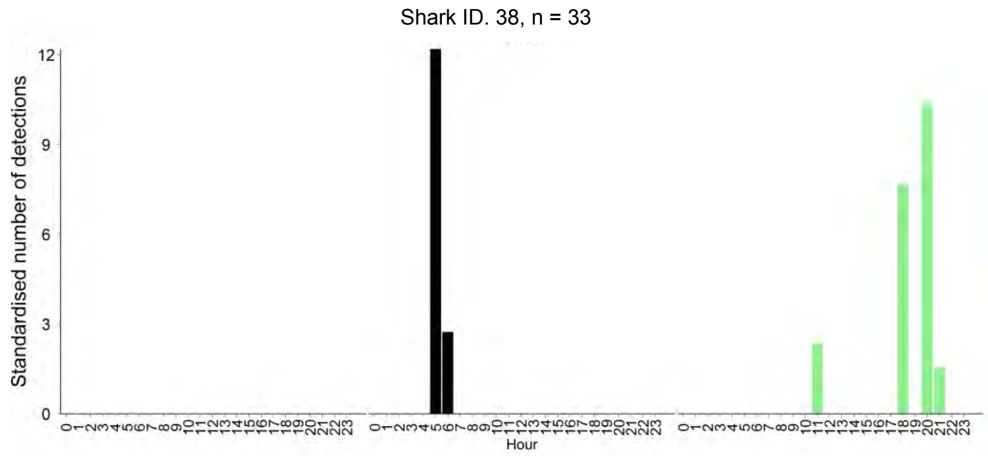
5
10
15
Hour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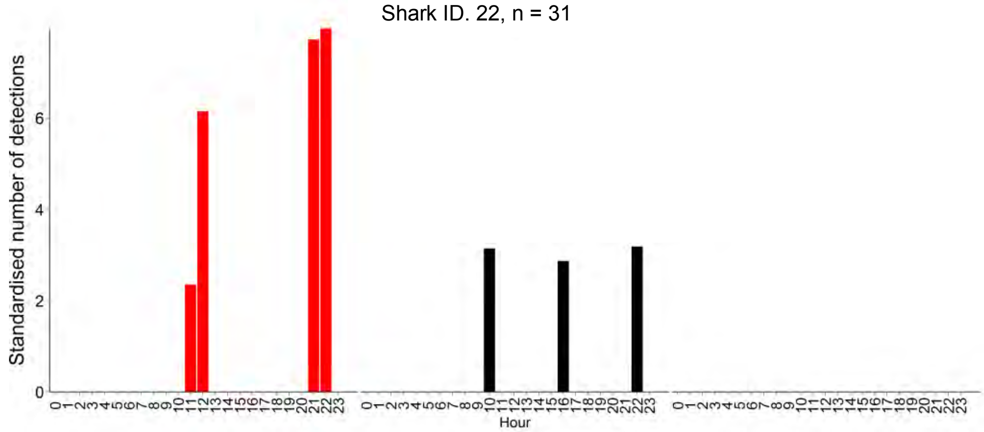
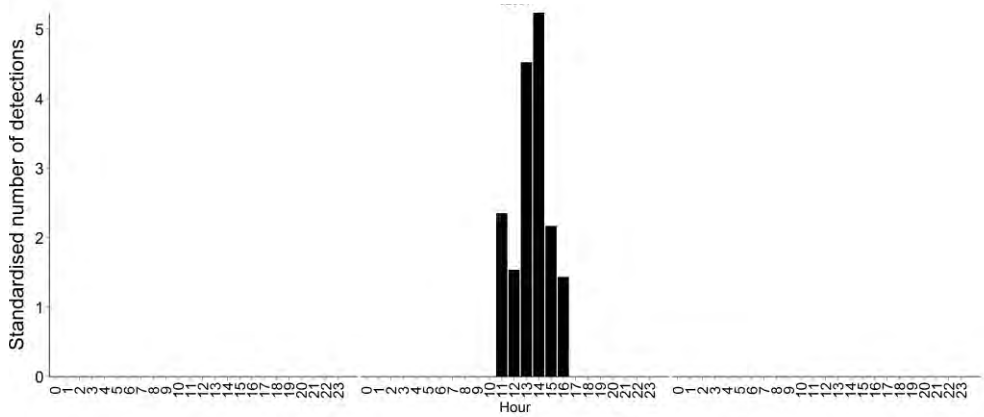
3
6
9
12
Hour

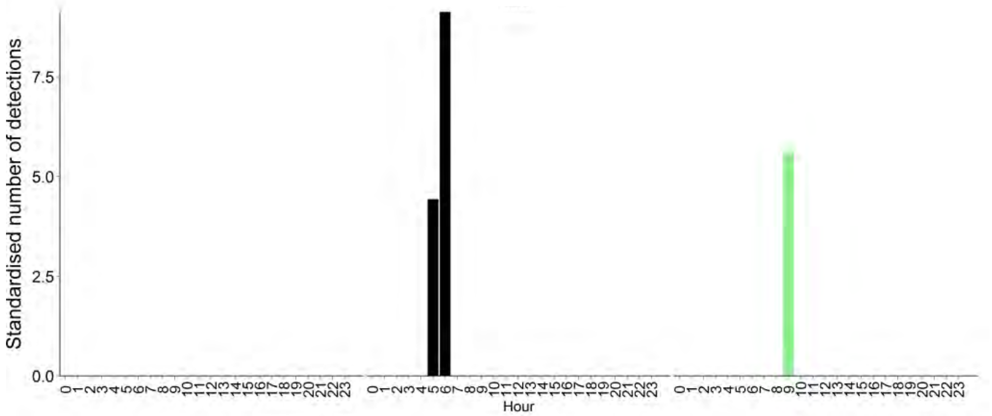
Shark ID. 22, n = 31



Shark ID. 37, n = 23

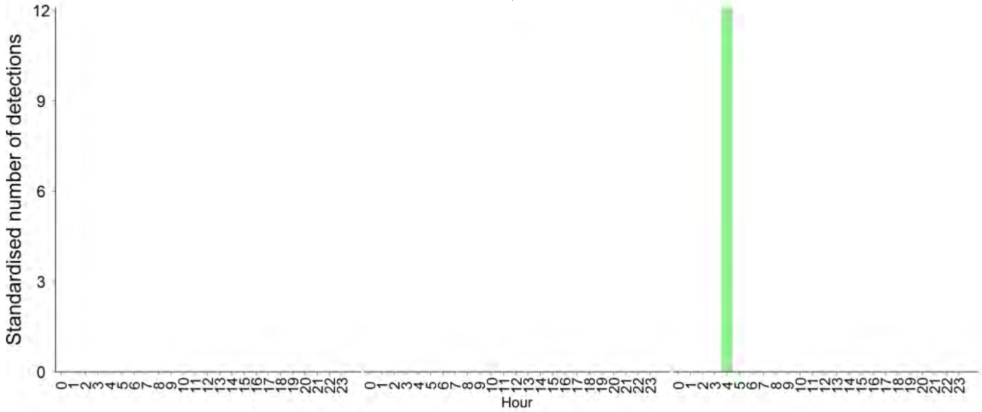


Shark ID. 39, n = 21

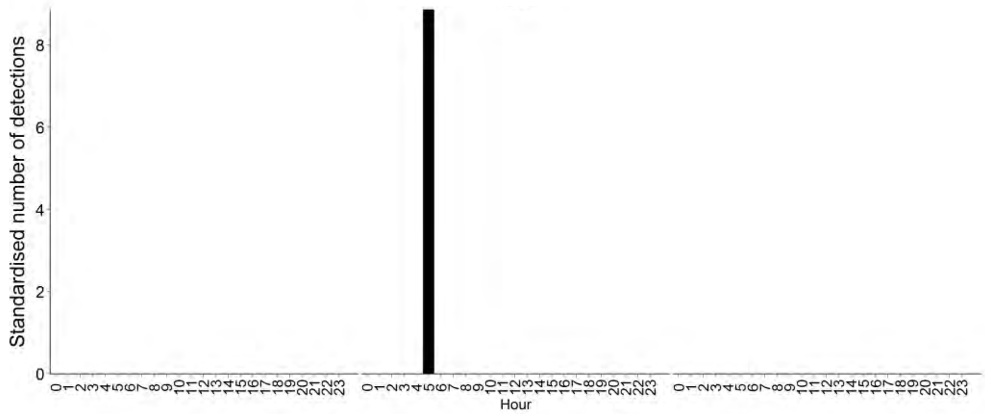


Shark ID. 43, n = 11

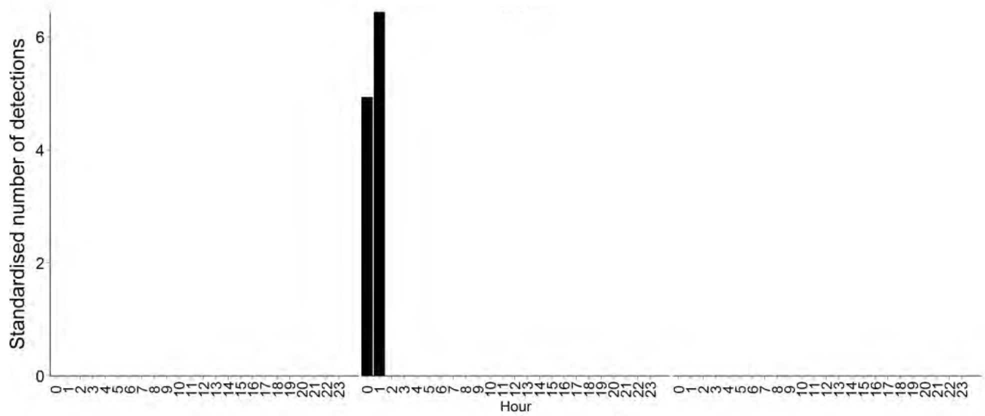
Shark ID. 12, n = 09



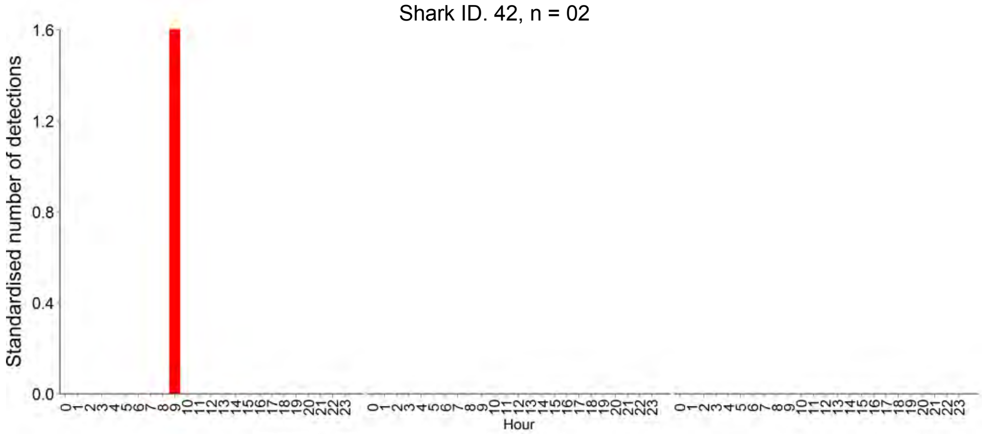
Shark ID. 36, n = 08



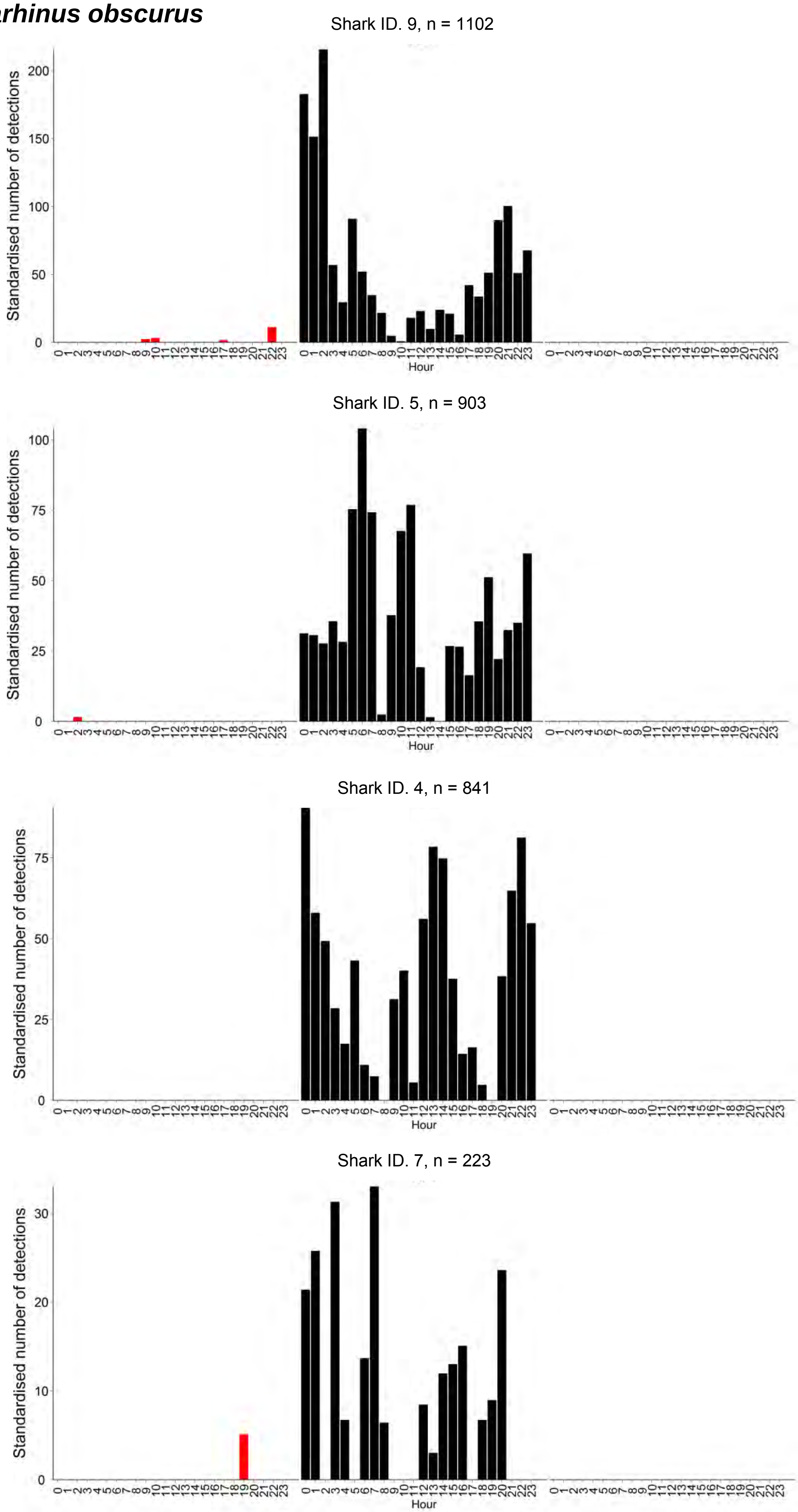
Shark ID. 21,n = 07

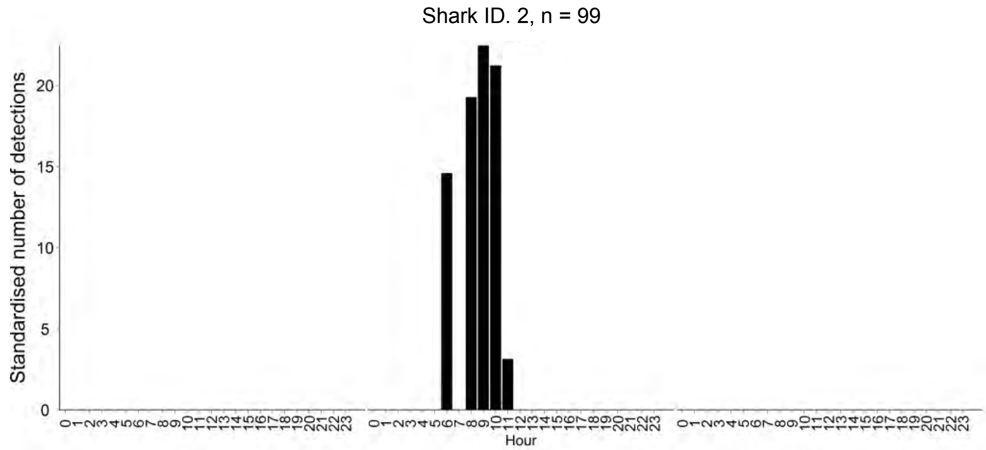


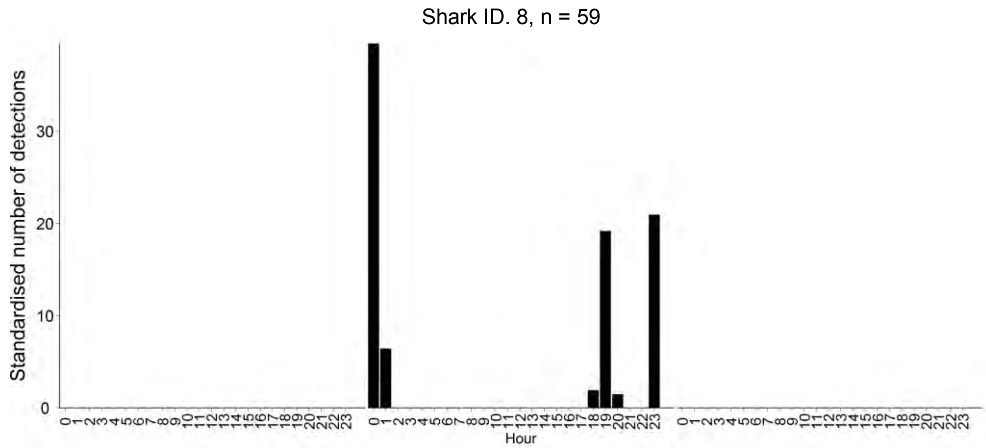
Shark ID. 42, n = 02

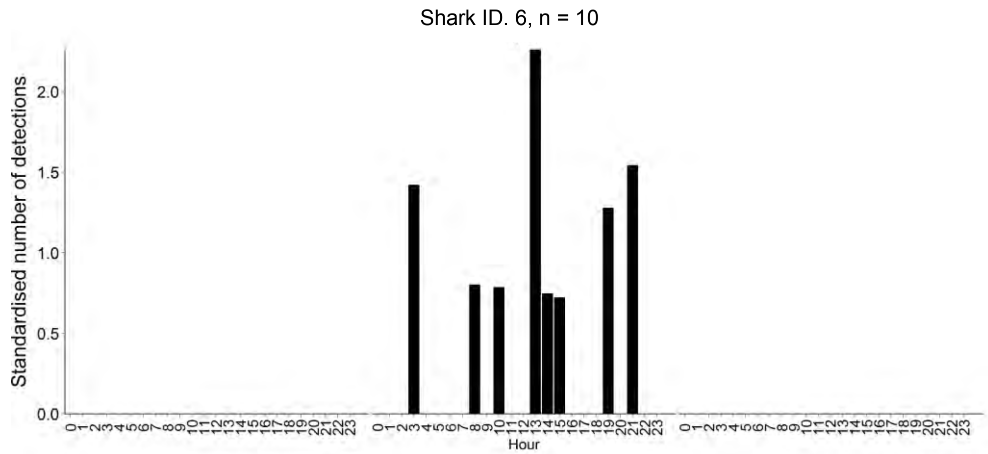


Carcharhinus obscurus




Shark ID. 2, n = 99
Standardised number of detections
Hour

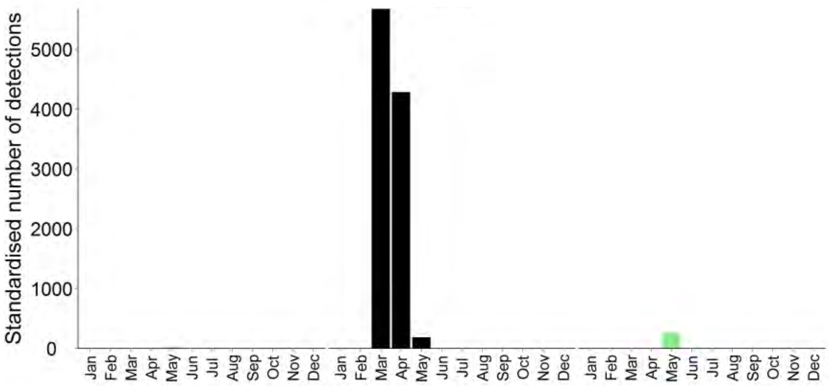

Shark ID. 8, n = 59
Standardised number of detections
Hour


Shark ID. 6, n = 10
Standardised number of detections
Hour

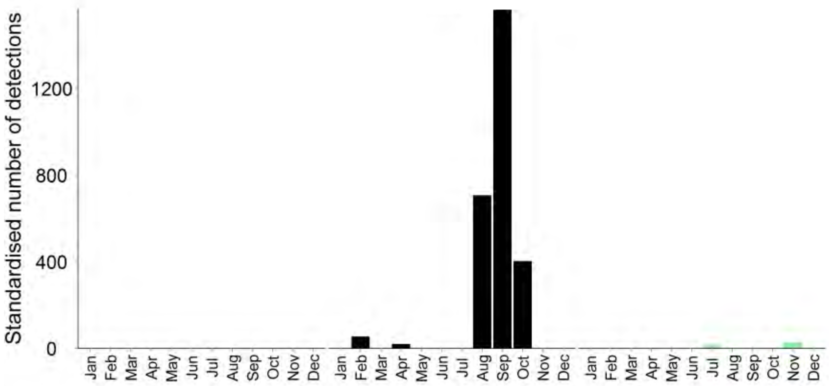
APPENDIX 2: Standardised number of detections per month for Northwest GSV (red), Northeast GSV (black), and the metropolitan region (green)

