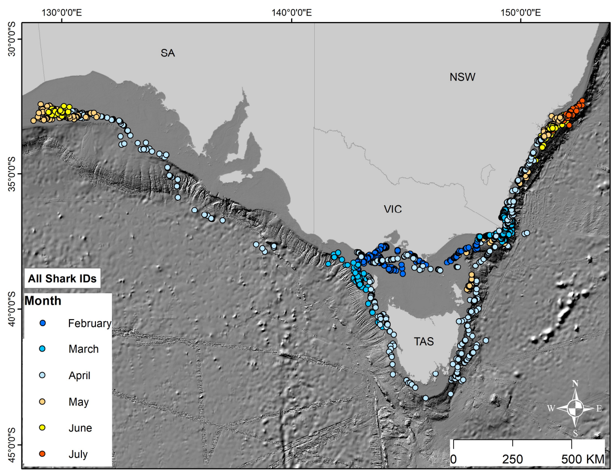
Victorian Gamefishing

Knowledge, movement, and best practice for catching and releasing shortfin mako sharks (*Isurus oxyrinchus*)



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Knowledge, movement, and best practice for catching and releasing shortfin mako sharks (*Isurus oxyrinchus*)

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Summary

Gamefishing is a popular activity for recreational anglers in Victoria particularly with the increasing prevalence of southern bluefin tuna and yellowtail kingfish in accessible locations along the coast. Targeting sharks has also become more popular, with the shortfin mako shark being highly prized due to its fighting ability and culinary qualities. Although considerable information about the population dynamics of mako sharks is available globally, targeted research is necessary to supplement existing information locally, close knowledge gaps identified during research extension activities, and test new innovative assessment tools.

This research project funded by Victorian Government's Recreational Fishing Grants Program investigated movement characteristics of shortfin mako sharks; developed innovative molecular techniques to detect near shore movements of shortfin mako sharks; and provided support to an existing federally funded project developing 'best practice principles' for the capture and release of sharks and rays.

Satellite tags were attached to the dorsal fins of five shortfin mako sharks caught and released off the coast of Victoria during 2021 and 2022. Results indicated that shortfin mako sharks display highly migratory movement patterns that are individually unique. These results were consistent with those from other tagging studies. A common feature was their association with the continental shelf break where the shelf transitions sharply to the slope. All five sharks were observed to have a strong association with this inflection point and although some time was spent within the shallower (<100 m) waters of Bass Strait and the Great Australian Bight, most was on or near the continental slope. The reason for this is likely to be prey availability.

Using environmental DNA techniques, we were able to validate the presence of shortfin mako shark from seawater samples and use species-specific assays to identify the presence of shortfin mako shark over different spatial and temporal scales. Results indicated that peak presence off the Victorian coast occurred during Autumn, but this was somewhat dependent on location and periodicity of sampling. Testing of monthly samples from inside the large embayment of Port Phillip Bay indicated that while occasional detections do occur near the entrance to the embayment, shortfin mako shark do not frequently enter and stay within this embayment for long periods.

Lastly, this research contributed to a larger FRDC project aiming to create 'best-practice' capture, handling, and release guidelines for recreational fishing of sharks and rays. A survey of over 1000 recreational anglers was conducted to assess current community attitudes and behaviours towards fishing for sharks and rays, with the survey subsequently informing an education campaign. An online platform called 'Shark Mates' was established in 2020 (https://sharkmates.com.au/) to help Victoria's recreational fishers take better care of sharks and rays when out fishing.

Ongoing spatially resolved management based upon sustainable fishing principles in conjunction with advocating for the importance of applying 'best practice' for the capture (and release) of sharks and rays will ensure that the underpinning research from this project will benefit the recreational fishing community into the future.

Background

Where fish go to seek out prey and reproduce is fundamental to developing an understanding of the dynamics of their populations (Free, Jensen et al. 2021). Large bodied, higher order carnivores, such as sharks that are generally long-lived, often with low fecundity, are well known for exhibiting extraordinary seasonal migration patterns (Nasby-Lucas, Dewar et al. 2019). These movements will be modulated by oceanographic conditions where both predator and prey species take advantage of oceanographic currents, seafloor bathymetry and environmental aspects of preferred habitats (Chen, Shan et al. 2021) to improve the chances of individual survival and population persistence or expansion. Conventional fisheries management decision-making is reliant on the availability of fundamental biological information about target and bycatch species and estimates of catch and biomass to provide a basis for stock assessments which produce advice within the context of strategic harvesting objectives (Punt and Hilborn 1997, Maunder and Punt 2013). These objectives are generally aimed at ensuring that populations either do not decline whilst fishers pursue catch targets or if stocks have become depleted that a reversal of trajectory towards restoration is facilitated (Dainys, Jakubavičiūtė et al. 2022). In any case, assumptions are often made about growth and reproduction to estimate recruitment parameters in model-based assessments creating uncertainty in their outputs. Alternative and increasingly commonly applied empirical approaches, also characterised by uncertainty, require arbitrarily chosen reference points as relative measures varying in conservatism in accordance with known life history characteristics of the target species (Bi, Zhang et al. 2023). These strategies, requiring estimates or proxy measures of biomass, are usually applied to commercial fisheries where management involves output control of total catch (Punt et al. 1997, Ovando, Free et al. 2022). These approaches are problematic and mostly inappropriate for the recreational sector in contrast with daily bag, boat or possession limits which apply to recreational anglers (Ford and Gilmour 2013).

In recreational fisheries total catch is rarely known and most of the other information required for commercial fisheries stock assessments is unavailable (Jalali, Bell et al. 2021, Dainys, Gorfine et al. 2022). Regardless of the fisheries context or management approach, assessments which ignore the dynamics of fish populations, especially migratory patterns, and spatial complexity, even when there is an abundance of other biological information, can get it wrong by generating decisions which do not produce the desired management outcomes due to mismatches with spatial heterogeneity in fish behaviour and productivity. For instance, although the IUCN categorised shortfin mako shark as 'Endangered' on its Red List in 2018, referring to the species' relatively long-life expectancy of ~25 years, its low biological productivity (triennial reproductive cycle and late age at maturity), and an estimated median global population decline of 46.6%, the assessment states "The south Pacific population appears to be increasing but with fluctuating catch rates." (https://www.iucnredlist.org/species/39341/2903170#assessment-information, accessed on 29 Jan 2024). Notwithstanding this, in Australia shortfin mako is classed as 'Vulnerable' "*due to contrasting situations in adjacent areas (declining in the Indian Ocean and increasing in New Zealand).*"(Kyne, Heupel et al. 2021). This highlights the importance of spatially resolved management to complement broadscale generic approaches so that interventions where needed are targeted to particular areas to resolve issues, thereby reducing costs and avoiding unwarranted imposition on fishers.