Carcharhinus brachyurus

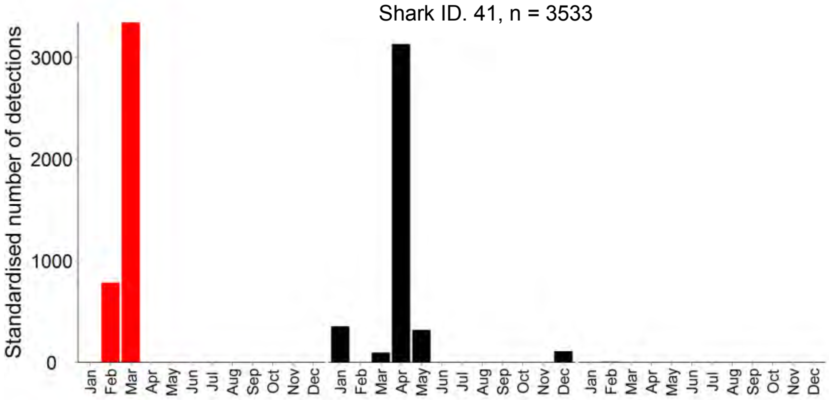
Shark ID. 53, n = 4443



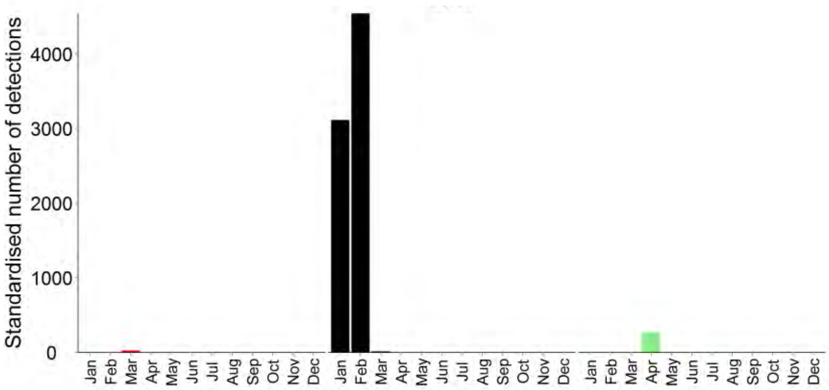
Shark ID. 29, n = 4166

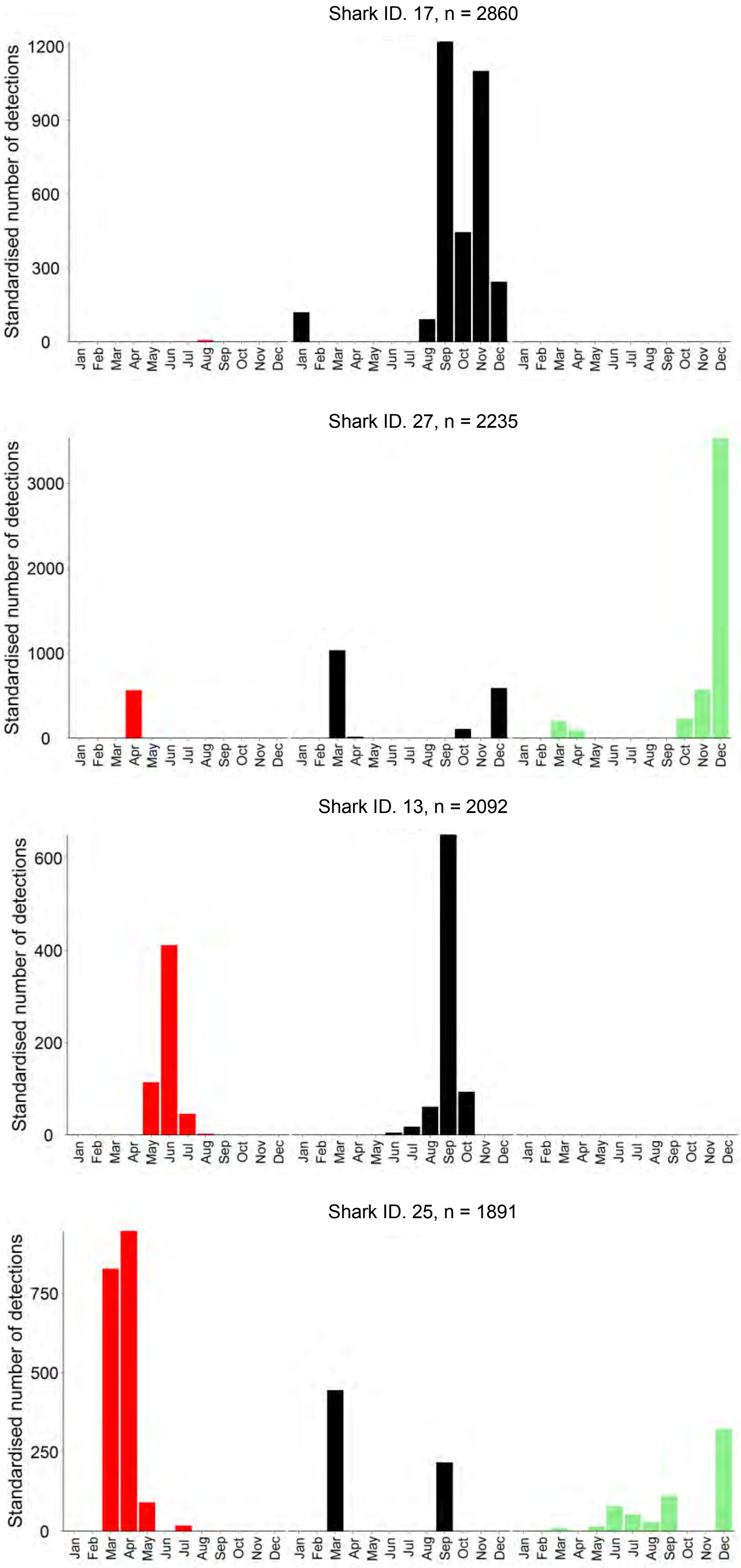


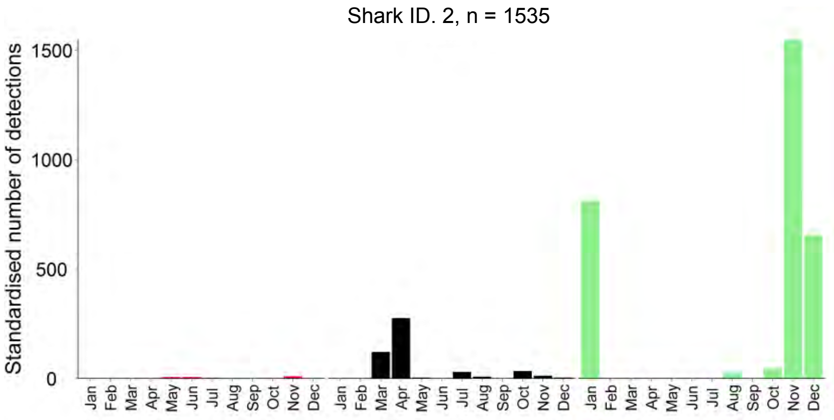
Shark ID. 41, n = 3533

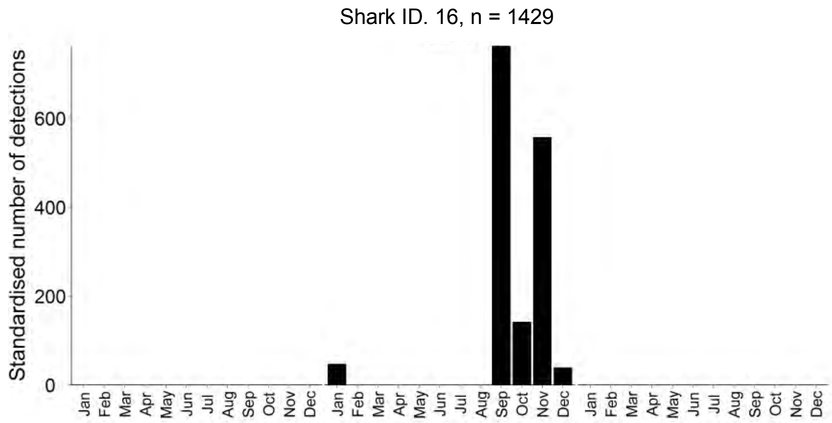


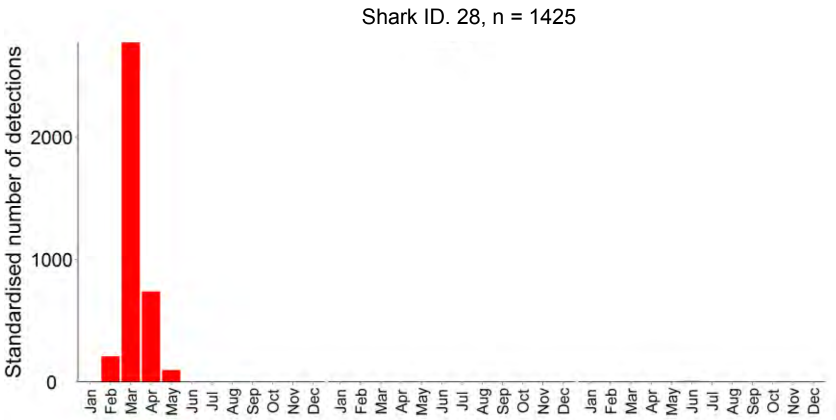
Shark ID. 47, n = 3319

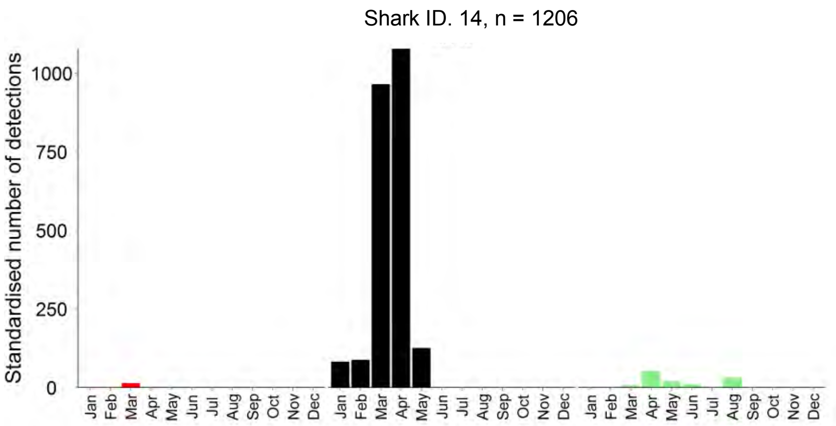


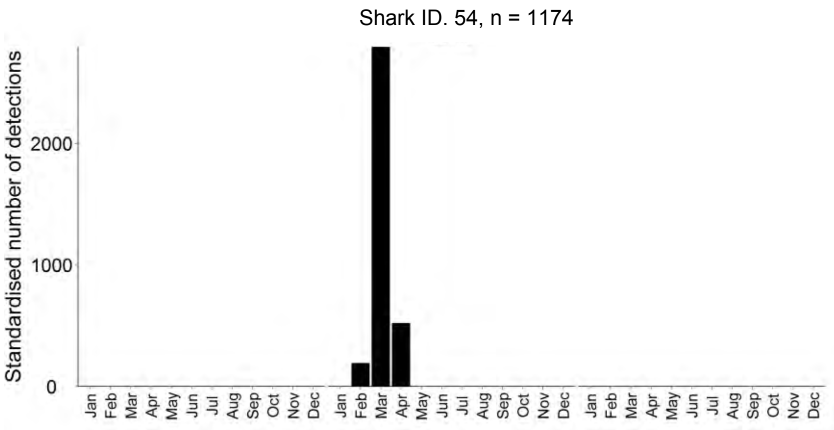

Shark ID. 17, n = 2860
Shark ID. 27, n = 2235
Shark ID. 13, n = 2092
Shark ID. 25, n = 1891
Standardised number of detections
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec

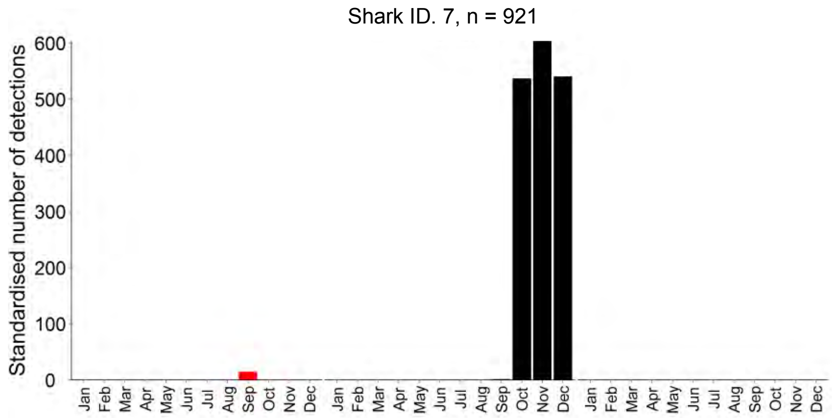

Shark ID. 2, n = 1535
Standardised number of detections
0
500
1000
1500
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec

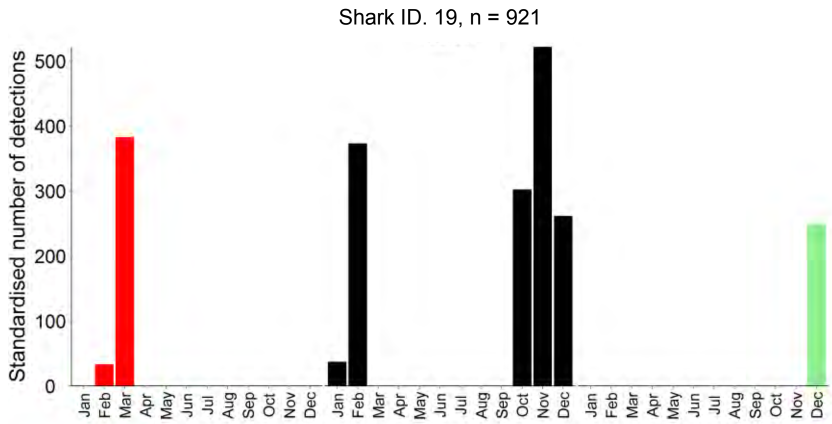

Shark ID. 16, n = 1429
Standardised number of detections
0
200
400
600
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec

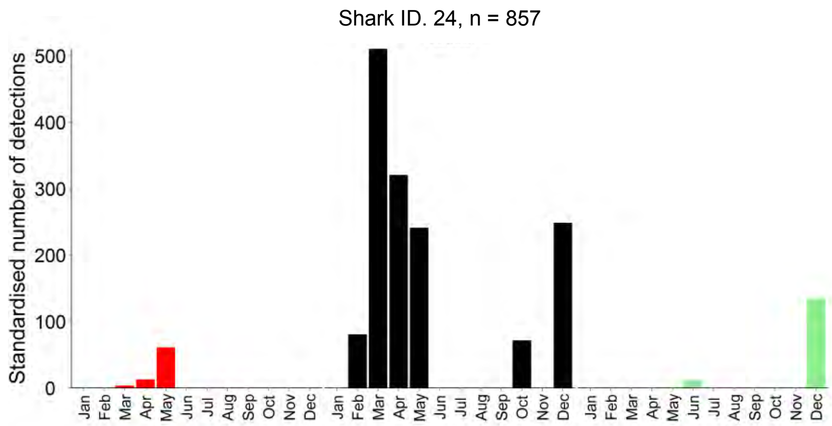

Shark ID. 28, n = 1425
Standardised number of detections
0
1000
2000
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec

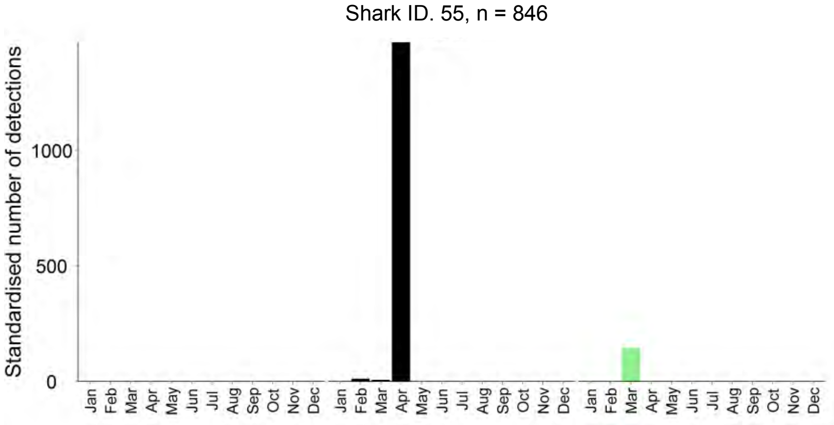

Shark ID. 14, n = 1206
Standardised number of detections
0
250
500
750
1000
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec

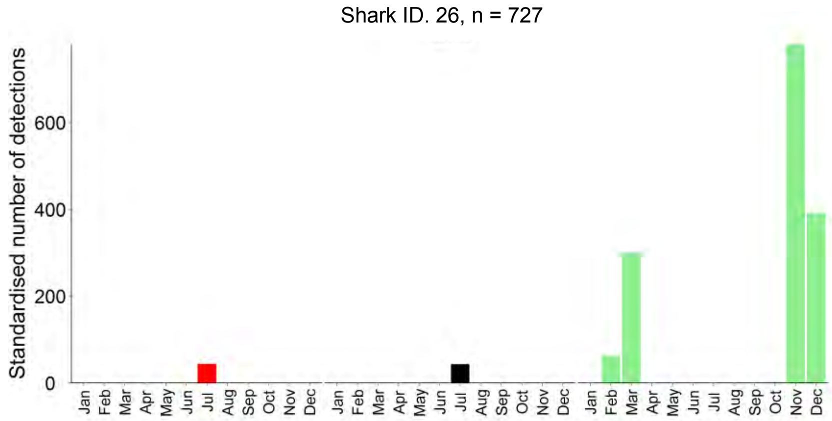

Shark ID. 54, n = 1174
Standardised number of detections
0
1000
2000
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec

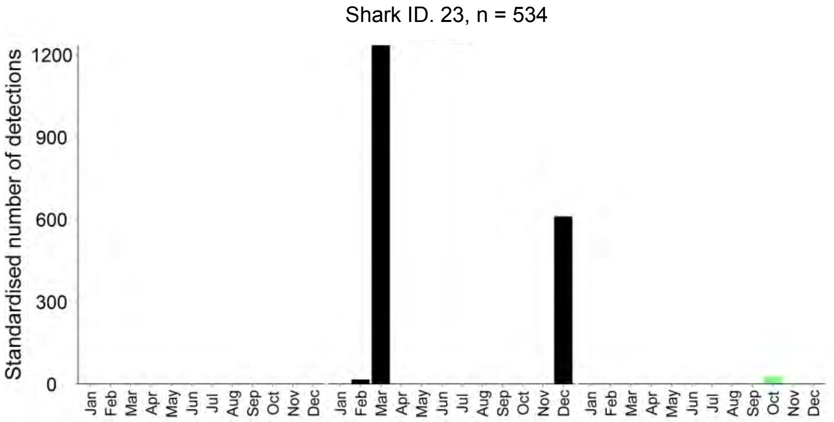

Shark ID. 7, n = 921
Standardised number of detections
0
100
200
300
400
500
600
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec

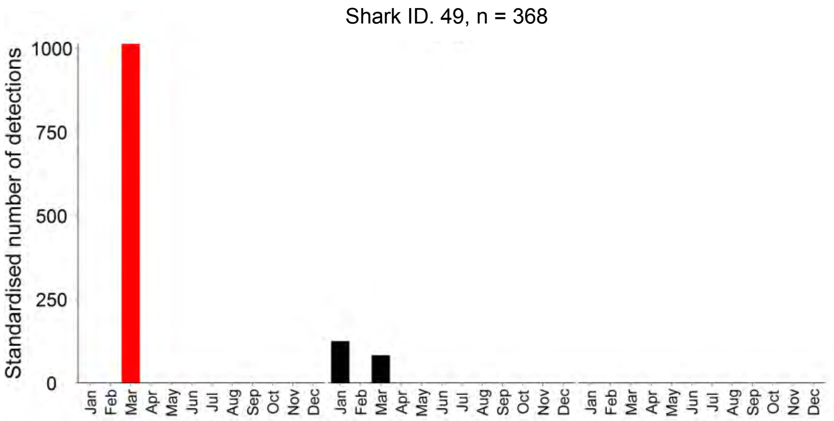

Shark ID. 19, n = 921
Standardised number of detections
0
100
200
300
400
500
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec


Shark ID. 24, n = 857
Standardised number of detections
0
100
200
300
400
500
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec

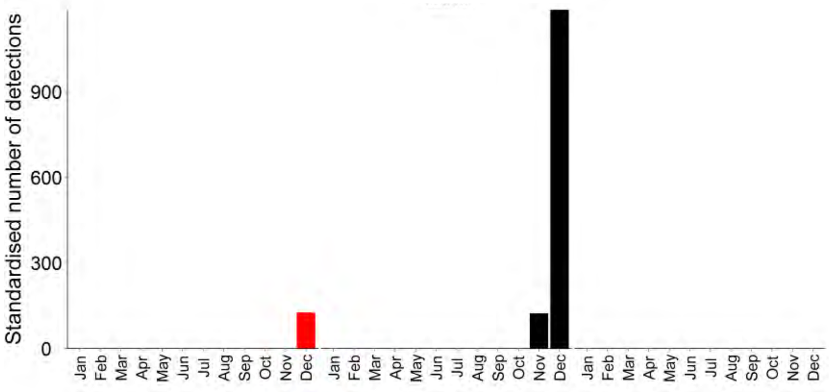

Shark ID. 55, n = 846
Standardised number of detections
0
500
1000
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec


Shark ID. 26, n = 727
Standardised number of detections
0
200
400
600
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec


Shark ID. 23, n = 534
Standardised number of detections
0
300
600
900
1200
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec

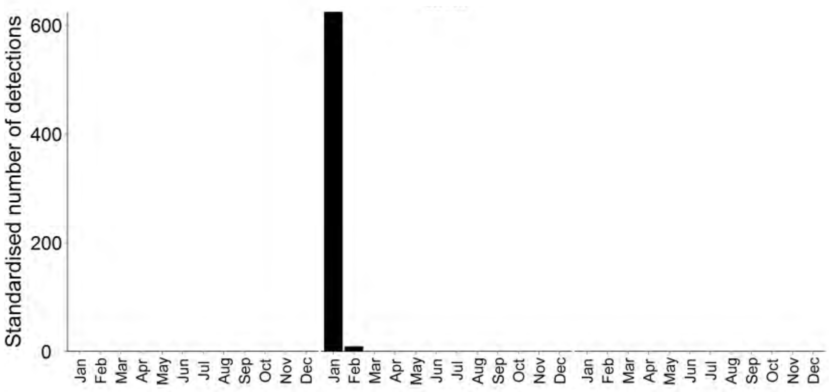

Shark ID. 49, n = 368
Standardised number of detections
0
250
500
750
1000
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec

Shark ID. 32, n = 349

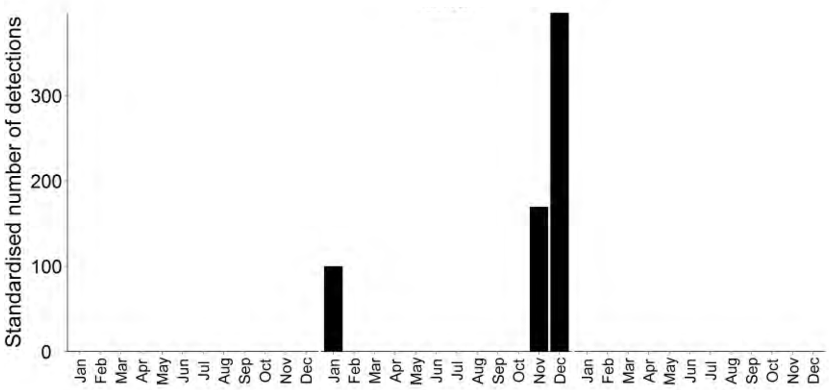


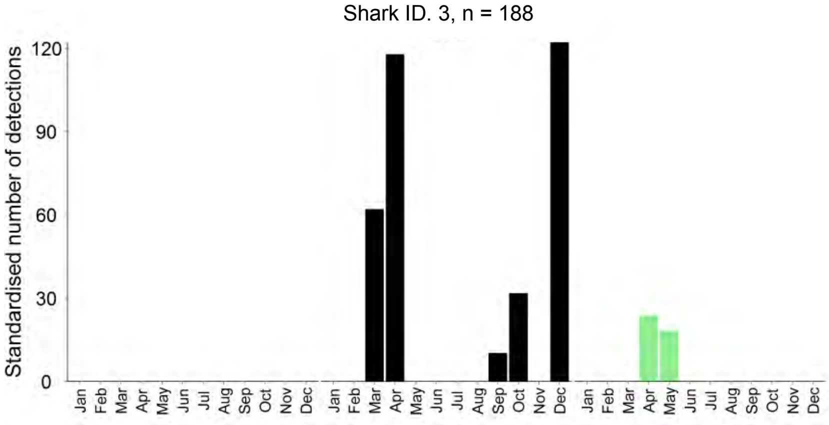
Shark ID. 9, n = 318

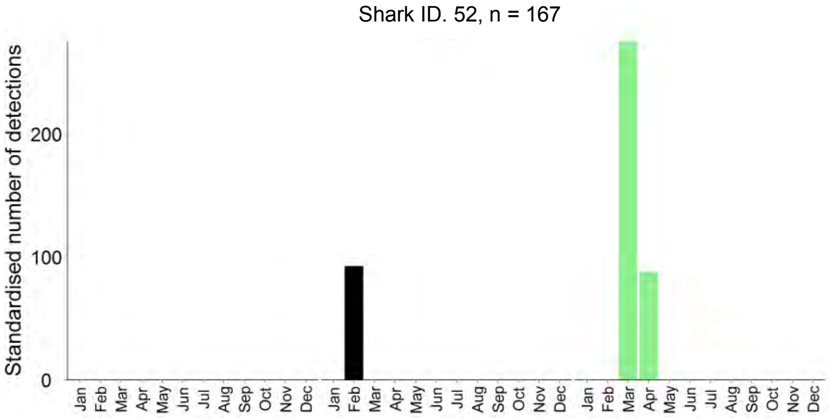
Shark ID. 46, n = 254

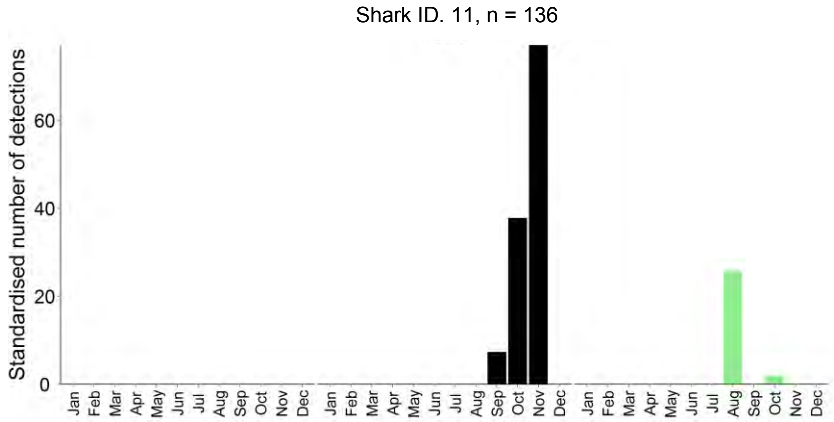


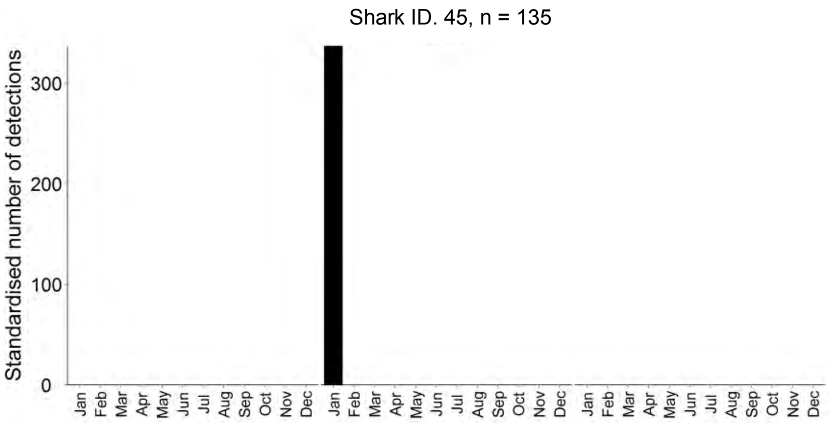
Shark ID. 20, n = 197

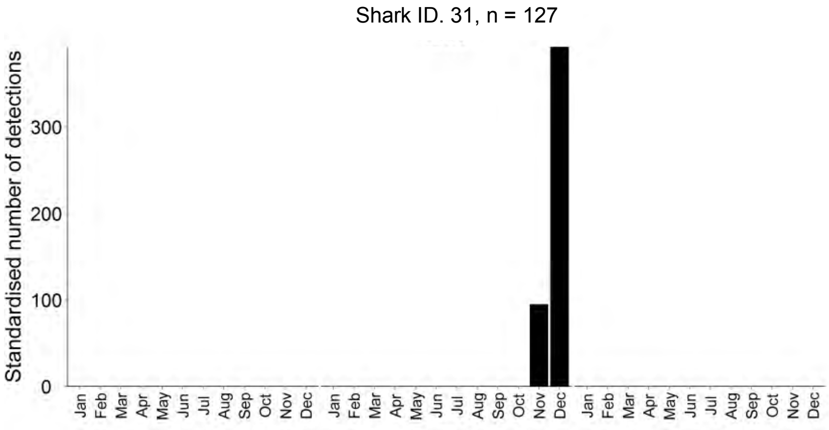


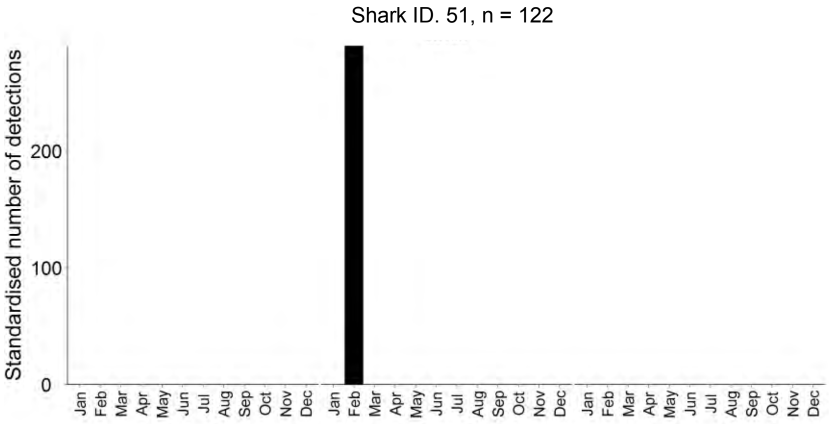

Shark ID. 3, n = 188
Standardised number of detections
0
30
60
90
120
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec

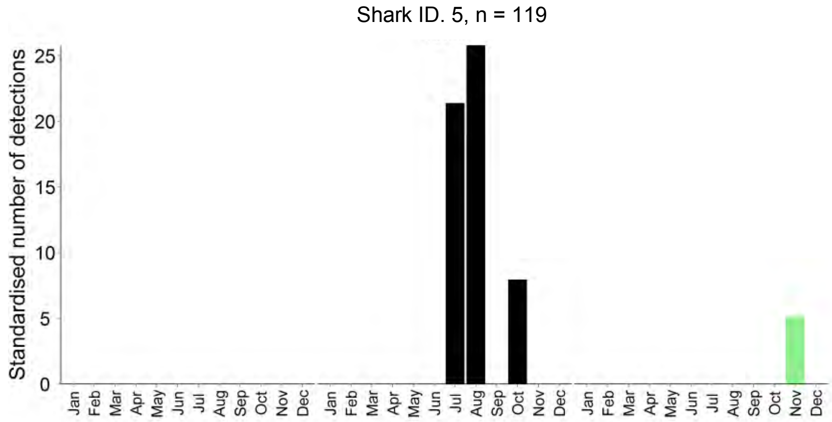

Shark ID. 52, n = 167
Standardised number of detections
0
100
200
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec

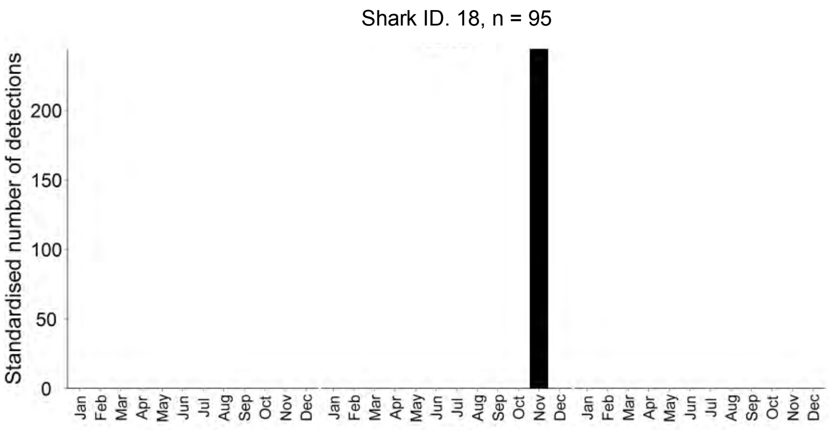

Shark ID. 11, n = 136
Standardised number of detections
0
20
40
60
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec


Shark ID. 45, n = 135
Standardised number of detections
0
100
200
300
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec

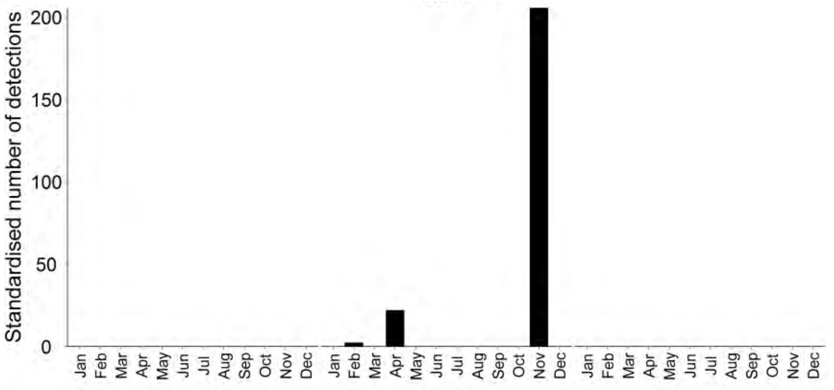

Shark ID. 31, n = 127
Standardised number of detections
0
100
200
300
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec


Shark ID. 51, n = 122
Standardised number of detections
0
100
200
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec

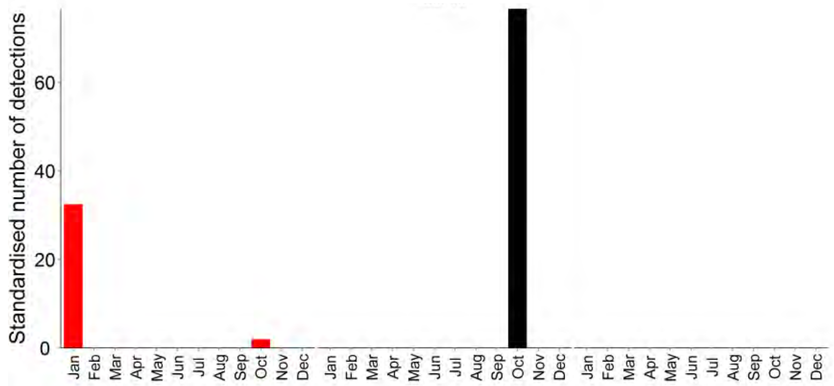

Shark ID. 5, n = 119
Standardised number of detections
0
5
10
15
20
25
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec


Shark ID. 18, n = 95
Standardised number of detections
0
50
100
150
200
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec

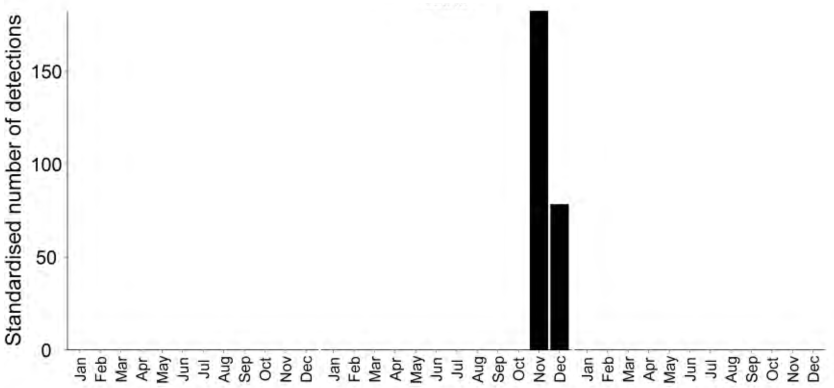
Shark ID. 34, n = 93



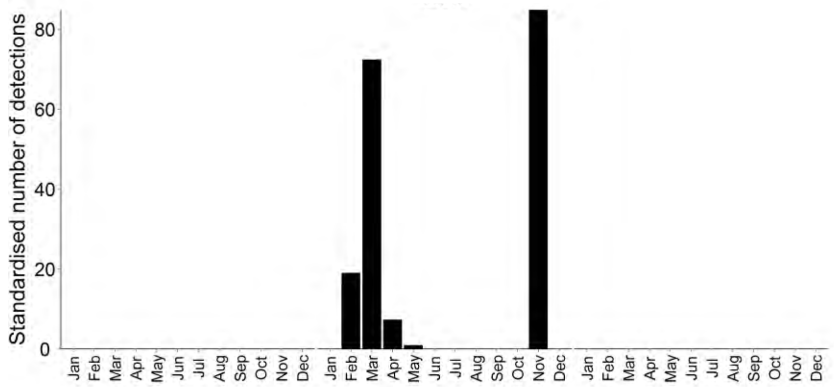
Shark ID. 15, n = 92

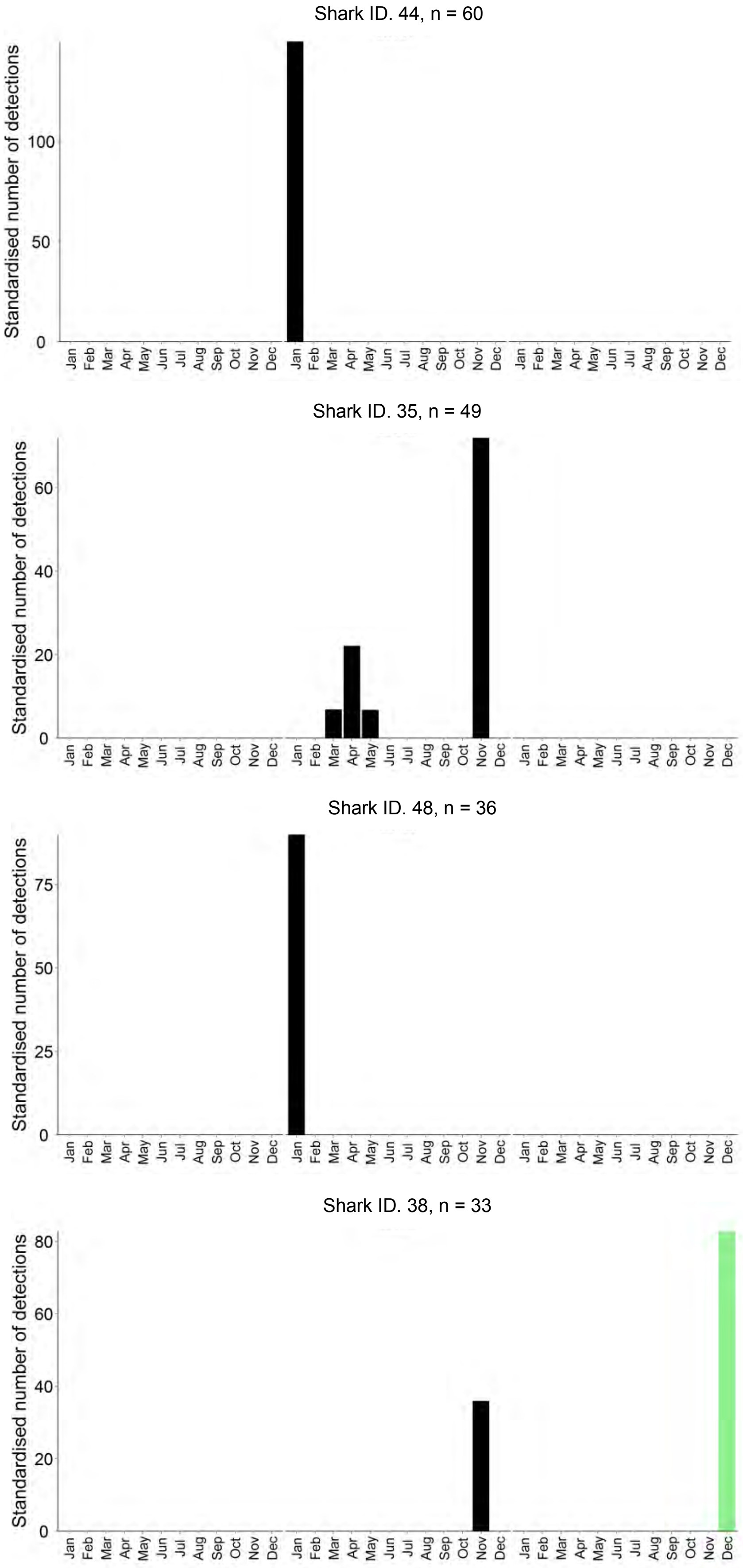


Shark ID. 30, n = 89

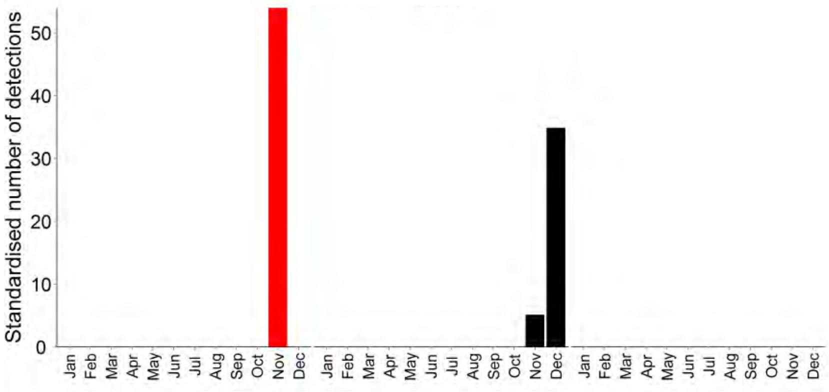


Shark ID. 33, n = 67

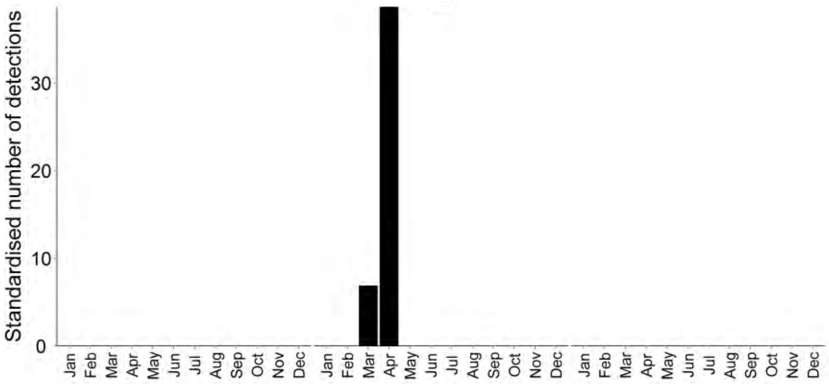



Shark ID. 44, n = 60
Standardised number of detections
0
50
100
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Shark ID. 35, n = 49
Standardised number of detections
0
20
40
60
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Shark ID. 48, n = 36
Standardised number of detections
0
25
50
75
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Shark ID. 38, n = 33
Standardised number of detections
0
20
40
60
80
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec

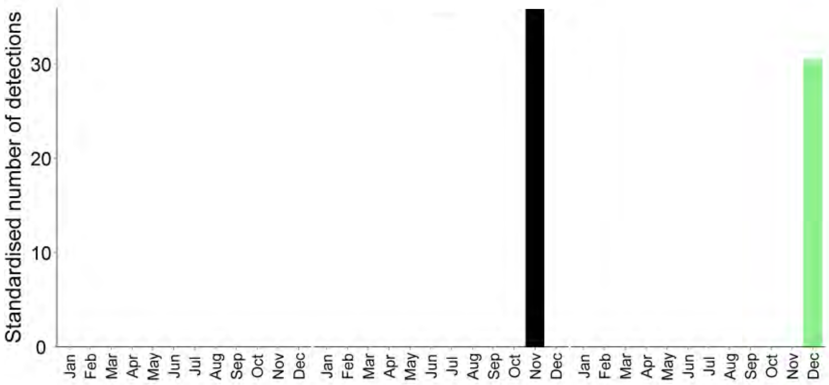
Shark ID. 22, n = 31



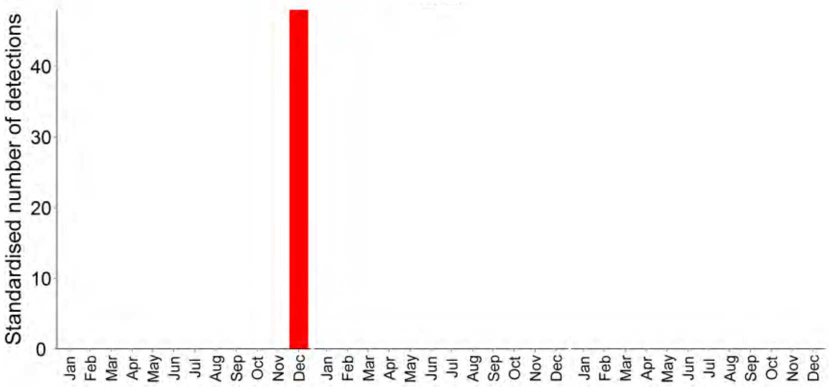
Shark ID. 37, n = 23

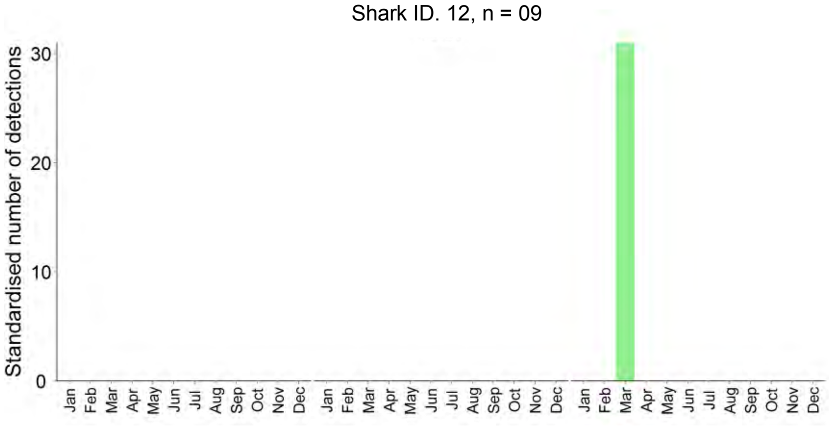


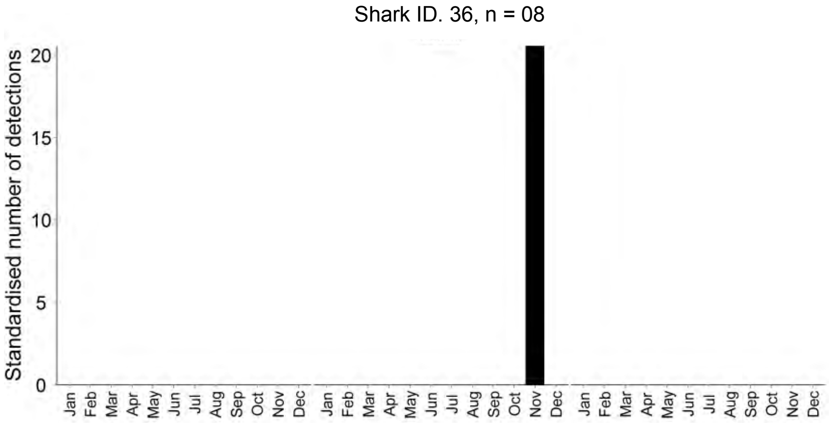
Shark ID. 39, n = 21

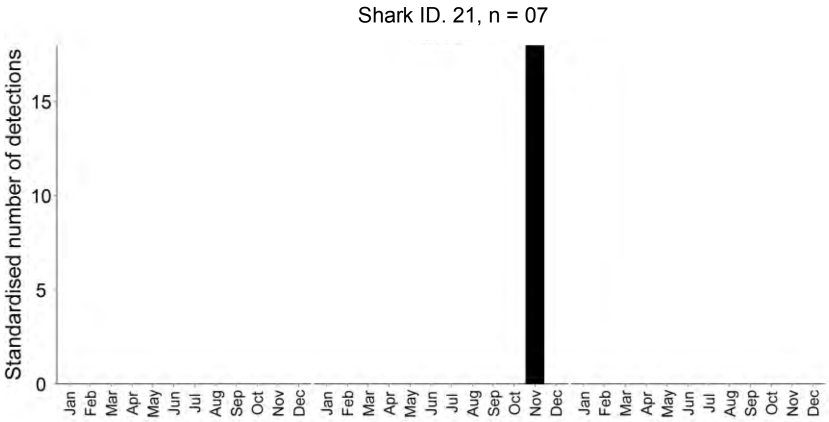


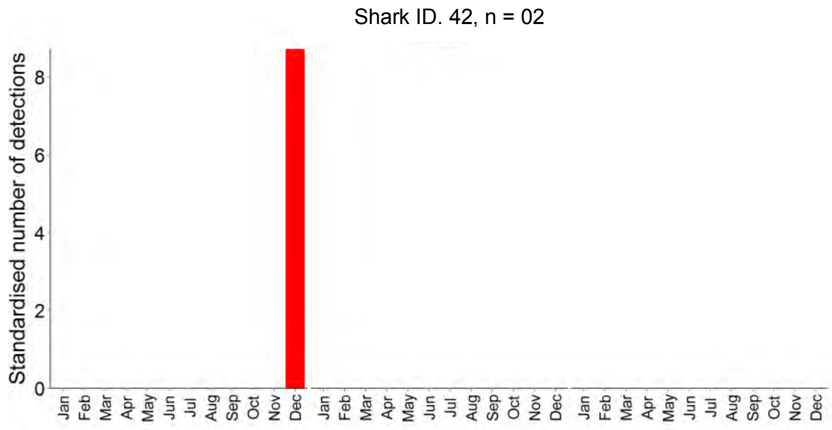
Shark ID. 43, n = 11




Shark ID. 12, n = 09
Standardised number of detections
0
10
20
30
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec

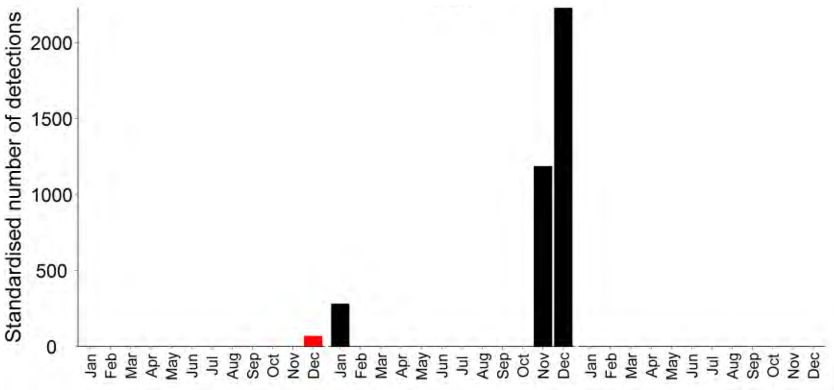

Shark ID. 36, n = 08
Standardised number of detections
0
5
10
15
20
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec


Shark ID. 21, n = 07
Standardised number of detections
0
5
10
15
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec

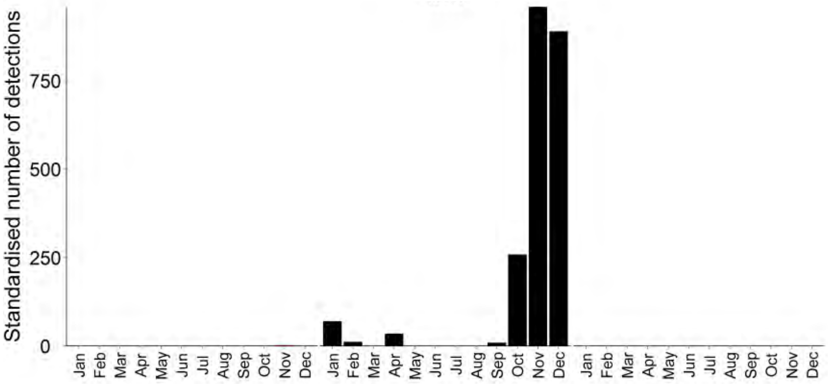

Shark ID. 42, n = 02
Standardised number of detections
0
2
4
6
8
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec

Carcharhinus obscurus

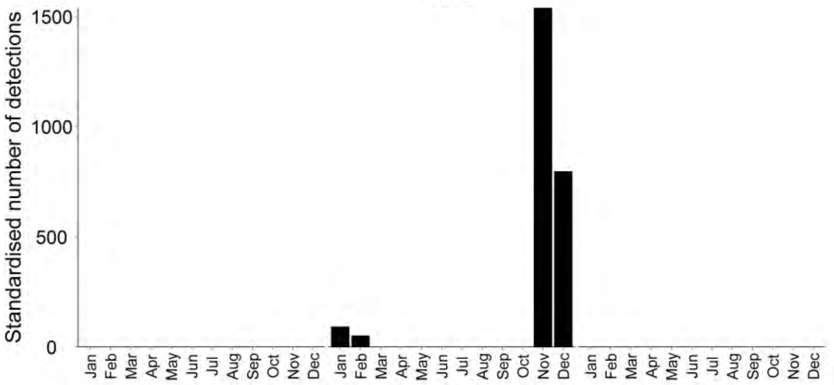
Shark ID. 9, n = 1102



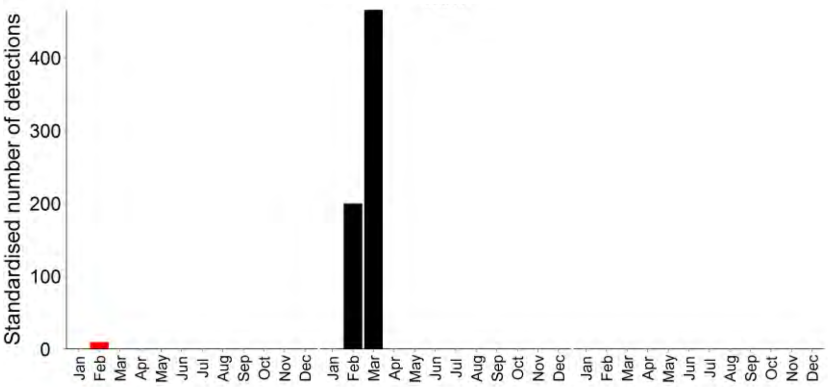
Shark ID. 5, n = 903

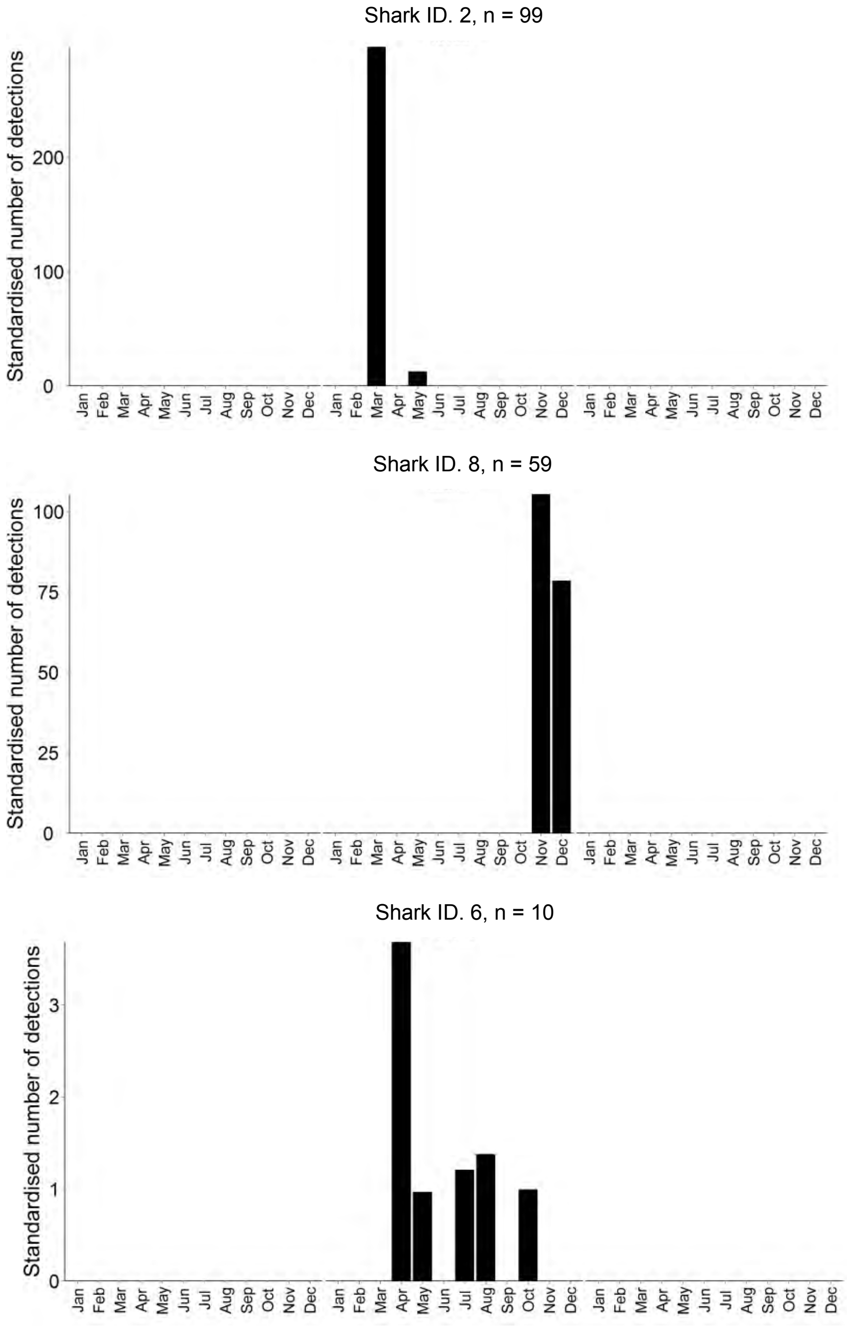


Shark ID. 4, n = 841



Shark ID. 7, = 223

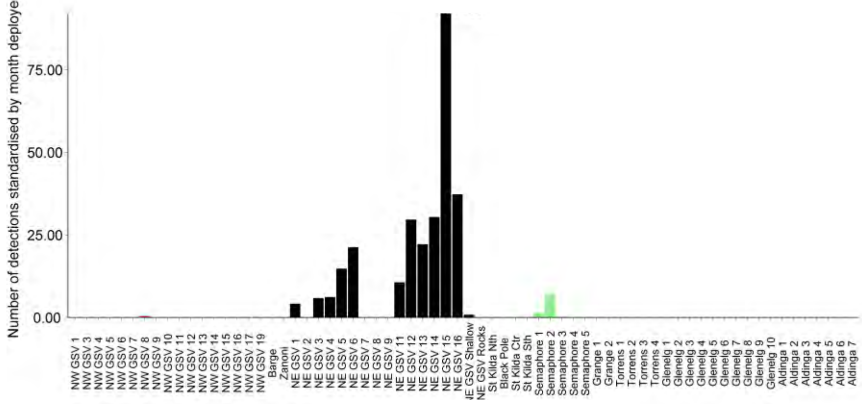



Shark ID. 2, n = 99
Standardised number of detections
0
100
200
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Shark ID. 8, n = 59
Standardised number of detections
0
25
50
75
100
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Shark ID. 6, n = 10
Standardised number of detections
0
1
2
3
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec

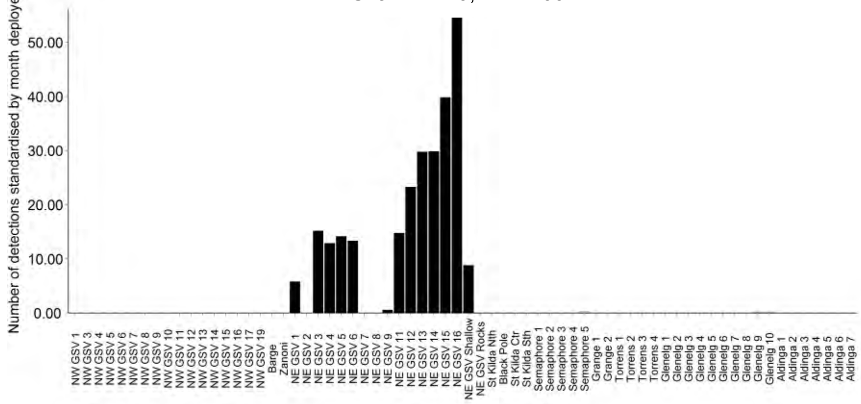
APPENDIX 3: Standardised number of detections per station for Northwest GSV (red), Northeast GSV (black), and the metropolitan region (green)

Carcharhinus brachyurus

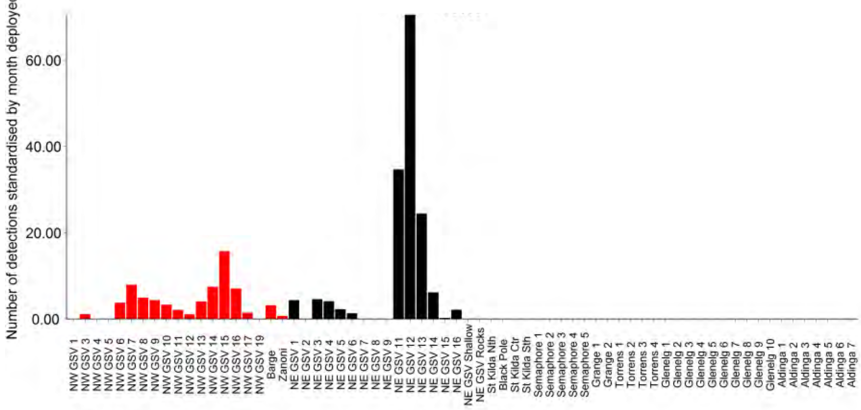
Shark ID. 53, n = 4443



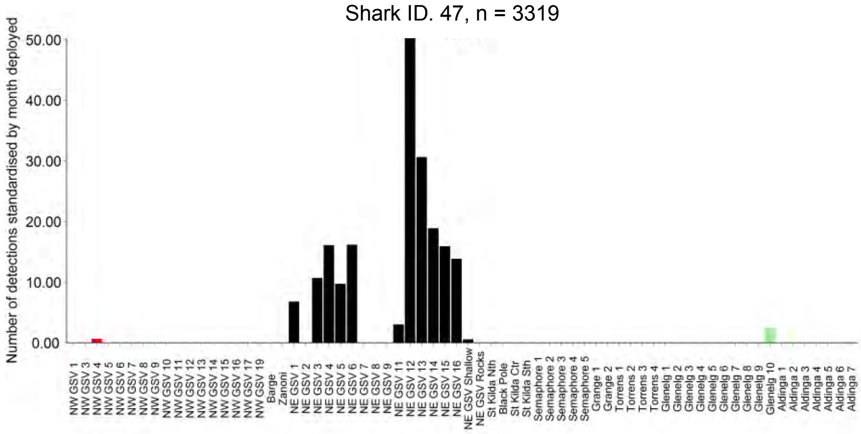
Shark ID. 29, n = 4166

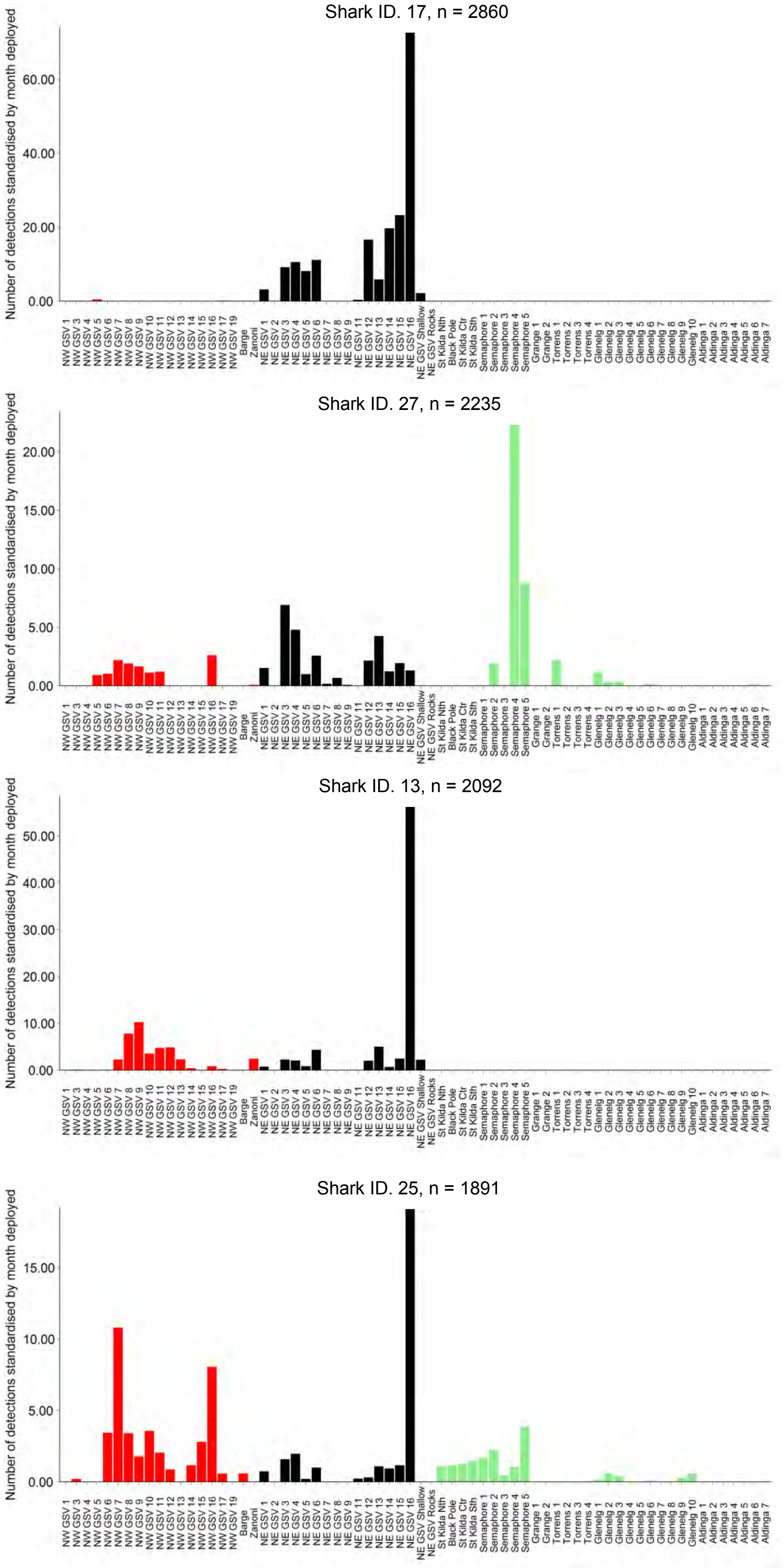


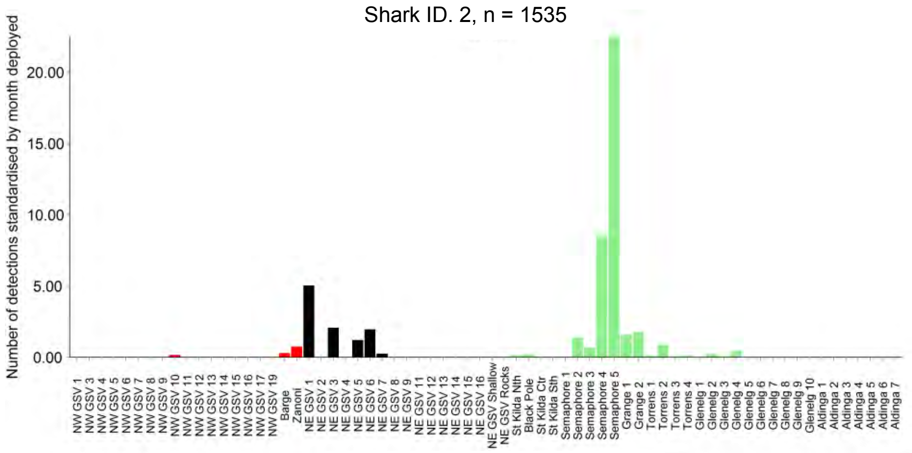
Shark ID. 41, n = 3533

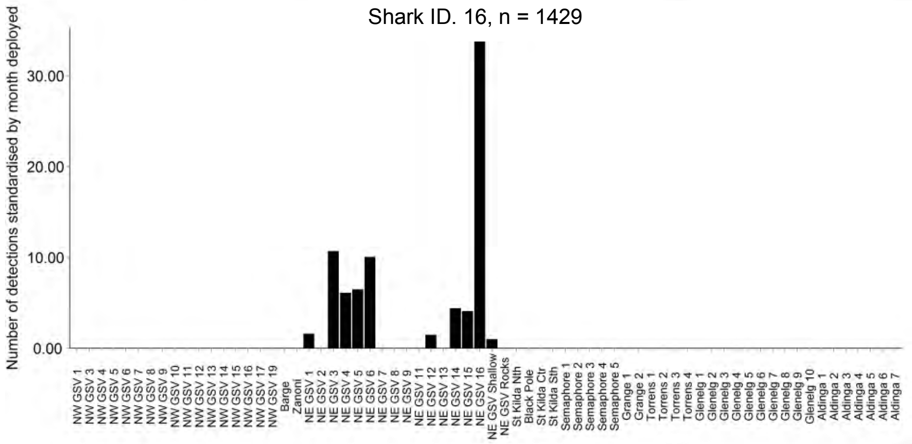


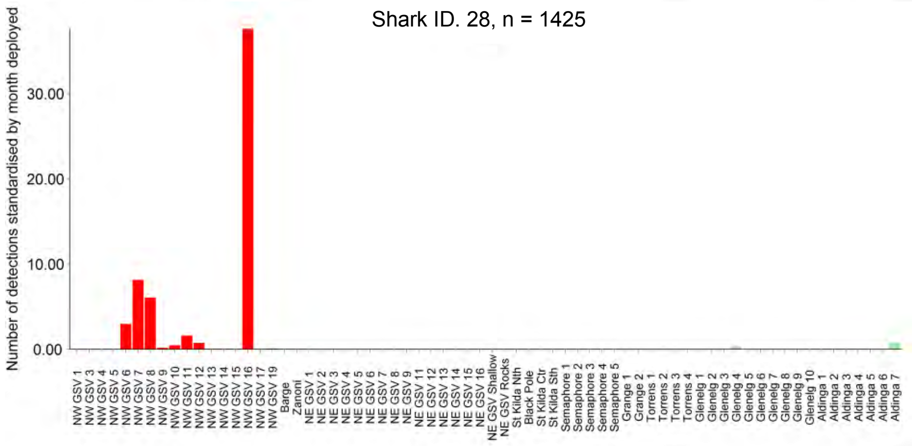
Shark ID. 47, n = 3319

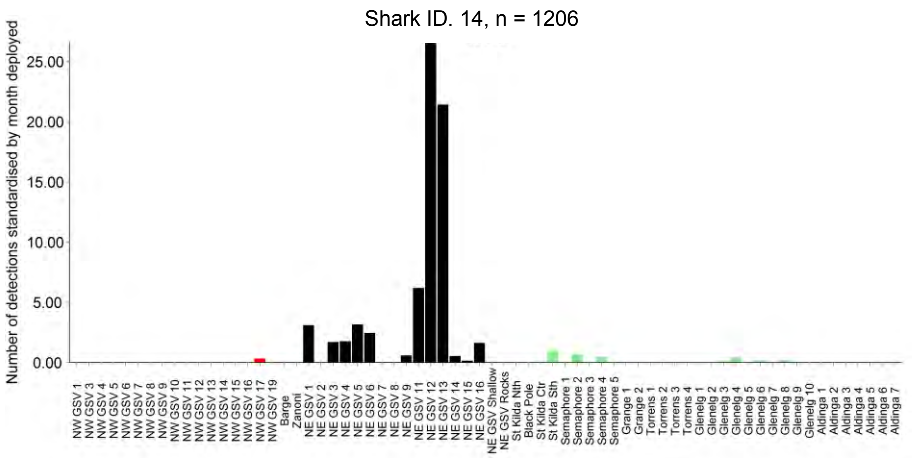


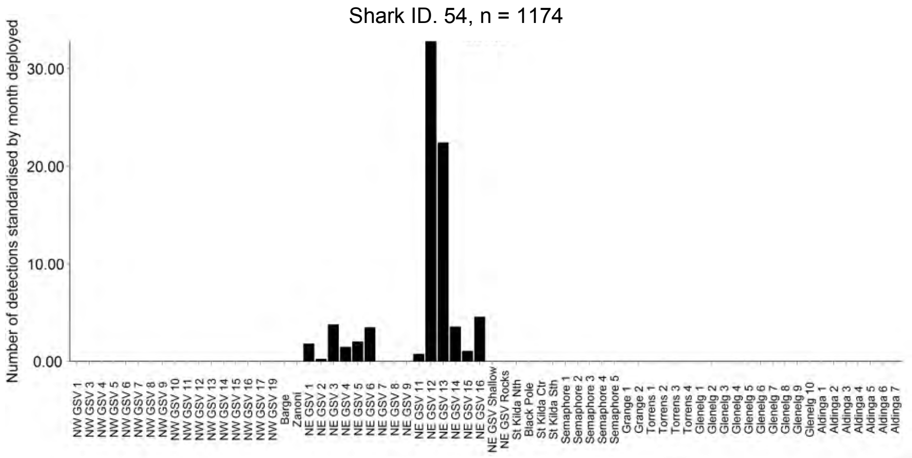

Shark ID. 17, n = 2860
Shark ID. 27, n = 2235
Shark ID. 13, n = 2092
Shark ID. 25, n = 1891
Number of detections standardised by month deployed
NW GSV 1
NW GSV 3
NW GSV 4
NW GSV 5
NW GSV 6
NW GSV 7
NW GSV 8
NW GSV 9
NW GSV 10
NW GSV 11
NW GSV 12
NW GSV 13
NW GSV 14
NW GSV 15
NW GSV 16
NW GSV 17
NW GSV 19
Barge
Zanoni
NE GSV 1
NE GSV 2
NE GSV 3
NE GSV 4
NE GSV 5
NE GSV 6
NE GSV 7
NE GSV 8
NE GSV 9
NE GSV 11
NE GSV 12
NE GSV 13
NE GSV 14
NE GSV 15
NE GSV 16
NE GSV Shallow
NE GSV Rocks
St Kilda Nth
Black Pole
St Kilda Ctr
St Kilda Sth
Semaphore 1
Semaphore 2
Semaphore 3
Semaphore 4
Semaphore 5
Grange 1
Grange 2
Torrens 1
Torrens 2
Torrens 3
Torrens 4
Glenelg 1
Glenelg 2
Glenelg 3
Glenelg 4
Glenelg 5
Glenelg 6
Glenelg 7
Glenelg 8
Glenelg 9
Glenelg 10
Aldinga 1
Aldinga 2
Aldinga 3
Aldinga 4
Aldinga 5
Aldinga 6
Aldinga 7

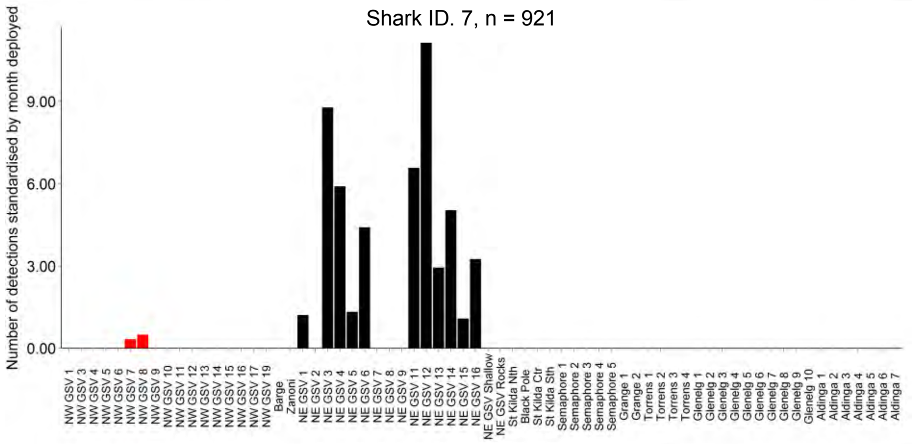

Shark ID. 2, n = 1535
Number of detections standardised by month deployed
20.00
15.00
10.00
5.00
0.00
NW GSV 1
NW GSV 3
NW GSV 4
NW GSV 5
NW GSV 6
NW GSV 7
NW GSV 8
NW GSV 9
NW GSV 10
NW GSV 11
NW GSV 12
NW GSV 13
NW GSV 14
NW GSV 15
NW GSV 16
NW GSV 17
NW GSV 19
Barge
Zanoni
NE GSV 1
NE GSV 2
NE GSV 3
NE GSV 4
NE GSV 5
NE GSV 6
NE GSV 7
NE GSV 8
NE GSV 9
NE GSV 11
NE GSV 12
NE GSV 13
NE GSV 14
NE GSV 15
NE GSV 16
NE GSV Shallow
NE GSV Rocks
St Kilda Nth
Black Pole
St Kilda Ctr
St Kilda Sth
Semaphore 1
Semaphore 2
Semaphore 3
Semaphore 4
Semaphore 5
Grange 1
Grange 2
Torrens 1
Torrens 2
Torrens 3
Torrens 4
Glenelg 1
Glenelg 2
Glenelg 3
Glenelg 4
Glenelg 5
Glenelg 6
Glenelg 7
Glenelg 8
Glenelg 9
Glenelg 10
Aldinga 1
Aldinga 2
Aldinga 3
Aldinga 4
Aldinga 5
Aldinga 6
Aldinga 7

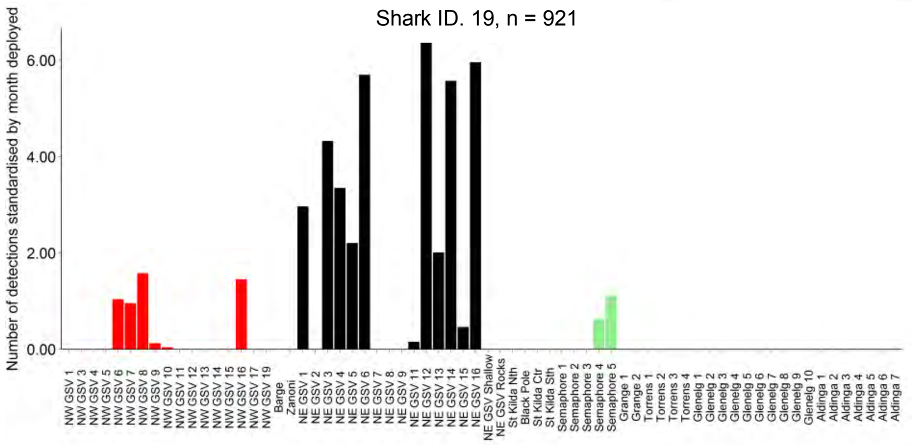

Shark ID. 16, n = 1429
Number of detections standardised by month deployed
30.00
20.00
10.00
0.00