Gamefishing effort has increased globally; largely driven by the greater size, reliability and number of recreational vessels, accessibility to fishing grounds, technology (depth sounder and GPS plotter), new angling techniques and social networking. In Victoria, gamefishing is limited to species such as southern bluefin tuna (*Thunnus maccoyii*), swordfish (*Xiphias gladius*), yellowtail kingfish (*Seriola lalandi*) and several species of shark, including the shortfin mako shark (*Isurus oxyrinchus* – termed 'mako shark' herein). The Game Fishing Association of Australia (GFAA) is reported to be the longest established national fishing association in the world, with some 17 clubs affiliated within the Victorian section. Although club members target mako sharks, there is a large presence of non-affiliated anglers who also target mako shark. Mako sharks are a highly prized recreational gamefish species largely due to their fighting abilities and eating qualities. In Victoria, mako sharks are targeted right across the Victorian coastline.

Although much research has been conducted on their lifecycle, reproduction and feeding behaviour, several knowledge gaps persist particularly in spatial and temporal habitat preference. However, obtaining such information can be problematic with large migratory species (Speed, Field et al. 2010, Simpfendorfer, Heupel et al. 2011). Some methods used to explore shark distribution and migration include tagging and genotyping, with more recently technologies including satellite telemetry and environmental DNA (eDNA) successfully elucidating migratory characteristics and population connectivity. Satellite telemetry is now broadly used to address information gaps in migratory patterns among species (Weng, Foley et al. 2008) with capabilities in providing position, depth, temperature and other environmental data (Stevens, Bradford et al. 2009, Teo, Kudela et al. 2009, Rogers, Huveneers et al. 2015). Like satellite telemetry, the use of eDNA techniques to determine shark connectivity is becoming more prevalent (Sigsgaard, Nielsen et al. 2016, Simpfendorfer, Kyne et al. 2016, Lafferty, Benesh et al. 2018). In Victoria, little is known about mako shark spatial and temporal habitat preference, which is a critical information gap. Acquisition of this information will assist in the ongoing management of this iconic species in Victorian waters.

The National Recreational and Indigenous Fishing Survey undertaken during 2000–2001 (Henry and Lyle 2003) estimated the annual recreational catch of 'sharks/rays' but did not provide any resolution of catch by species. Importantly, the survey showed that 82% of sharks/ rays caught by recreational fishers were released (Kyne et al. 2021). Angler behaviour whilst catching and handling of sharks is sometimes inadequate (Rogers and Bailleul

2015) with some sharks becoming mutilated and killed inhumanely, as observed on several occasions in 2017 in various Australian states (Williamson, Huveneers et al. 2023). As such, greater emphasis is needed to understand angler behaviour during game fishing to underpin development of ‘best practice’ handling techniques which promote better custodianship and conservation of targeted species (Heard, Sutton et al. 2016, Cinner 2018, Mackay, Jennings et al. 2018).

To help resolve some of main knowledge gaps, this research project funded by the Victorian Government’s Recreational Fishing Grants Program aimed to:

1. investigate movement characteristics of recreationally caught mako sharks in Victorian waters,
2. investigate genetic connectivity of mako sharks in Victoria, and
3. gain a greater understanding of catch and release practices of shark anglers and develop ‘best practice’ principles for recreational angling.

Delivery of Aims

The three aims of this research were pursued by different organisations. This report details findings by the Victorian Fisheries Authority to fulfil the first project aim to **investigate movement characteristics of recreationally caught mako sharks in Victorian waters**.

The second aim, **investigating genetic connectivity of mako sharks in Victoria** was delivered by Rebecca Skurrie (Skurrie, 2021) and Julia Gray (Gray, 2022) as partial fulfilment of the requirements of the Degree of Bachelor of Environmental Science (Honours) at Deakin University under the supervision of Assoc. Prof. Craig Sherman.

<u>References</u>:

Skurrie (2021) The Development and Validation of eDNA Protocols for Detecting the Presence and Movement of Mako Sharks in Victoria. Deakin University Honours Thesis

Gray (2022) Assessing nearshore visitation of shark species in Victorian waters using environmental DNA. Deakin University Honours Thesis

The third aim, **gaining a greater understanding of catch and release practices of shark anglers and develop 'best practice' principles for recreational angling** was delivered by Dr. Sean Williamson

<u>Reference:</u>

Williamson, S., Huveneers, C., Walker, T., Green, C., Reina, R. 2023 Improving outcomes of fisher interactions with sharks, rays, and chimaeras, Melbourne, Australia, January CC BY 3.0 doi: 10.26180/21966668) as a part of a larger research project supported by the Fisheries Research and Development Corporation (FRDC) with supplemented funding provided by the Recreational Fishing Grants Program associated with this research project. The full report can be found here: https://www.frdc.com.au/sites/default/files/products/2018-042-DLD.pdf).

Abstracts for the two Deakin University Honours theses investigating genetic connectivity, as well as the FRDC report titled 'Improving outcomes of fisher interactions with sharks, rays, and chimaeras" are provided within the Appendix section of this report.

Findings from all the associated research completed by Rebecca Skurrie (Deakin University), Julia Gray (Deakin University), and Dr. Sean Williamson (Monash University) is provided within the Discussion section and will form part of the overarching Summary.

Methods

Investigating movement of mako sharks using satellite tags

To investigate the movement of mako sharks we used SPOT-196 satellite tags from Wildlife Computers™ (https://wildlifecomputers.com/taxa/shark-finmount/). These tags are designed to rapidly connect to the ARGOS network of satellites whenever the animal surfaces, thereby identifying its location with an accuracy as high as 150 metres. The battery in the tags lasts for up to a year implying that it is possible to identify seasonal patterns in spatial utilisation along with any site fidelity. Mako sharks are particularly suitable for this type of tag because they frequently surface (Rogers et al. 2015, Rogers, Corrigan et al. 2015, Rogers et al. 2015, Francis, Shivji et al. 2019) providing long-term travel paths.

Previous analyses (French, Lyle et al. 2015, Rogers et al. 2015, Rogers et al. 2015, Francis et al. 2019) have identified an eastern and western Australian stock divided around Victoria. It is currently unknown which stock comprises the majority of the catch in central Victoria as only a single animal has been tagged in central Bass Straight by Rogers & Bailleul (2015), and the two stocks are genetically indistinguishable, likely due to the highly transient behaviour of relatively few reproductive individuals (Corrigan, Lowther et al. 2018). As such, sampling was focussed in central Victoria (off Port Phillip Heads). However, given the geographical proximity, and the high likelihood that the Bassian Isthmus (historical land bridge that connected mainland Australia to Tasmania) once functioned as a divider between the stocks (as per great white sharks, Port Jackson sharks and dozens of fish species), targeting mako sharks occurred in western Victoria, particularly because large mako sharks are more common in this region for which data is lacking (Paul Rogers, personal communication). The tagging ratio between the two locations will also be influenced by mako availability, which is largely dictated by the spatial distribution of their preferred prey species.

Charter vessels were engaged to actively target mako sharks. At locations where mako sharks have previously been caught, a berley trail was made using a constant stream of fish waste released to the water while the vessel was at drift to attract mako sharks to the vessel.

Capture and securing mako sharks

When a mako shark was sighted in the burley trail, baited circle hooks were lowered into the water using gamefishing rods and reels. Recreational fishing equipment was used that included a 24 – 37 kg gamefishing rod/reel outfit, ~130 kg monofilament leader and ~2 metre wire trace with a single hook attached. Circle hooks are preferable because they tend to lodge in the corner of the mouth, thereby minimising the likelihood of deep hooking and damage to the animal. High carbon circle hooks were used to ensure that in the event they cannot be removed (i.e. the shark is struggling risking injury to itself or the researcher) and therefore have to be cut, they will rust, and dislodge, very quickly, likely within days. Information on fight time, hook location, handling time, vigour, release condition was recorded to inform post release survival and recommendations on handling practices.

Two methods have successfully been used to restrain mako sharks during tagging: 1) placing the shark in a sling (Rogers et al. 2015), and 2) lassoing the shark (French, Lyle et al. 2015). Both have been highly successful and resulted in no mortality that can be attributed to the handling and tagging procedure. For the current study we opted to use a V-shaped aluminium cradle (Figure 1). When a mako shark was positioned in the cradle, a damp cloth was placed over their eyes to prevent visual stimulation. The cradle allowed sufficient water to ventilate the gills during the tagging process. A vessel door allowed relatively easy access to the animals dorsal fin for tag application. Upon release, ropes used to secure the cradle were release that allowed the cradle to fully open enabling the shark to swim away.

Figure 1. V-shaped aluminium cradle used to secure a mako shark during the tagging procedure. The tag and antenna can be visible on the dorsal fin.

Tagging of mako sharks

Wildlife Computer™ Smart Position or Temperature (SPOT) satellite tags were used to acquire movement activity of mako sharks (Figure 2 Left). Threaded Teflon™ bolts were pre-glued into place using a two-part epoxy glue. A template was designed that enabled the correct alignment of the bolts onto the dorsal fin of the mako shark. Once the template was secured (pre-holed Teflon plate secured with spring loaded clamps, Figure 2 Right), a cordless drill was used to drill holes in the dorsal fin, which does not result in any sign of pain or distress to the animal (Paul Rogers, personal communication).

Figure 2. Wildlife Computers SPOT satellite tag (left), Teflon / clamp template (right).

Teflon tag bolts were pushed through the dorsal fin followed by a Teflon and high carbon steel washer, and stainless-steel lock nuts. Any remaining bolts were cut lose and discarded close to each secured bolt. Following tagging, total length was measured (+/- 5 cm), sex recorded as well as other metadata including tag number, date of tagging, GPS co-ordinates of release, time of release and duration of procedure.

Tag specifications were as follows: Temperature sampled at every 3 seconds with data binned from 12 – 22ºC over ten intervals. Time-at-Temperature histogram reports the amount of time that an animal spent within each temperature bin was recorded in-situ.

Tags were set to Auto Start; tags automatically activated when submerged in water. Satellite tags transmitted signals to the low polar orbiting environmental satellite network to receiver stations. Position data were provided in seven location classes (LC) ranging from the highest to the lowest quality between 3, 2, 1, 0, A, B and Z (no positions); with LC3 the most reliable with a root mean square error of around 150 m (ARGOS 2016). 3 – B were used accuracies of 3 =<250 m, 2 = 250–500 m,1 = 500–1500 m and 0–B =>1500 m, Z = no position. Transmission rates were set to hourly. As this study was primarily investigating broadscale movement patterns, all GPS co-ordinates were utilised (except where no position was obtained).

Data analysis

The position of tagged mako sharks was regularly checked via the Wildlife Computers™ online portal. When no detections were observed after a period of one month since the last detection, it was assumed that no more data was able to be acquired due to either mortality (capture or natural death) or failed tag transmissions. All mako shark data was downloaded from the portal and combined in a single database that was analysed in R (R Core Team 2023 https://www.R-project.org/). Erroneous coordinates (i.e., those on land) were removed from further analyses. Of the 7994 individual coordinates recorded from all tagged mako sharks, 7857 datapoints were able to be used for subsequent analysis. Dates recorded in UTC format and were converted to local date / time (AEST) and adjusted for daylight savings.

Individual mako shark movement and habitat utilisation was presented in a number of ways including location by month; location on (<200m) and off-shelf continental shelf (>200m); percentage of time observed during daylight and night periods using the 'suntools' R package v.1.0.0 (Bivand 2023) with day defined as the period between dawn and dusk and night the period between dusk and dawn; temperature observed at detection; speed (km/hr) between each detection location; and spatial utilisation distribution estimated using dynamic Brownian bridge movement models (dBBMM) using the R packages 'move' v.4.2.4 (Kranstauber and Smolla 2014). The shelf-break was defined as the inflection between the continental shelf and the continental slope. Unlike traditional movement models (e.g., Kernel density), dBBMM uses the observed speed that animals moved, dynamically estimated in dBBMM (unlike BBMM) to estimate where the animal could have been while they are not being detected, which is ideal for sparse spatial time series such as those gained from SPOT tags.

Results

Investigating movement and site fidelity of short finned mako sharks

A total of five mako sharks (4 female and 1 male) were satellite-tagged between February 2021 and February 2022 (Table 1). These sharks ranged from 1.2 m – 1.95 m in total length. Following capture and tagging, all sharks were visibly observed to swim away from the boat with no visible signs of adverse impact.

Table 1. Mako sharks' satellite-tagged in 2021 and 2022. Date of capture, sex, total length, co-ordinates of release provided. Note that precise release locations of tagged mako shark are not provided to respect charter operator confidentiality.

Shark ID	Date of capture	Sex	Total length (m)	Latitude	Longitude	General location of capture	Last date of detection
197610	09/02/2022	Female	1.65	-38º 23.xxx	144º 24.xxx	Port Phillip Heads	17/04/2022
197617	11/02/2021	Female	1.2	-38º 26.xxx	144º 47.xxx	Port Phillip Heads	24/03/2021
197613	29/03/2021	Female	1.95	-38º 49.xxx	141º 53.xxx	Portland	31/07/2021
197619	29/03/2021	Female	1.65	-38º 49.xxx	141º 53.xxx	Portland	09/06/2021
197612	30/03/2021	Male	2.2	-38º 49.xxx	141º 56.xxx	Portland	17/06/2021

Longevity of detections was relatively short compared to other studies on shortfin mako sharks (Rogers et al. 2015) with deployment durations ranging from 41–124 days. During this period the distance travelled ranged from 1702 km to 5676 km. Although the battery life of the tags deployed can operate for up to one year, it is not known whether sharks died from natural causes, were captured by anglers, or if there were any transmission problems with the tags. French (2015) found that survival rates of recreationally caught mako sharks were around 90%, including some with relatively serious injuries, suggesting that mako sharks caught, tagged and released in this study should have survived the procedure, particularly given none had any form of injury.