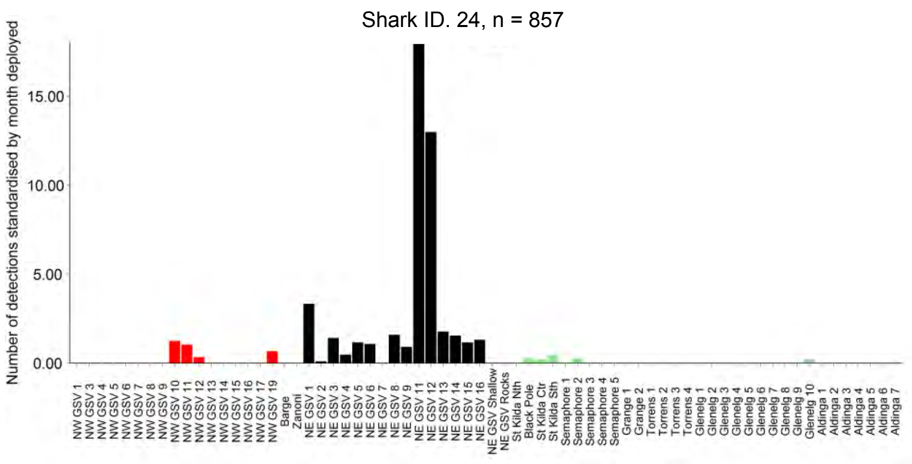

Shark ID. 28, n = 1425
Number of detections standardised by month deployed
30.00
20.00
10.00
0.00

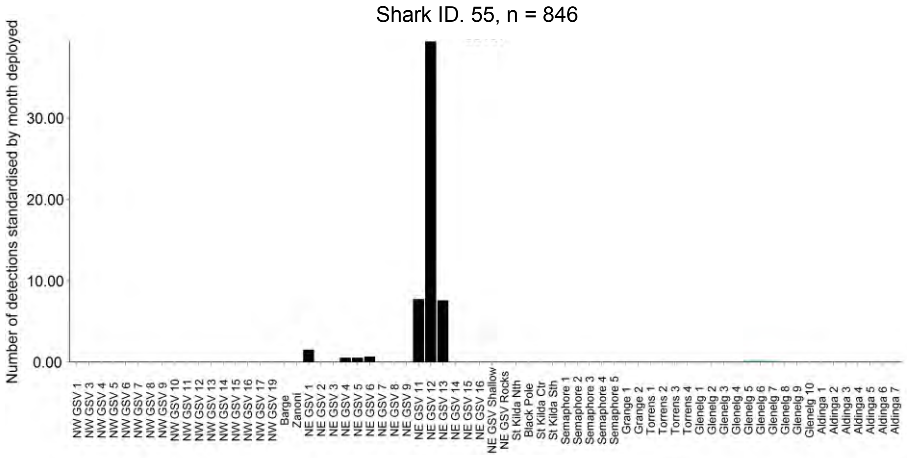

Shark ID. 14, n = 1206
Number of detections standardised by month deployed
25.00
20.00
15.00
10.00
5.00
0.00

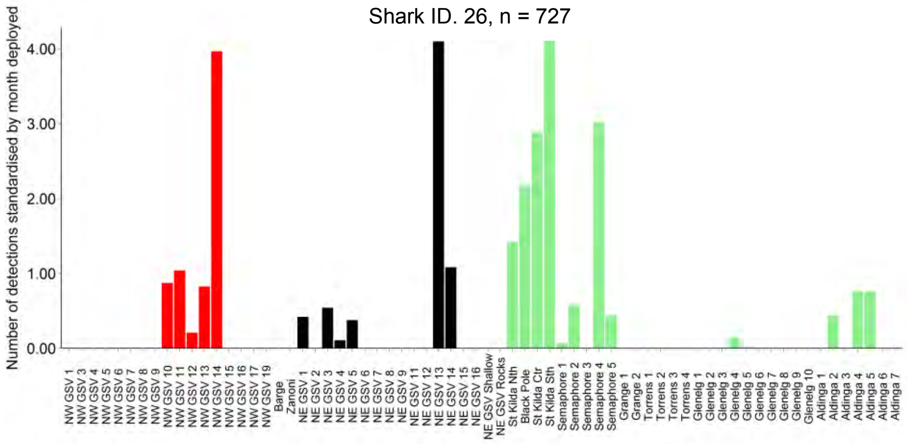

Shark ID. 54, n = 1174
Number of detections standardised by month deployed
30.00
20.00
10.00
0.00

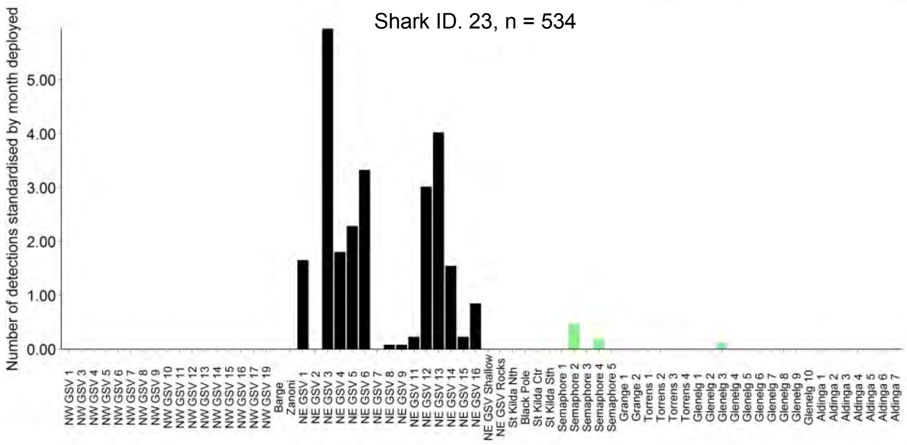

Shark ID. 7, n = 921
Number of detections standardised by month deployed
9.00
6.00
3.00
0.00

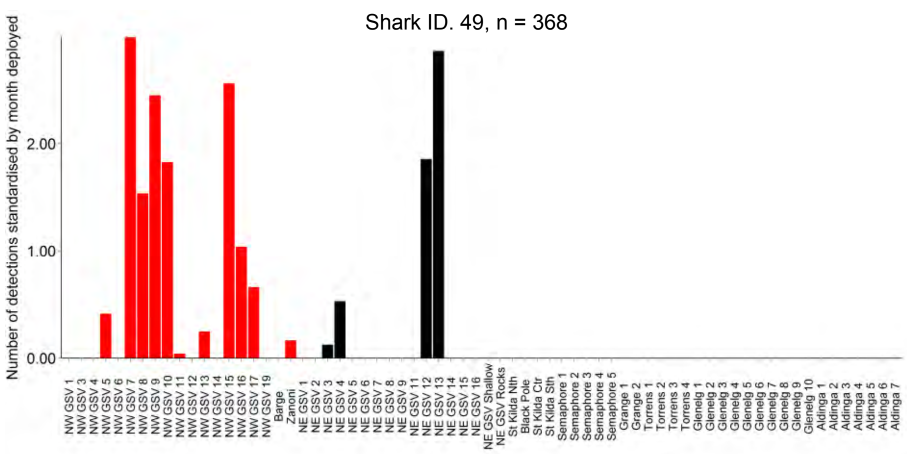

Shark ID. 19, n = 921
Number of detections standardised by month deployed
6.00
4.00
2.00
0.00

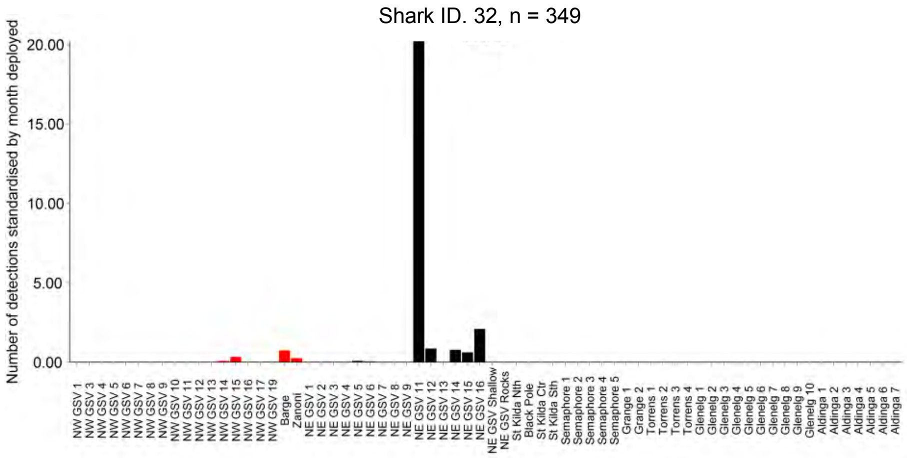

Shark ID. 24, n = 857
Number of detections standardised by month deployed
15.00
10.00
5.00
0.00

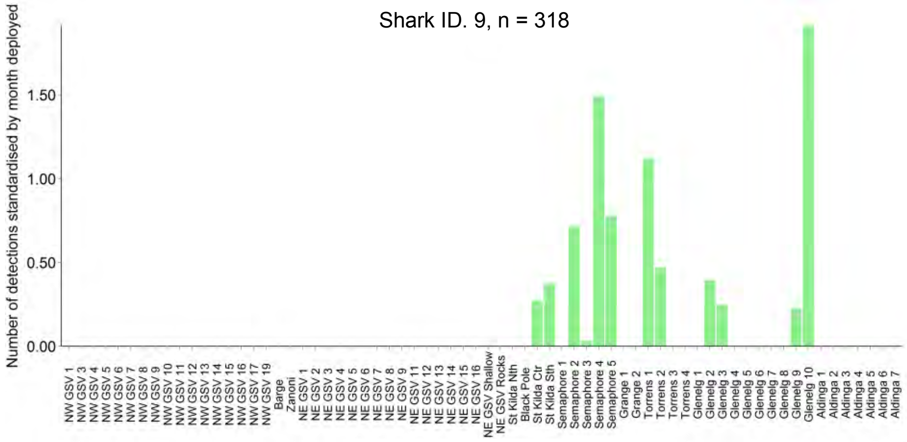

Shark ID. 55, n = 846
Number of detections standardised by month deployed
30.00
20.00
10.00
0.00

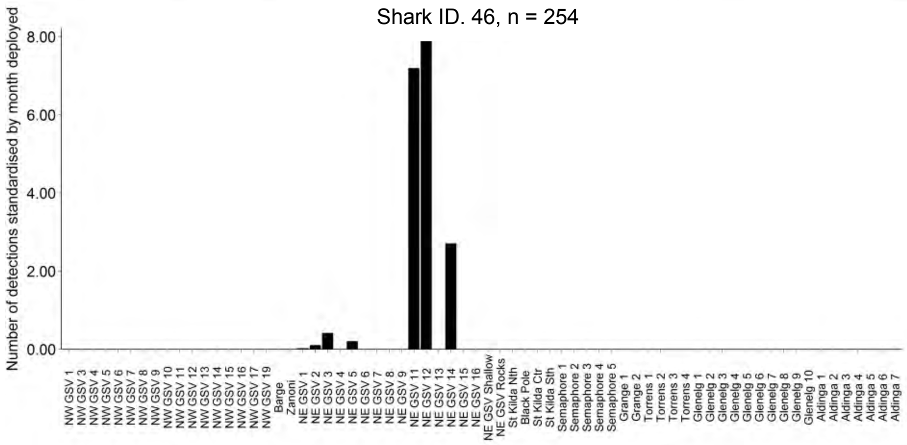

Shark ID. 26, n = 727
Number of detections standardised by month deployed
4.00
3.00
2.00
1.00
0.00

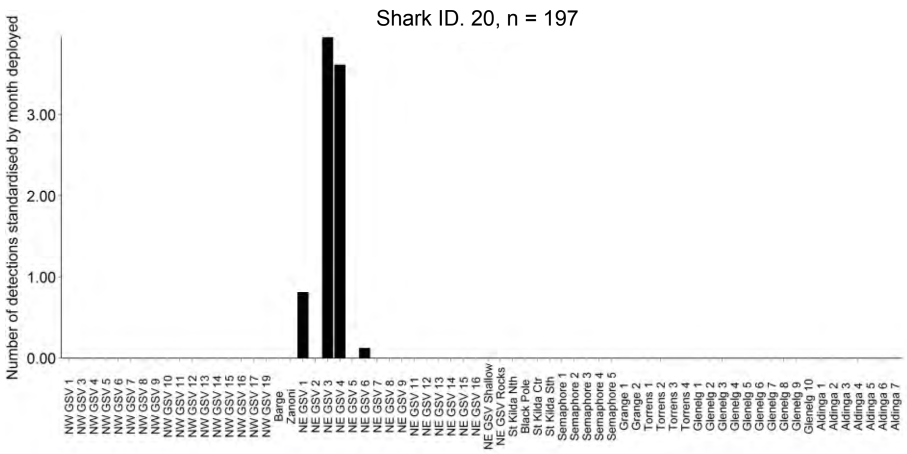

Shark ID. 23, n = 534
Number of detections standardised by month deployed
5.00
4.00
3.00
2.00
1.00
0.00

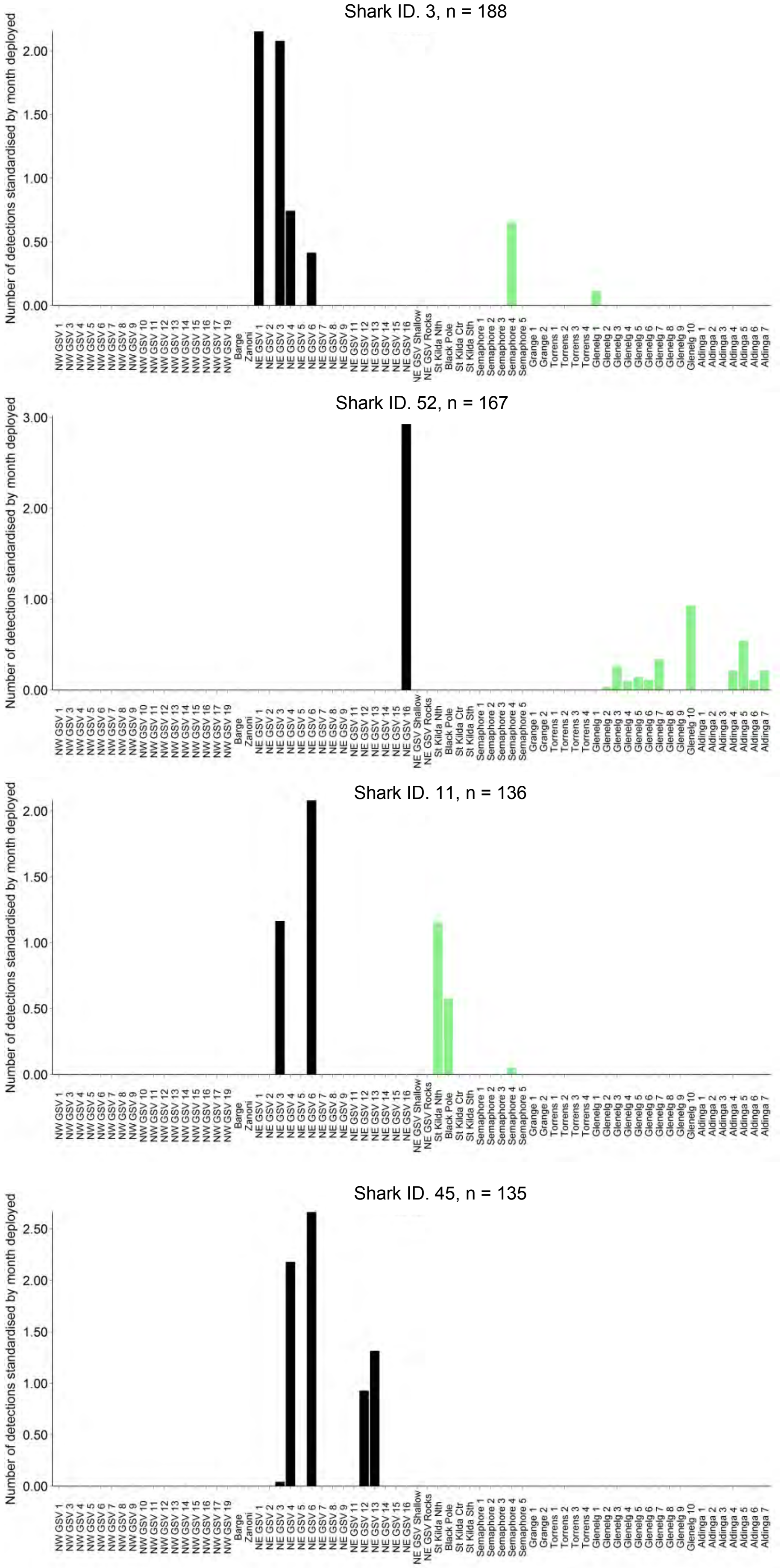

Shark ID. 49, n = 368
Number of detections standardised by month deployed
2.00
1.00
0.00

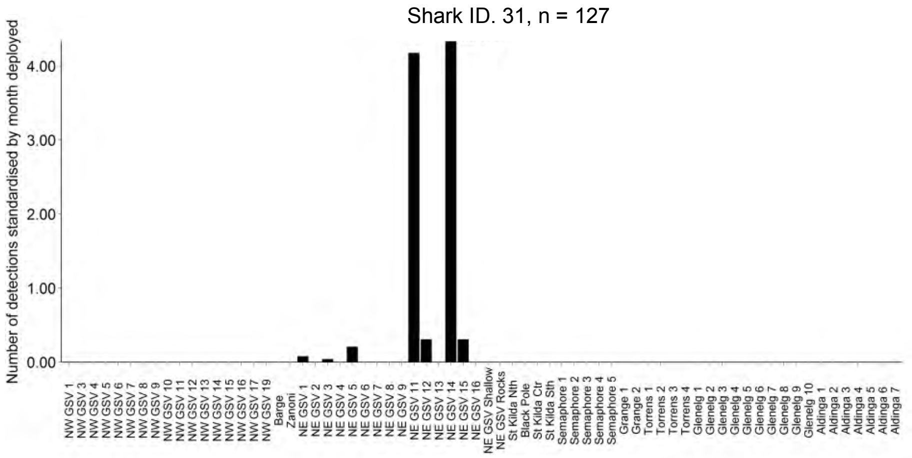

Shark ID. 32, n = 349
Number of detections standardised by month deployed
20.00
15.00
10.00
5.00
0.00
NW GSV 1
NW GSV 3
NW GSV 4
NW GSV 5
NW GSV 6
NW GSV 7
NW GSV 8
NW GSV 9
NW GSV 10
NW GSV 11
NW GSV 12
NW GSV 13
NW GSV 14
NW GSV 15
NW GSV 16
NW GSV 17
NW GSV 19
Barge
Zanoni
NE GSV 1
NE GSV 2
NE GSV 3
NE GSV 4
NE GSV 5
NE GSV 6
NE GSV 7
NE GSV 8
NE GSV 9
NE GSV 11
NE GSV 12
NE GSV 13
NE GSV 14
NE GSV 15
NE GSV 16
NE GSV Shallow
NE GSV Rocks
St Kilda Nth
Black Pole
St Kilda Ctr
St Kilda Sth
Semaphore 1
Semaphore 2
Semaphore 3
Semaphore 4
Semaphore 5
Grange 1
Grange 2
Torrens 1
Torrens 2
Torrens 3
Torrens 4
Glenelg 1
Glenelg 2
Glenelg 3
Glenelg 4
Glenelg 5
Glenelg 6
Glenelg 7
Glenelg 8
Glenelg 9
Glenelg 10
Aldinga 1
Aldinga 2
Aldinga 3
Aldinga 4
Aldinga 5
Aldinga 6
Aldinga 7

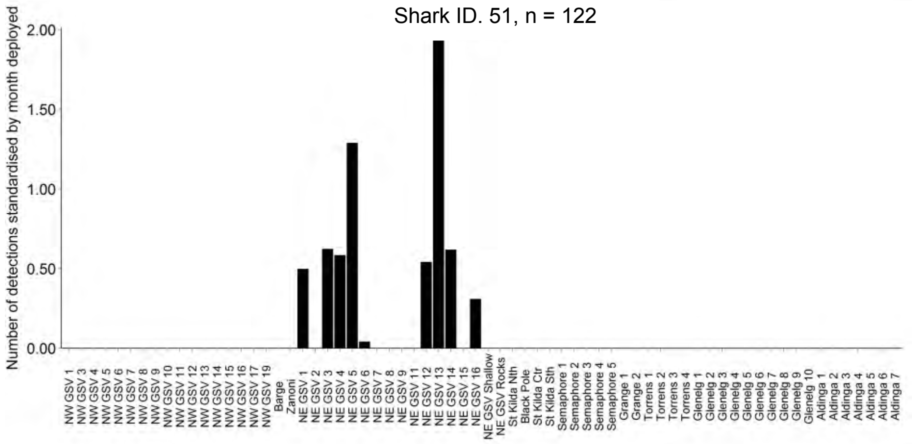

Shark ID. 9, n = 318
Number of detections standardised by month deployed
1.50
1.00
0.50
0.00