All of the tagged mako sharks displayed unique behaviour, with few similarities between individuals (Figure 3). Even three sharks tagged off Portland within close proximity over a two-day period displayed highly unique movement following release. Given the large differences in behaviour, it is not possible to summarise the animals' behaviour collectively, so this is described individually as follows:

Shark #197610

Tagged off Port Phillip Heads, during February Shark #197610 spent time in the shallower waters of western Bass Strait before moving south-westwards to the continental slope west of King Island in March. It then followed the continental slope south-southeast, venturing anti-clockwise around southern Tasmania then northwards during April until it was located ~40 km east of Cape Barron Island having travelled 1632 km over a 67-day period (Figure 3 A).

Shark #197617

Shark #197617 was also tagged off Port Phillip Heads and traversed eastwards close to the coast as far as Wilsons Promontory before swimming across eastern Bass Strait to the continental shelf-break at the head of the Bass Canyon, all within a relatively short period of < 1 month. It then travelled inshore to the areas around Point Hicks (Cape Everard) before heading offshore towards the New Zealand Star Banks and continental shelf/shelf-break region maintaining a position around the Vic / NSW border region of Mallacoota to Eden during March (Figure 3 B). Over a 41-day period this shark travelled 1702 km.

Shark #197613

Shark #197613 was tagged off Portland in March and subsequently travelled in various directions for 5676 km over a 124-day period (Figure 3 C). It immediately travelled southeast, along the western coast of Tasmania, around the south coast of Tasmania before travelling northwards, along the eastern Tasmanian coast and the mainland to the central NSW coast. This shark travelled a distance of ~2150km (line of sight) in 124 days.

Shark #197619

Shark #197619 travelled 2637 km over a 72-day period. During this time, it traversed eastwards through the shallower waters of Bass Strait until it reached the continental slope near the Vic / NSW border, where it then proceeded northwards to the mid-coast of NSW, a journey of approximately 1350 km (Figure 3D). It then spent 54 days along the central NSW coast, predominantly on the continental shelf (Figure 3D) and was last detected on the 09/06/2021 in shelf waters ~40 km East of Gosford (NSW).

Shark #197612

Shark #197612, the only male tagged, travelled westwards in various directions for 4200 km over a 79-day period. Post tagging, it maintained a north-westerly direction from Portland that roughly followed the continental shelf-break and was last detected approximately 1300 km away from the tagging location within the Great Australian Bight (Figure 3 E).

Mako shark movement through time indicates that they are highly mobile and capable of moving great distances in short periods of time. A degree of site fidelity was evident, particularly in the Great Australian Bight, northern NSW and in waters adjacent to the Vic/NSW border. In general, sharks spent a relatively limited period of time within the shallow waters of Bass Strait, with sharks #197617, #197619 and #197610 displaying distinct movement patterns from Bass Strait to the continental slope. Independent of whether sharks were tagged on or near the continental shelf-break, all sharks displayed a general patten associated with the transition between the continental shelf-break.

Association of mako sharks with either inshore (<200 m) or offshore habitats (>200 m) varied among individuals (Figure 4). Obviously, all sharks when observed within Bass Strait were classified as being on-shelf; however, most sharks were observed where there was a distinct inflection of the oceanographic topography at the shelf-break. Mako sharks #197610 and #197612 (Figure 4 A and E respectively) showed some site fidelity to inshore locations of western Bass Strait and the Great Australian Bight; however, inshore habitats were largely associated with the shelf-break. Interestingly, shark #197613 was mostly observed off the shelf waters on the western and on the shelf on eastern sides of Tasmania (Figure 4 C).

Satellite tags only transmit position data when the antenna (positioned above the dorsal fin) breaches the water surface. Detections from all sharks were consequently unavailable within specific areas attributable to their diurnal activity (Figure 5). Except for shark #197617, the tagged sharks displayed a stronger association with surface activity during daylight hours (Figure 6). Here, sharks were found to be near the surface 50–70% of the duration of the tagged period.

Water temperature recorded by all sharks ranged from 15.8–24.1 °C (Figure 7). Although average surface temperature observed ranged from 18.8 °C (± 0.09 SE) to 21.2°C (± 0.08 SE) this was largely attributable to their spatial and temporal location rather than a preference for specific water temperatures. Water temperatures experienced by all tagged sharks within Bass Strait and around Tasmania was relatively cooler (15–20°C) when compared to the waters in some areas of the Great Australian Bight and the in SE NSW under the influence of the Eastern Australian Current. Seasonally, sharks left Victorian / Tasmanian waters in winter and moved to warmer waters of the GAB and NSW. Temperatures at depth were not recorded.

Swimming speed of sharks (calculated from the distance and time travelled between locations) varied among detection intervals (Figure 8) ranging from <1 km/h to >10 km/h with most speeds around 4 km/h. Whilst at liberty, the average speed of mako sharks ranged between 1.5–2.2 km/h. The maximum speed attained was around 50km/hr however this is likely associated with high levels of error due to the accuracy of ARGOS location data.

Habitat utilisation (site fidelity) summaries derived from Brownian bridge movement models indicated that shortfin mako sharks had preferred locations, including regions offshore from the Vic / NSW border region, northern NSW, western Bass Strait and the Great Australian Bight (Figure 9). Although the tagged mako sharks exhibited strong affinity within regions, all sharks demonstrated an association with the continental shelf-break.

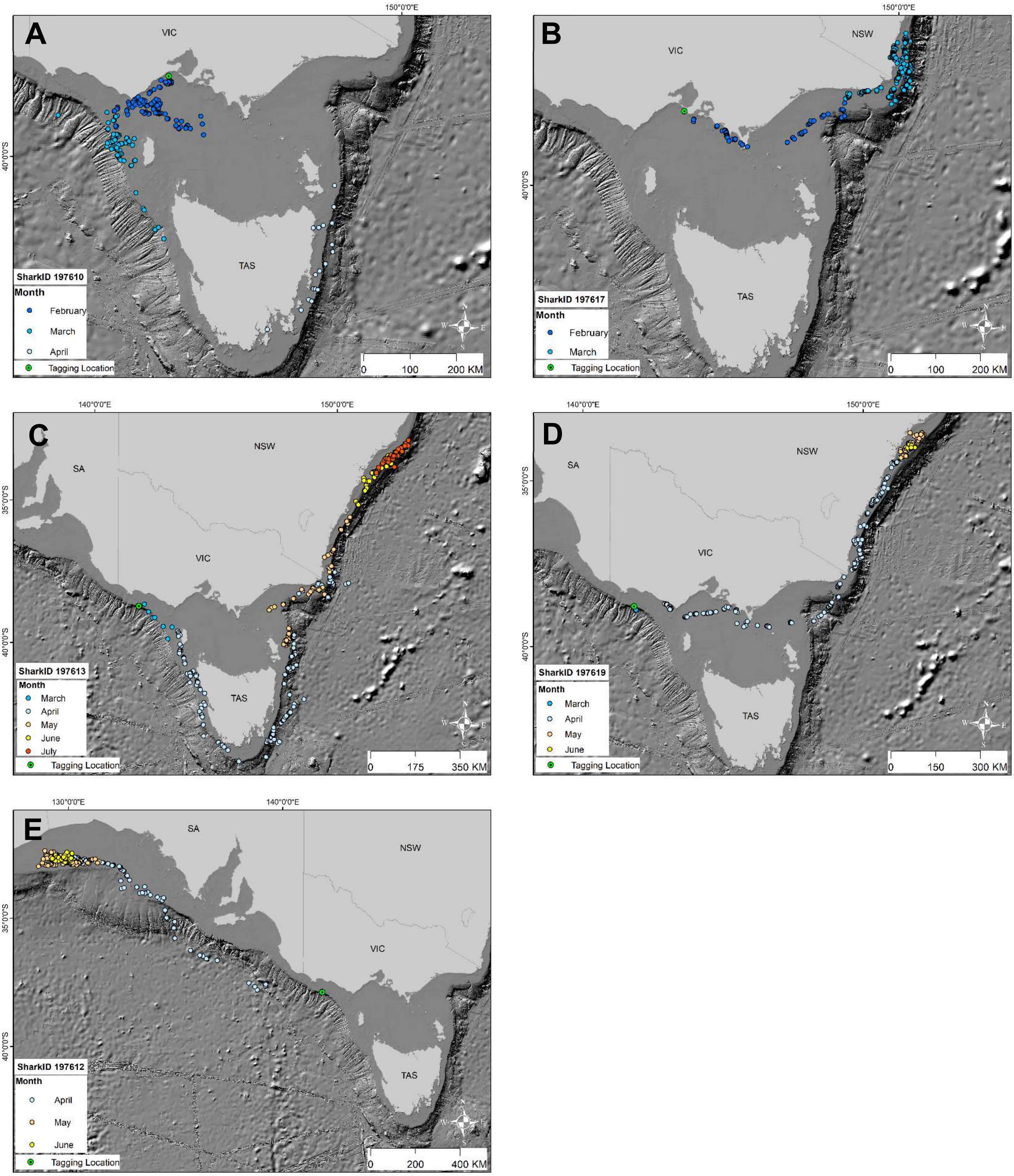


Figure 3. Monthly movement pattern of shortfin mako shark caught off Victoria (A = 197610; B = 197617; C = 197613; D = 197619; E = 197612). Different colour detections indicate monthly position. Green dot indicates capture location.

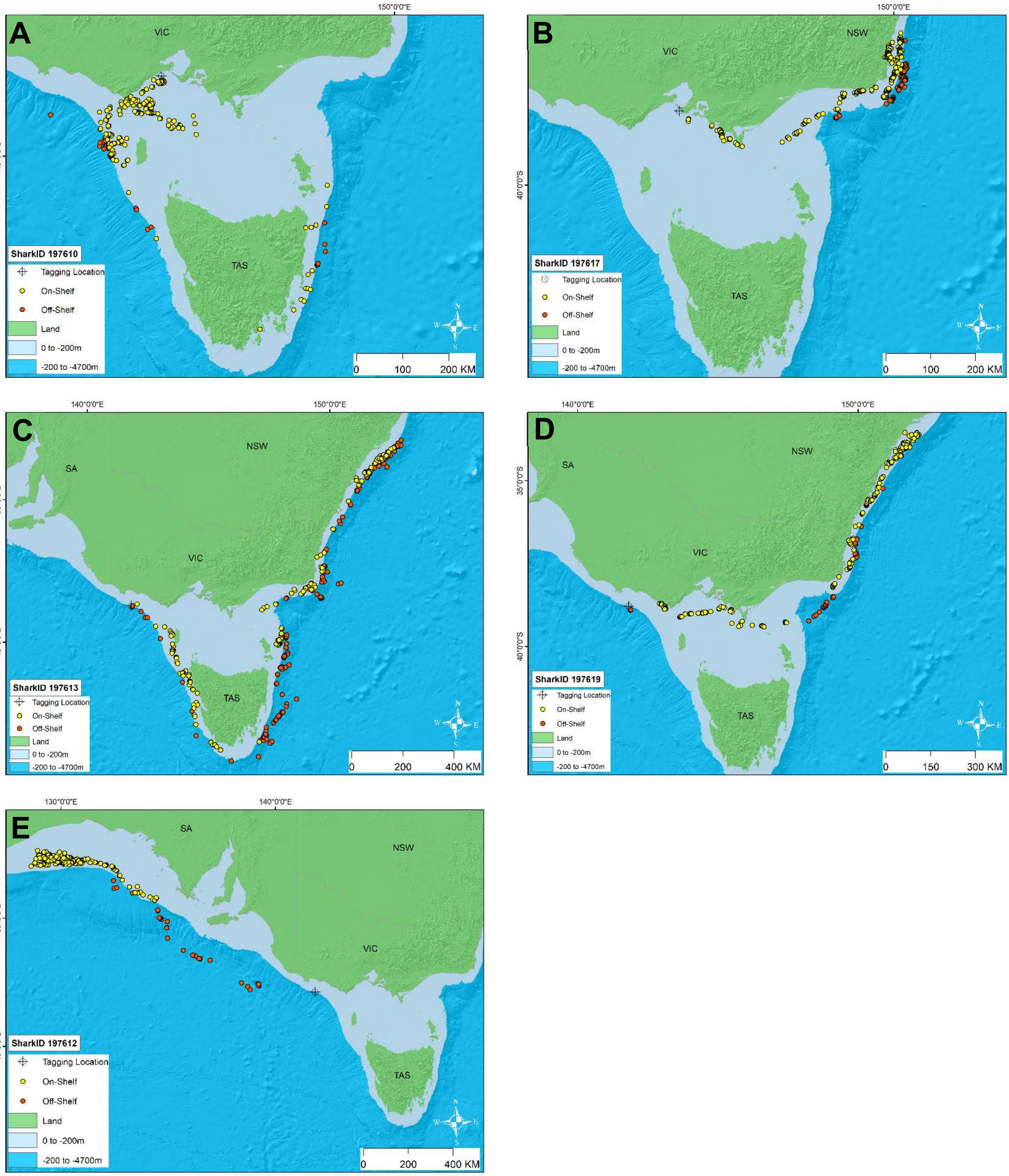


Figure 4. On-shelf (<200 m) / off-shelf (>200 m) distribution shortfin mako shark tagged off Victoria (A = 197610; B = 197617; C = 197613; D = 197619; E = 197612).