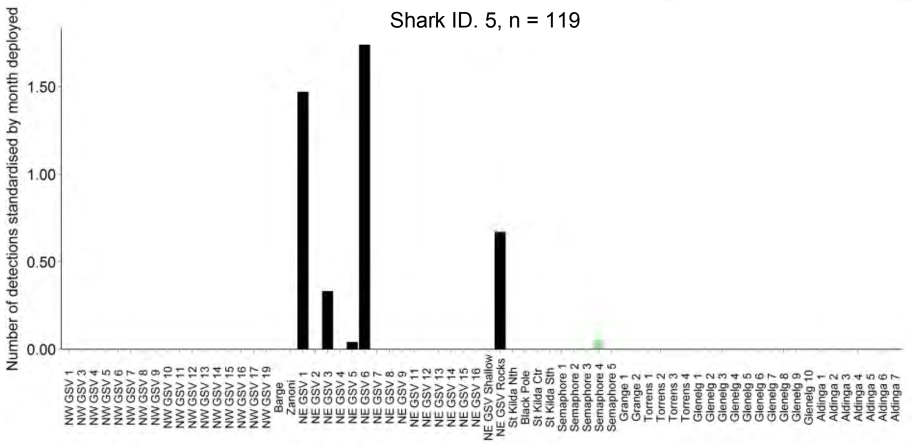

Shark ID. 46, n = 254
Number of detections standardised by month deployed
8.00
6.00
4.00
2.00
0.00

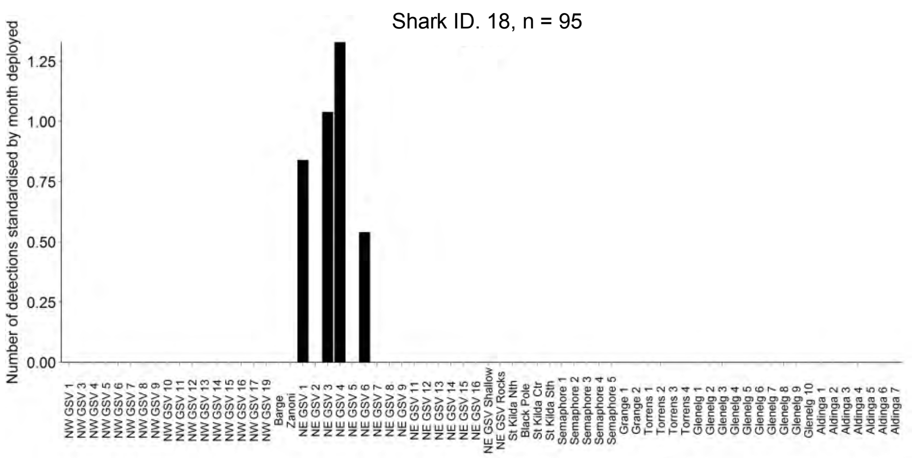

Shark ID. 20, n = 197
Number of detections standardised by month deployed
3.00
2.00
1.00
0.00

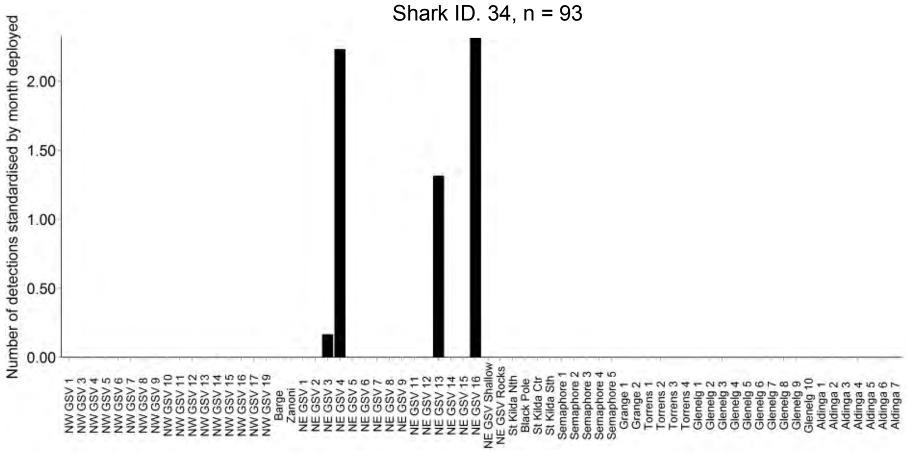

Shark ID. 3, n = 188
Shark ID. 52, n = 167
Shark ID. 11, n = 136
Shark ID. 45, n = 135
Number of detections standardised by month deployed

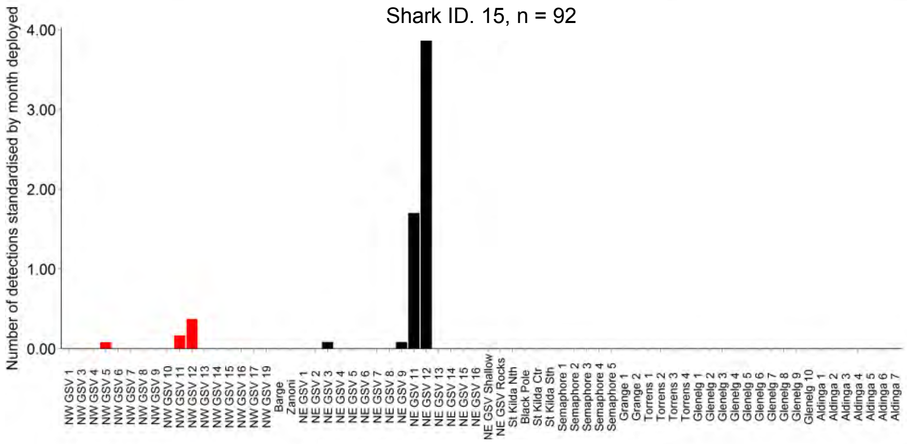

Shark ID. 31, n = 127
Number of detections standardised by month deployed
4.00
3.00
2.00
1.00
0.00
NW GSV 1
NW GSV 3
NW GSV 4
NW GSV 5
NW GSV 6
NW GSV 7
NW GSV 8
NW GSV 9
NW GSV 10
NW GSV 11
NW GSV 12
NW GSV 13
NW GSV 14
NW GSV 15
NW GSV 16
NW GSV 17
NW GSV 19
Barge
Zanoni
NE GSV 1
NE GSV 2
NE GSV 3
NE GSV 4
NE GSV 5
NE GSV 6
NE GSV 7
NE GSV 8
NE GSV 9
NE GSV 11
NE GSV 12
NE GSV 13
NE GSV 14
NE GSV 15
NE GSV 16
NE GSV Shallow
NE GSV Rocks
St Kilda Nth
Black Pole
St Kilda Ctr
St Kilda Sth
Semaphore 1
Semaphore 2
Semaphore 3
Semaphore 4
Semaphore 5
Grange 1
Grange 2
Torrens 1
Torrens 2
Torrens 3
Torrens 4
Glenelg 1
Glenelg 2
Glenelg 3
Glenelg 4
Glenelg 5
Glenelg 6
Glenelg 7
Glenelg 8
Glenelg 9
Glenelg 10
Aldinga 1
Aldinga 2
Aldinga 3
Aldinga 4
Aldinga 5
Aldinga 6
Aldinga 7

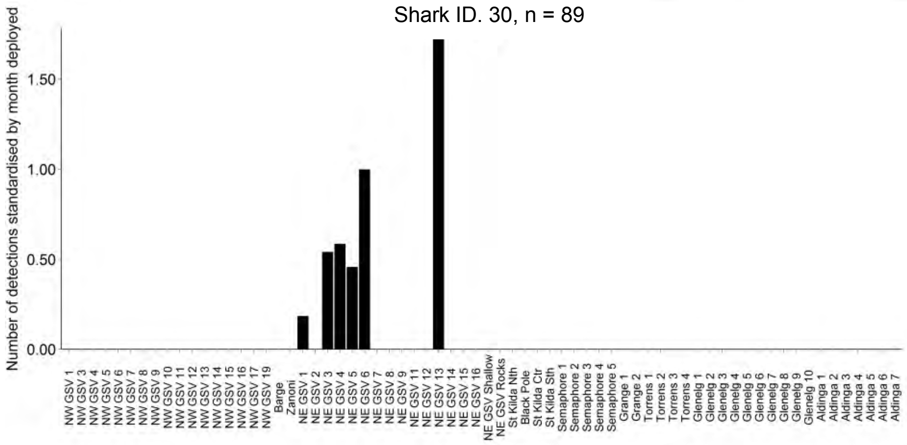

Shark ID. 51, n = 122
Number of detections standardised by month deployed
2.00
1.50
1.00
0.50
0.00

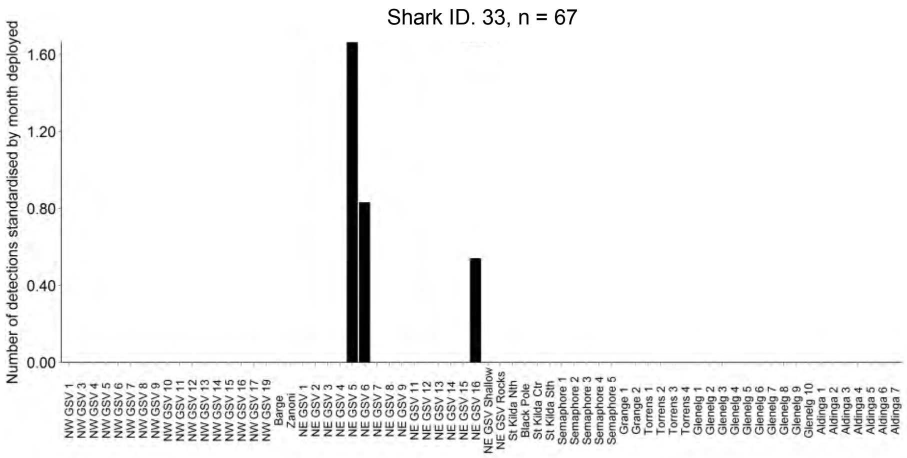

Shark ID. 5, n = 119
Number of detections standardised by month deployed
1.50
1.00
0.50
0.00

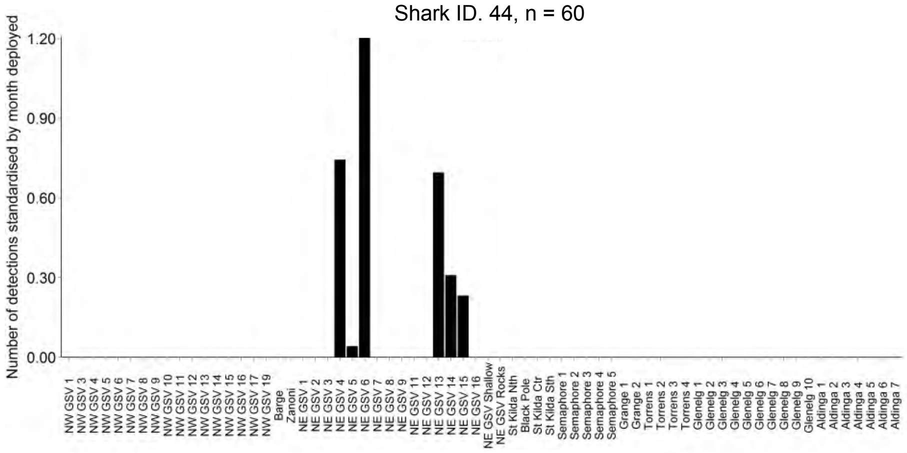

Shark ID. 18, n = 95
Number of detections standardised by month deployed
1.25
1.00
0.75
0.50
0.25
0.00

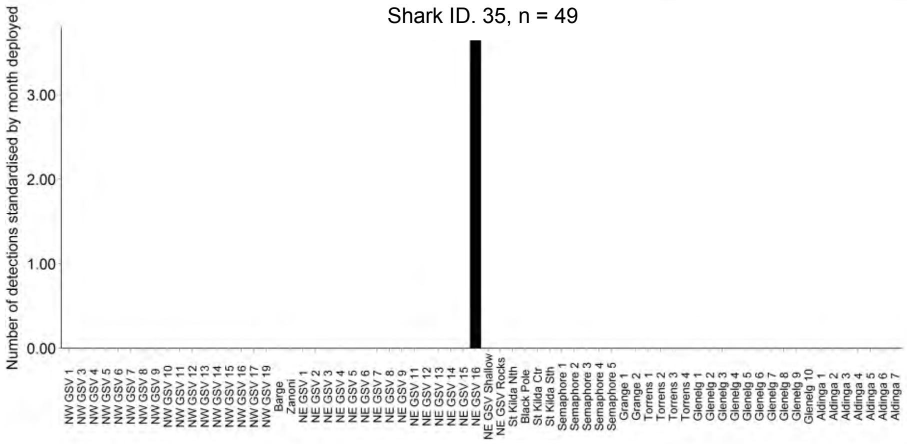

Shark ID. 34, n = 93
Number of detections standardised by month deployed
0.00
0.50
1.00
1.50
2.00
NW GSV 1
NW GSV 3
NW GSV 4
NW GSV 5
NW GSV 6
NW GSV 7
NW GSV 8
NW GSV 9
NW GSV 10
NW GSV 11
NW GSV 12
NW GSV 13
NW GSV 14
NW GSV 15
NW GSV 16
NW GSV 17
NW GSV 19
Barge
Zanoni
NE GSV 1
NE GSV 2
NE GSV 3
NE GSV 4
NE GSV 5
NE GSV 6
NE GSV 7
NE GSV 8
NE GSV 9
NE GSV 11
NE GSV 12
NE GSV 13
NE GSV 14
NE GSV 15
NE GSV 16
NE GSV Shallow
NE GSV Rocks
St Kilda Nth
Black Pole
St Kilda Ctr
St Kilda Sth
Semaphore 1
Semaphore 2
Semaphore 3
Semaphore 4
Semaphore 5
Grange 1
Grange 2
Torrens 1
Torrens 2
Torrens 3
Torrens 4
Glenelg 1
Glenelg 2
Glenelg 3
Glenelg 4
Glenelg 5
Glenelg 6
Glenelg 7
Glenelg 8
Glenelg 9
Glenelg 10
Aldinga 1
Aldinga 2
Aldinga 3
Aldinga 4
Aldinga 5
Aldinga 6
Aldinga 7

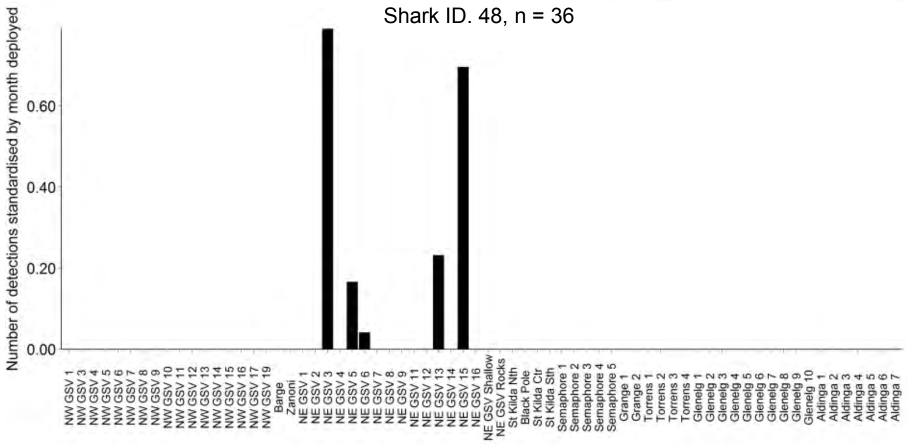

Shark ID. 15, n = 92
Number of detections standardised by month deployed
0.00
1.00
2.00
3.00
4.00

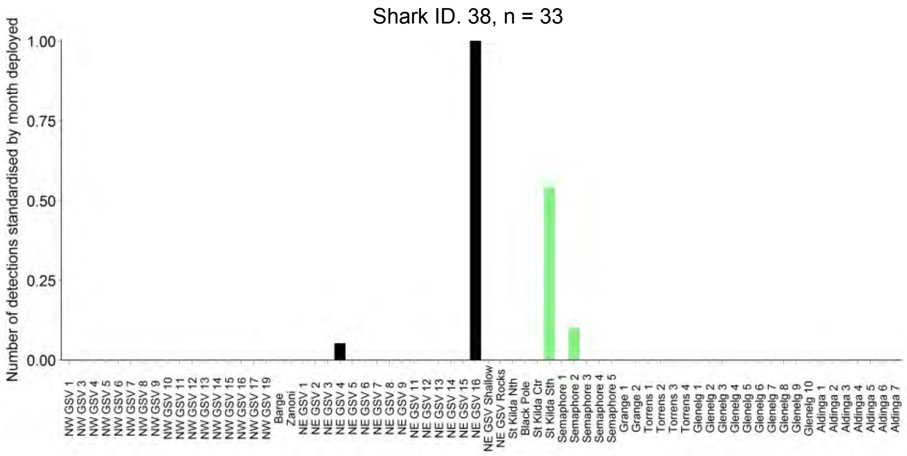

Shark ID. 30, n = 89
Number of detections standardised by month deployed
0.00
0.50
1.00
1.50

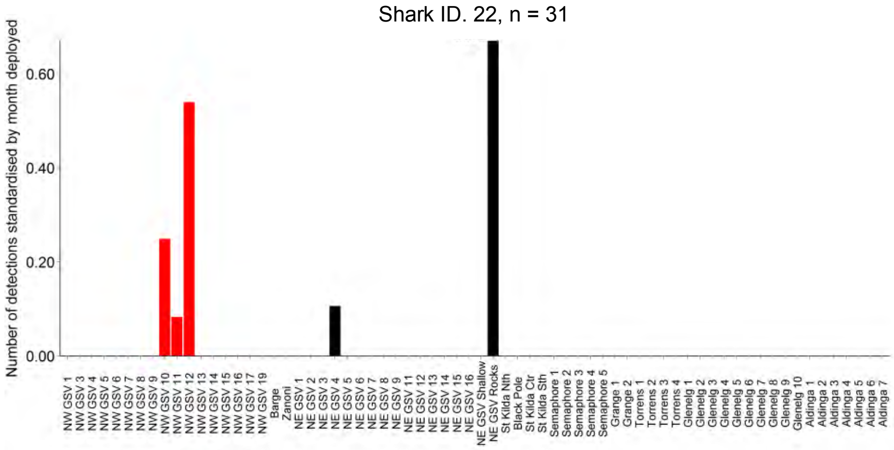

Shark ID. 33, n = 67
Number of detections standardised by month deployed
0.00
0.40
0.80
1.20
1.60

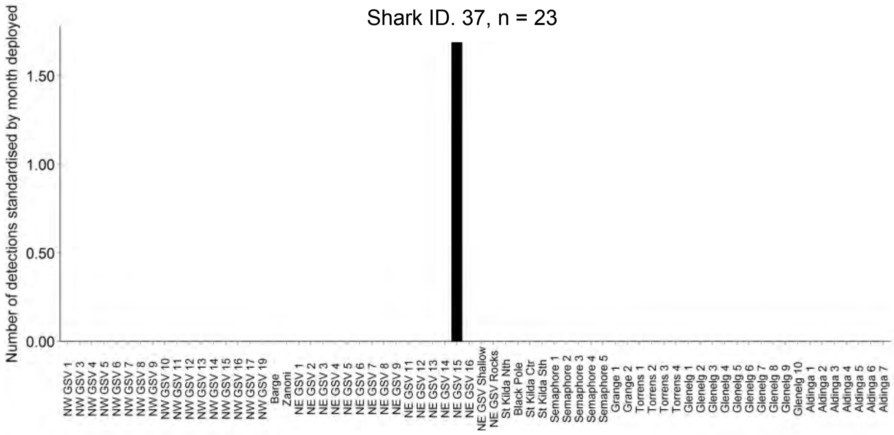

Shark ID. 44, n = 60
Number of detections standardised by month deployed
0.00
0.30
0.60
0.90
1.20
NW GSV 1
NW GSV 3
NW GSV 4
NW GSV 5
NW GSV 6
NW GSV 7
NW GSV 8
NW GSV 9
NW GSV 10
NW GSV 11
NW GSV 12
NW GSV 13
NW GSV 14
NW GSV 15
NW GSV 16
NW GSV 17
NW GSV 19
Barge
Zanoni
NE GSV 1
NE GSV 2
NE GSV 3
NE GSV 4
NE GSV 5
NE GSV 6
NE GSV 7
NE GSV 8
NE GSV 9
NE GSV 11
NE GSV 12
NE GSV 13
NE GSV 14
NE GSV 15
NE GSV 16
NE GSV Shallow
NE GSV Rocks
St Kilda Nth
Black Pole
St Kilda Ctr
St Kilda Sth
Semaphore 1
Semaphore 2
Semaphore 3
Semaphore 4
Semaphore 5
Grange 1
Grange 2
Torrens 1
Torrens 2
Torrens 3
Torrens 4
Glenelg 1
Glenelg 2
Glenelg 3
Glenelg 4
Glenelg 5
Glenelg 6
Glenelg 7
Glenelg 8
Glenelg 9
Glenelg 10
Aldinga 1
Aldinga 2
Aldinga 3
Aldinga 4
Aldinga 5
Aldinga 6
Aldinga 7