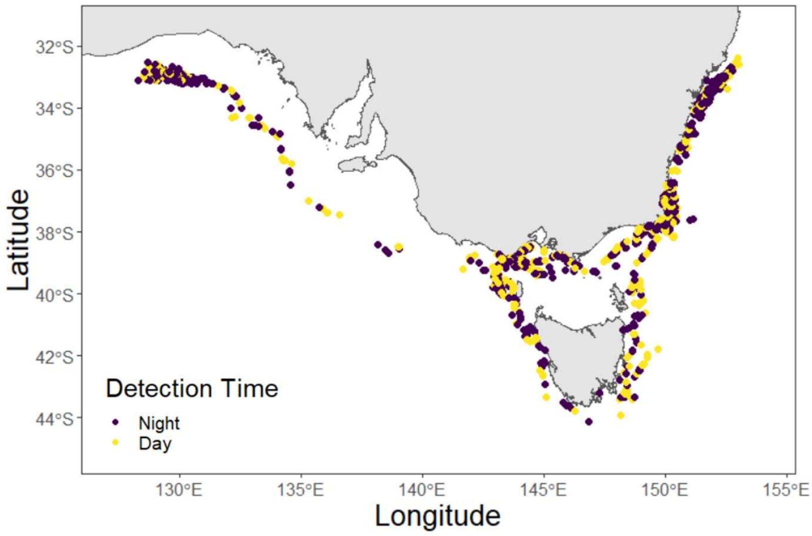


Figure 5. Surface detection of shortfin mako shark caught off Victoria during the day and night. Individual shark detections presented.

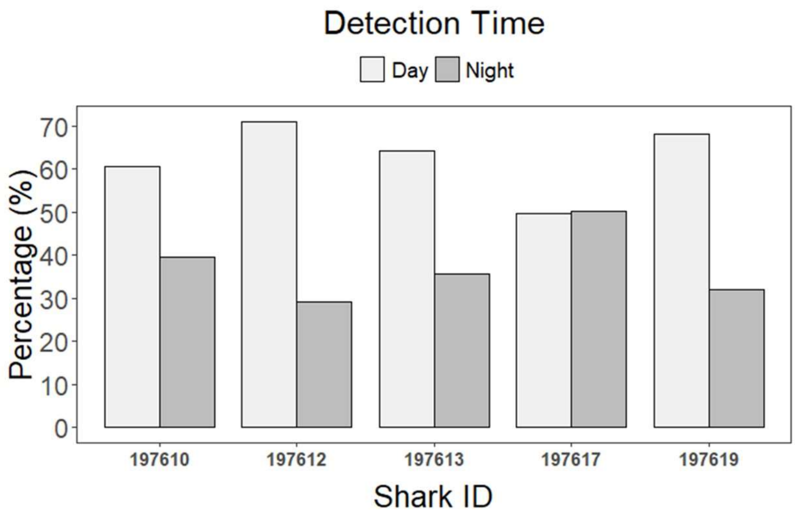


Figure 6. Percentage of day / night surface detection of shortfin mako shark tagged off Victoria.

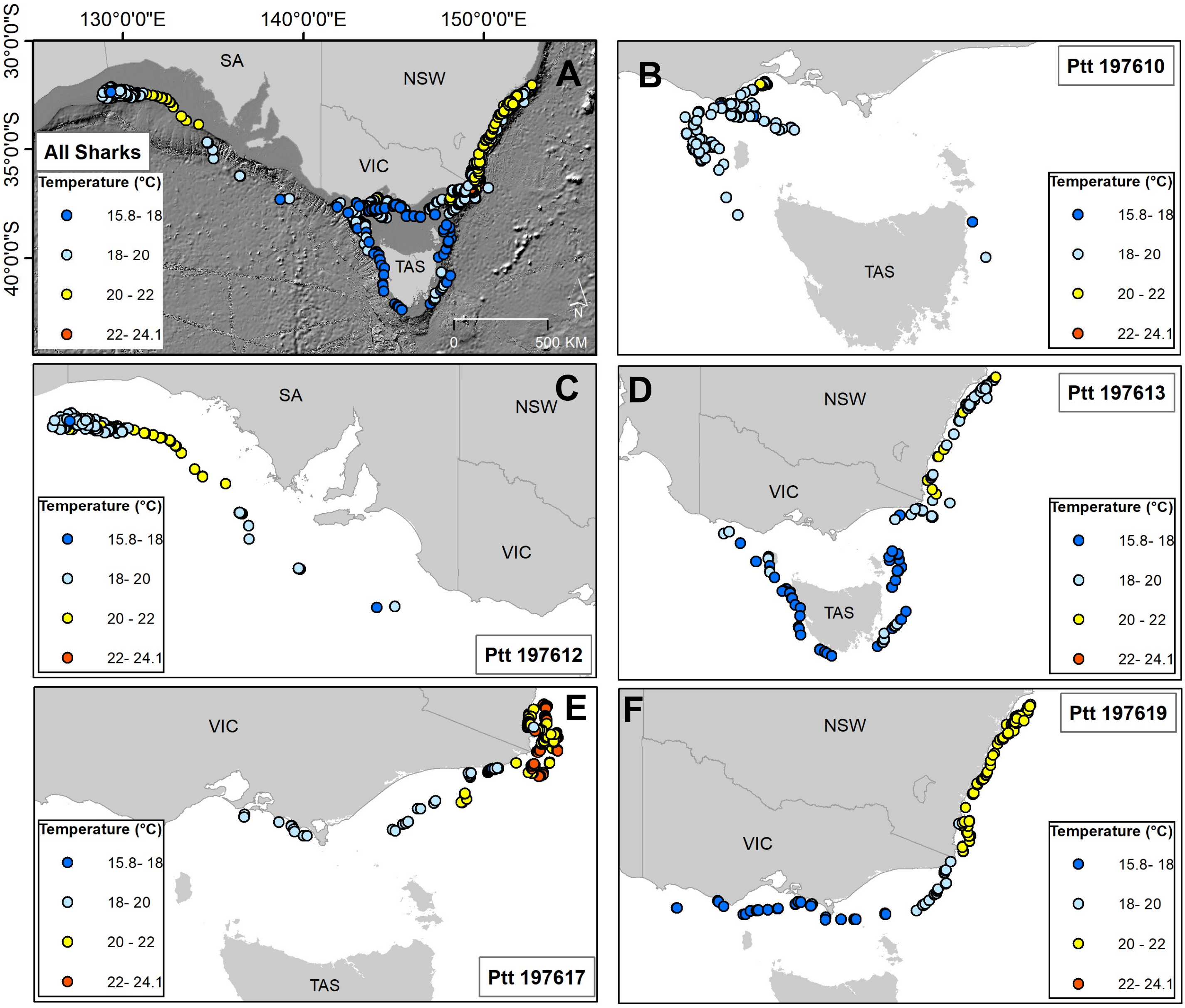


Figure 7. Recorded temperature for all shortfin mako sharks (A) and individual shortfin mako shark caught off Victoria (B = #197610; C = #197612; D = #197613; E = #197617; F = #197619).

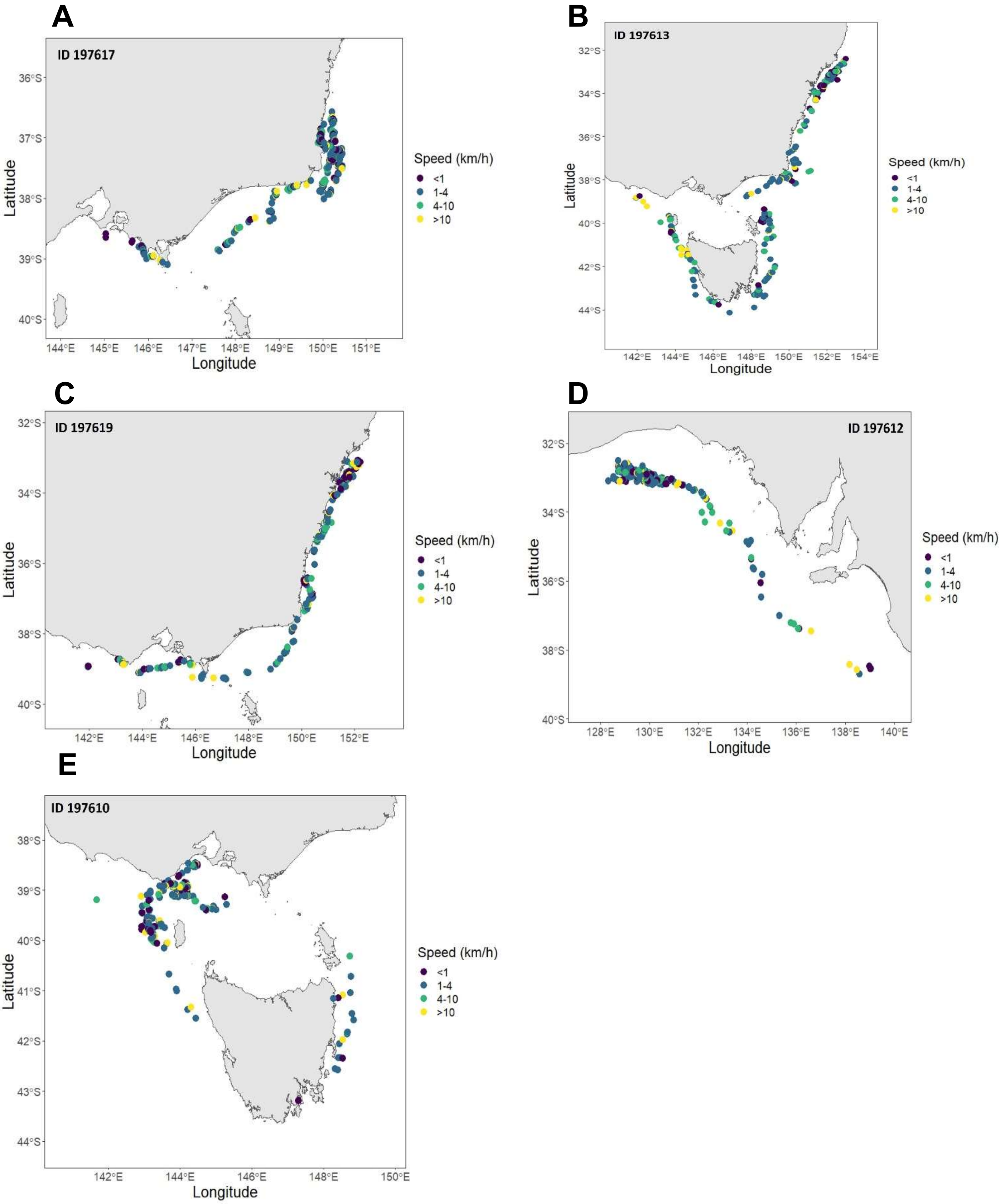


Figure 8. Speed (km/h) calculated between detection intervals of shortfin mako shark tagged off Victoria (A = #197617; B = #197613; C = #197619; D = #197612; E = #197610).