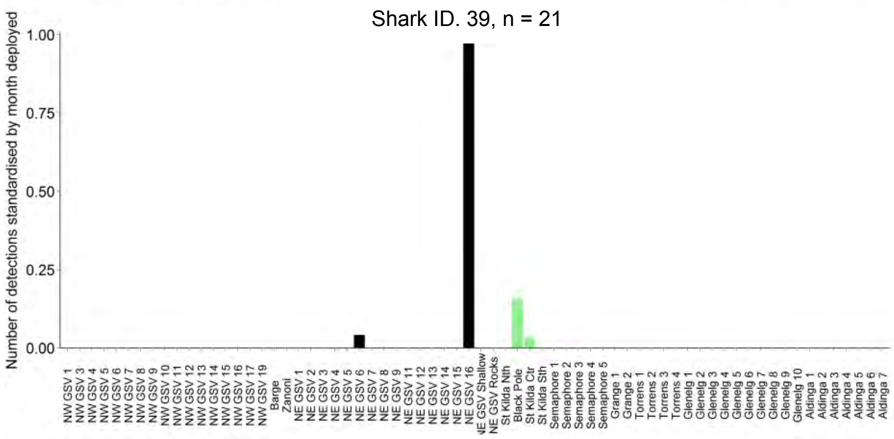

Shark ID. 35, n = 49
Number of detections standardised by month deployed
0.00
1.00
2.00
3.00

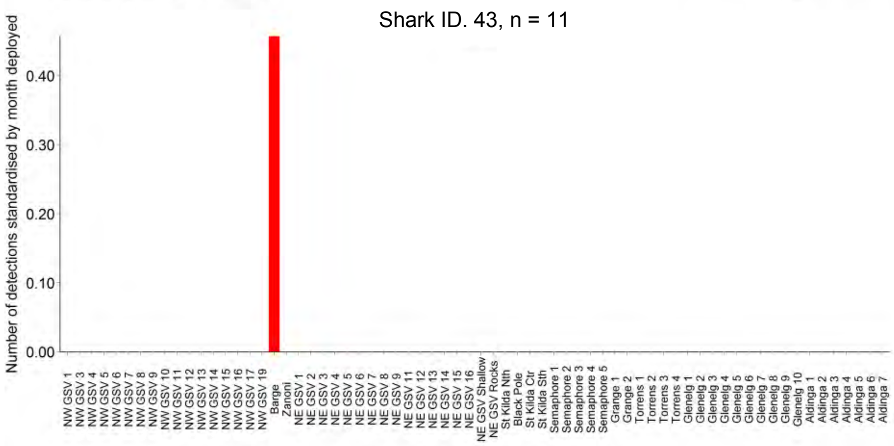

Shark ID. 48, n = 36
Number of detections standardised by month deployed
0.00
0.20
0.40
0.60

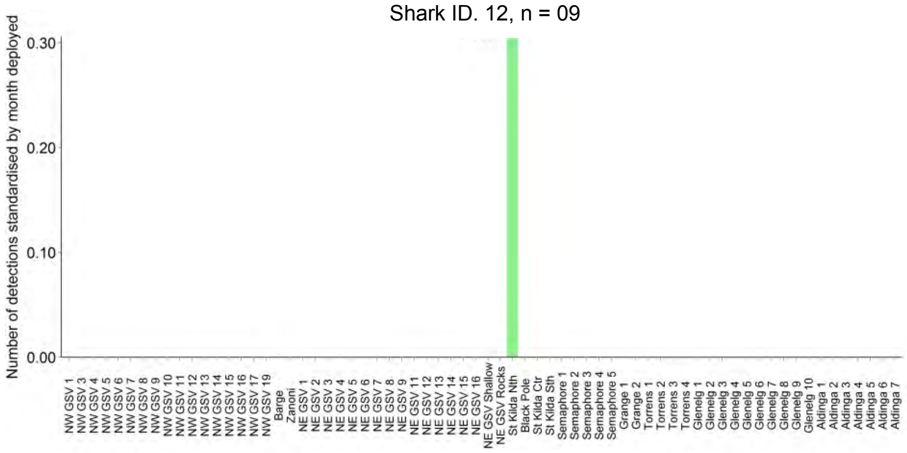

Shark ID. 38, n = 33
Number of detections standardised by month deployed
0.00
0.25
0.50
0.75
1.00

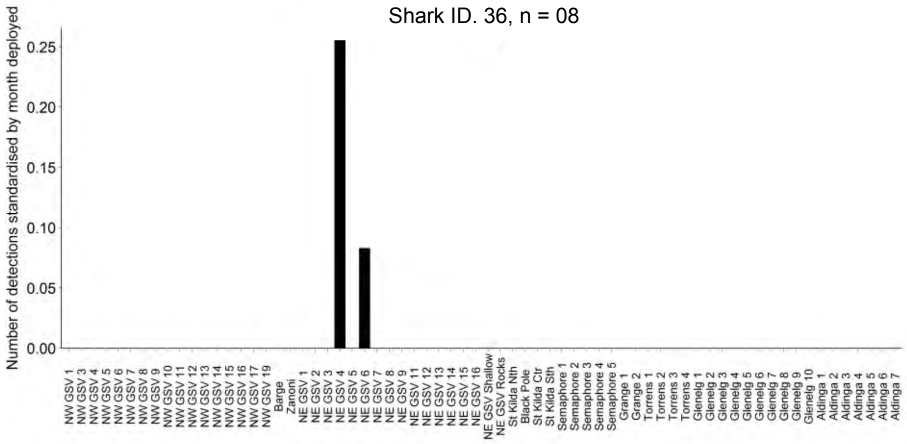

Shark ID. 22, n = 31
Number of detections standardised by month deployed

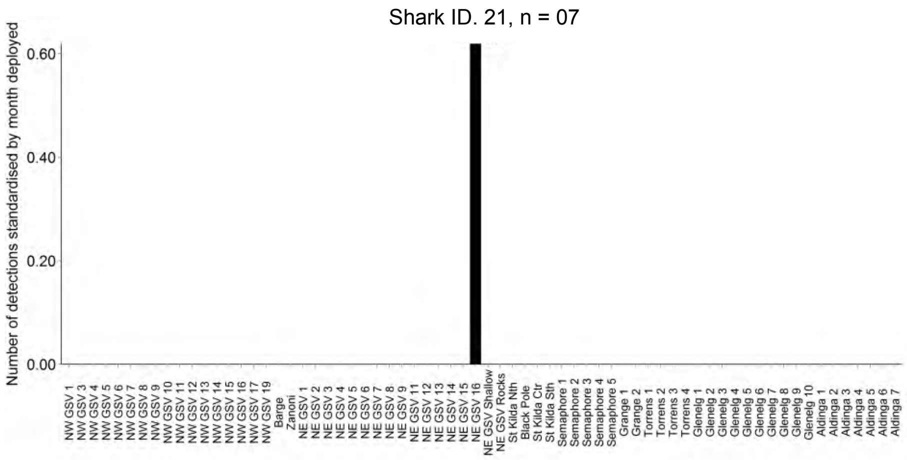

Shark ID. 37, n = 23
Number of detections standardised by month deployed

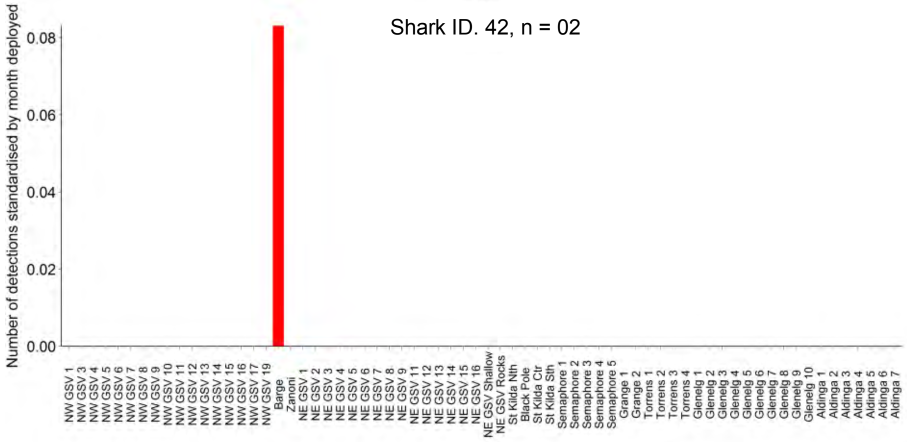

Shark ID. 39, n = 21
Number of detections standardised by month deployed


Shark ID. 43, n = 11
Number of detections standardised by month deployed

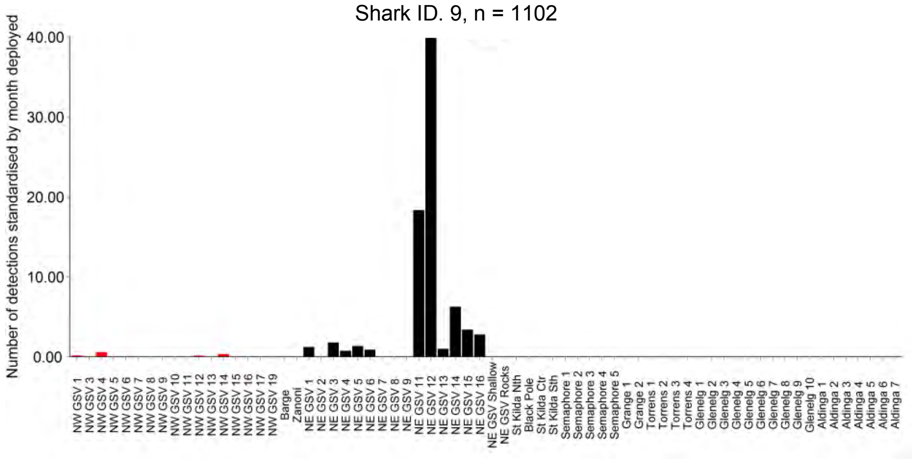

Shark ID. 12, n = 09
Number of detections standardised by month deployed
0.30
0.20
0.10
0.00

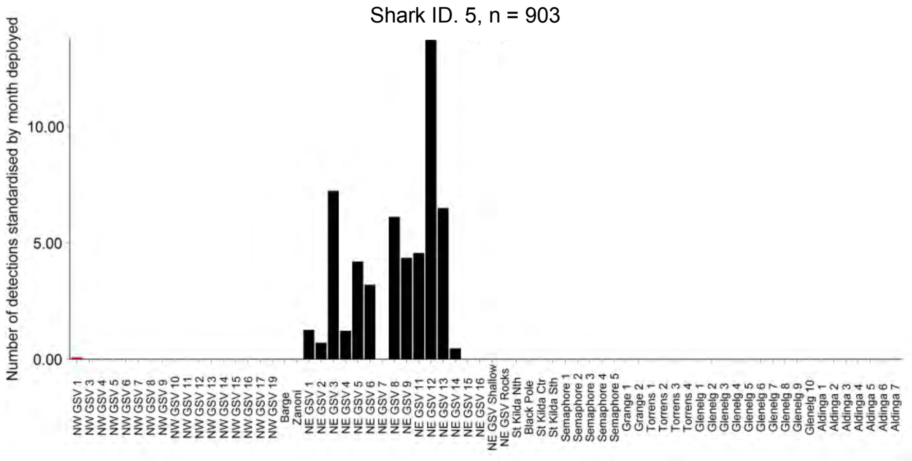

Shark ID. 36, n = 08
Number of detections standardised by month deployed
0.25
0.20
0.15
0.10
0.05
0.00

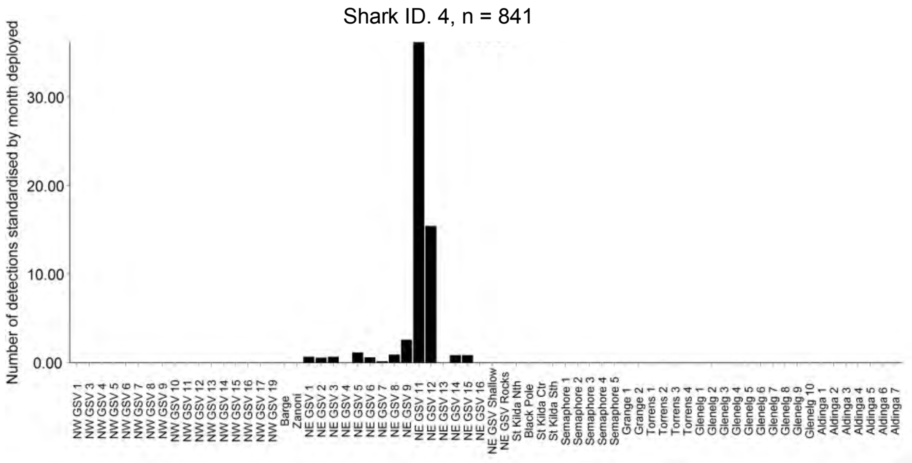

Shark ID. 21, n = 07
Number of detections standardised by month deployed
0.60
0.40
0.20
0.00

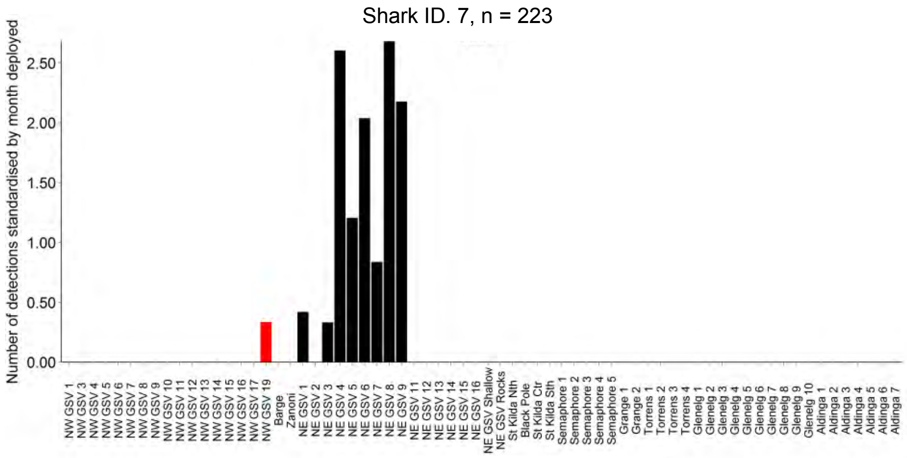

Shark ID. 42, n = 02
Number of detections standardised by month deployed
0.08
0.06
0.04
0.02
0.00

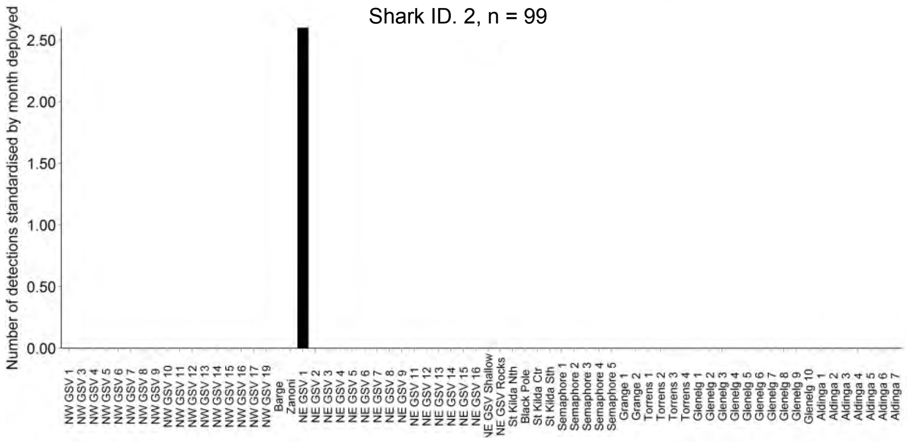
Carcharhinus obscurus

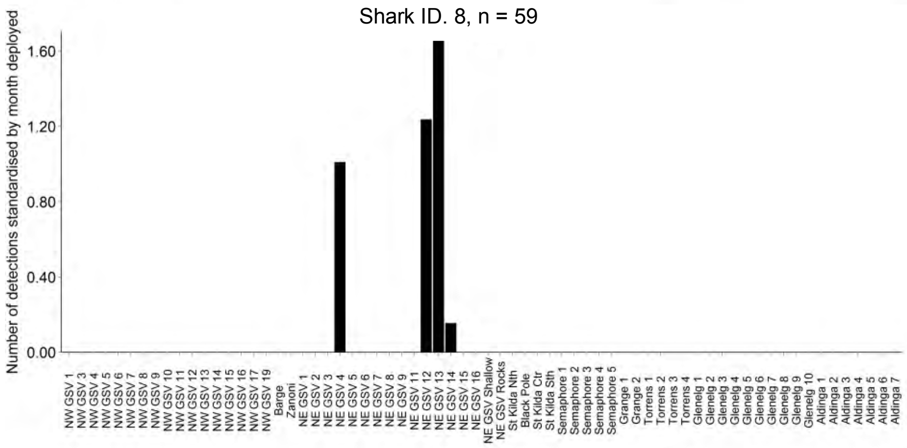


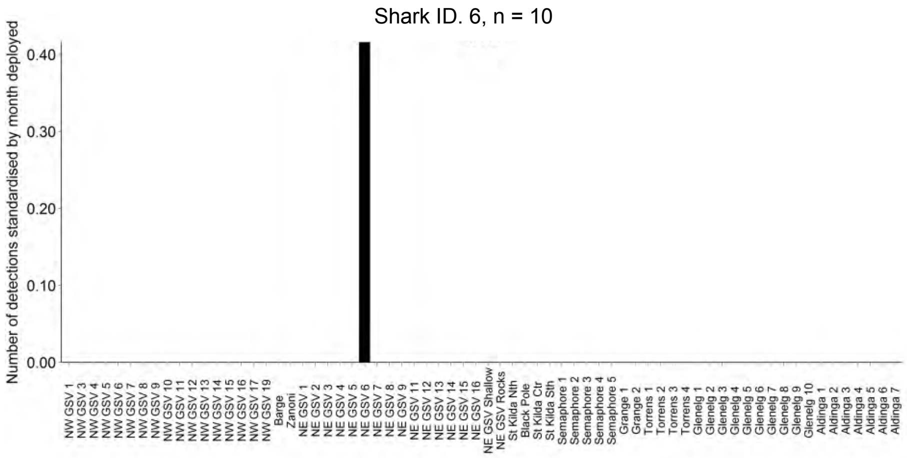





Shark ID. 7, n = 223
Number of detections standardised by month deployed
0.00
0.50
1.00
1.50
2.00
2.50
NW GSV 1
NW GSV 3
NW GSV 4
NW GSV 5
NW GSV 6
NW GSV 7
NW GSV 8
NW GSV 9
NW GSV 10
NW GSV 11
NW GSV 12
NW GSV 13
NW GSV 14
NW GSV 15
NW GSV 16
NW GSV 17
NW GSV 19
Barge
Zanoni
NE GSV 1
NE GSV 2
NE GSV 3
NE GSV 4
NE GSV 5
NE GSV 6
NE GSV 7
NE GSV 8
NE GSV 9
NE GSV 11
NE GSV 12
NE GSV 13
NE GSV 14
NE GSV 15
NE GSV 16
NE GSV Shallow
NE GSV Rocks
St Kilda Nth
Black Pole
St Kilda Ctr
St Kilda Sth
Semaphore 1
Semaphore 2
Semaphore 3
Semaphore 4
Semaphore 5
Grange 1
Grange 2
Torrens 1
Torrens 2
Torrens 3
Torrens 4
Glenelg 1
Glenelg 2
Glenelg 3
Glenelg 4
Glenelg 5
Glenelg 6
Glenelg 7
Glenelg 8
Glenelg 9
Glenelg 10
Aldinga 1
Aldinga 2
Aldinga 3
Aldinga 4
Aldinga 5
Aldinga 6
Aldinga 7


Shark ID. 2, n = 99
Number of detections standardised by month deployed
0.00
0.50
1.00
1.50
2.00
2.50


Shark ID. 8, n = 59
Number of detections standardised by month deployed
0.00
0.40
0.80
1.20
1.60


Shark ID. 6, n = 10
Number of detections standardised by month deployed
0.00
0.10
0.20
0.30
0.40