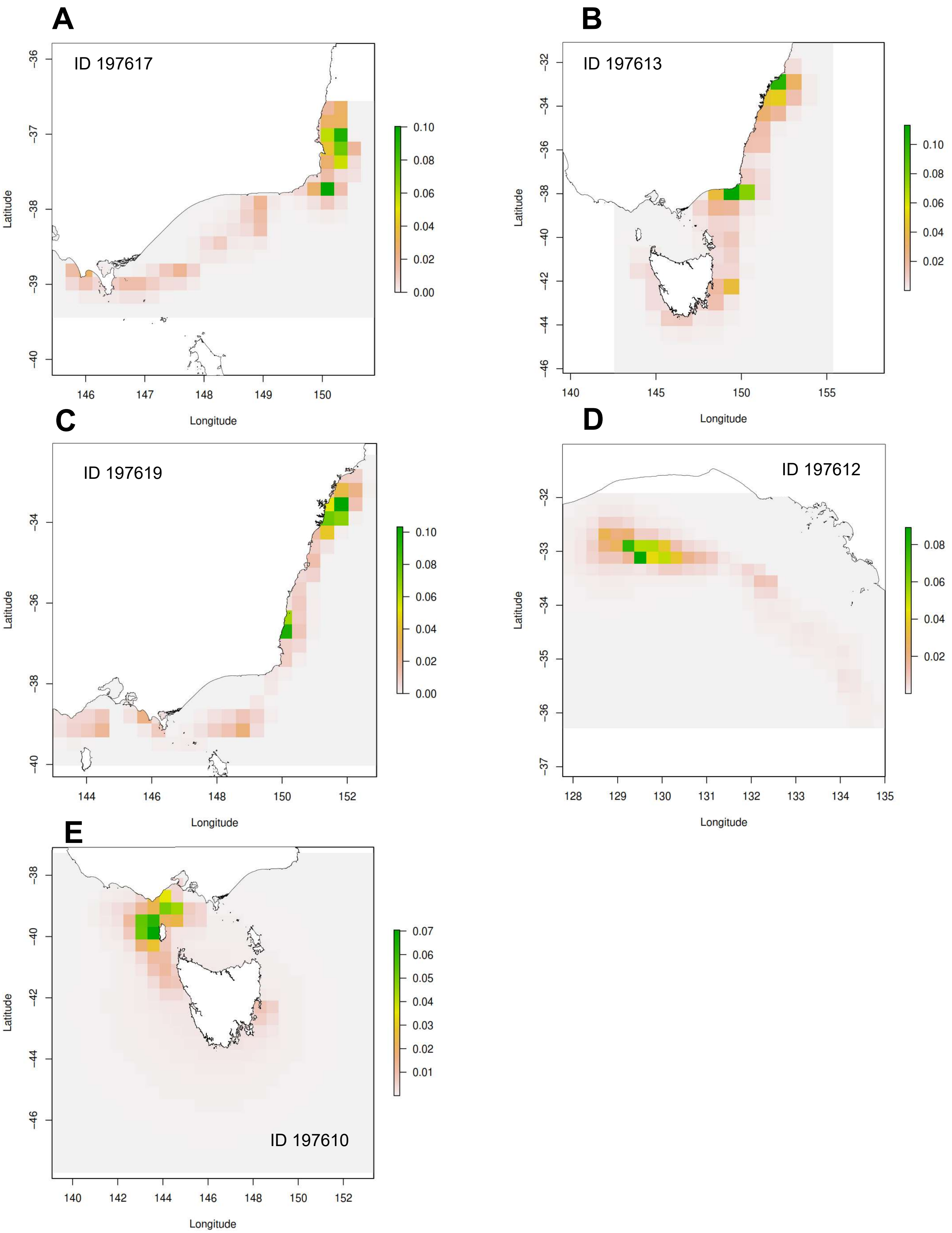


Figure 9. Brownian bridge movement model outputs of shortfin mako shark caught off Victoria (A = #197617; B = #197613; C = #197619; D = #197612; E = #197610).

Discussion

Movement characteristics

Understanding movement characteristics of shortfin mako sharks on a global scale has previously indicated that they are a highly migratory species and this research has validated findings for mako sharks found off Victoria (Rogers et al. 2015, Rogers, Knuckey et al. 2017, Vaudo, Byrne et al. 2017, Corrigan et al. 2018, Francis et al. 2019, Francis, Lyon et al. 2023). Although only five mako sharks were tagged, each showed complex movement characteristics. For example, three individuals tagged off Portland over a two-day period ventured in completely different directions. The male travelled west to the Great Australian Bight (GAB), and while both females travelled to northern NSW, one did so via Bass Strait whereas the other circumnavigated Tasmania. Independent of the direction of travel, there was a distinct affiliation of all tagged mako sharks for continental shelf-break waters, with movement in and out of neritic and oceanic environments. This is consistent with sharks tagged in the GAB and the Southern Californian Bight (North-east Pacific Ocean) by Rogers et al. (2015) and Block et al. (2011) respectively, which is likely associated with prey distribution.

Although mako shark movement extended >5600 km over a relatively brief period (124 days), site fidelity was observed where animals spent extended periods in specific regions. It's well established that mako sharks travel extensive distances; however, regions such as the GAB, the shelf-break off King Island and eastern Victoria, as well as the central coast of NSW were significant in this study where sharks remained within a 100 km radius rather than travelling long distances. Francis (2019) found that mako sharks switched between resident and transient behavioural states with residency patterns sometimes lasting several months. These regions typically possess distinct bathymetric features (i.e. continental slope) associated with highly productive waters, upwelling events and thermal frontal zones, particularly during late summer and autumn (Rogers, Huveneers et al. 2012, Rogers et al. 2015), and are thus linked to the fidelity of higher order predators such as mako sharks (Holts and Bedford 1993, Stevens et al. 2009, Block et al. 2011).

The Eastern Australian Current moves southward from Queensland to eastern Tasmania; whereas, the Leeuwin current flows from Western Australia into the GAB where it eventually forms the Zeehan current off the west coast of Tasmania (Cresswell 2000, Middleton and Bye 2007). These ocean currents provide a mechanism for nutrient transport, spawning and larval dispersal of aquatic organisms that help support biodiversity and fisheries productivity. Site fidelity Brownian bridge models highlighted the importance of areas including the GAB, the border between Victoria and NSW, and the northern NSW region. Off Victoria and within the GAB, oceanographic and environmental variables fluctuate largely due to variable current systems, as well as ocean floor topography (Middleton et al. 2007). In such areas, upwelling events periodically occur where cooler, nutrient rich water is pushed towards the ocean surface. In western Victoria the Bonney upwelling is a seasonal event that drives an increase in primary productively and may be associated predatory behaviour and site fidelity of mako sharks. Like the Bonney upwelling, the GAB also holds highly productive waters where nutrient rich sub-Antarctic waters are pushed to surface waters fuelling productivity. Primary productivity in the form of algae containing chlorophyll forms the basis of food webs where many aquatic animals from all trophic orders benefit from an abundance of food. Mako shark are well known to prey on cephalopods (Maia, Queiroz et al. 2006, Vetter, Kohin et al. 2008, Preti, Soykan et al. 2012) and off the coast of Australia, arrow squid (*Nototodarus gouldi*) are a dominant oceanic species that is preferred in the diet of mako shark (Stevens 1984, Arnould, Trinder et al. 2003, Green 2011, Rogers et al. 2012). Arrow squid are prevalent particularly on the continental shelf-break where mako sharks are known to inhabit. When squid are less abundant, pelagic sharks consume larger quantities of small forage fish (Virtue, Green et al. 2011), contributing to their movement activity to search for prey.

We found that ambient water temperature experienced by mako sharks tagged in this project ranged from 15.8–24.1°C with average temperatures experienced by individuals ranging from around 19–21°C. This is range is consistent with other research, with both Carey (1985) and Holts (1993) finding that tagged sharks off the coast of California preferred temperatures 20–21°C (range 13–21°C) and 18–20°C for mako sharks in the northwest Atlantic (Carey, Scharold et al. 1990). Abascal (2011) observed that mako shark descended rapidly below thermoclines (possible foraging pattern) followed by slower ascents. Depth was not recorded during this present study; however, previous research has indicated that vertical movement is associated with temperature preference. Although depth of mako sharks was not acquired, sharks may descend to deeper water and use the shelf-break for navigational purposes, similar to movement pathways found with white sharks (Bruce, Stevens et al. 2006). As muscular and visceral temperature of mako shark are maintained above ambient water temperature via vascular counter-current heat exchangers (Carey et al. 1985), seeking cooler waters may be a response to increased activity. We found that tagged sharks spent most of their time (60%) in surface waters, a characteristic also found by Carey (1985) where 80% of time was spent in <12m off southern California. In contrast, mako sharks from eastern Australia were observed moving to deeper cooler waters during daylight hours (Stevens et al. 2009).

Near shore detections using environmental DNA

Results from this and other similar studies on movement characteristics of shortfin mako sharks illustrates the complexities of managing highly migratory species. Although tagging technologies have greatly improved our knowledge of movement, connectivity, behaviour, and habitat preference (Jepsen, Thorstad et al. 2015), there are some limitations in conducting such research including relatively high cost, difficulty in capturing sharks, and labour intensity (Hammerschlag, Gallagher et al. 2011). Tagging has been extremely beneficial for exploring and testing alternative management strategies; however, other methods complementary to tagging are becoming more readily available to help close knowledge gaps (Sassoubre, Yamahara et al. 2016). One component of this research was to explore the use of environmental DNA (eDNA) as a tool for detecting mako shark near shore movements and identify temporal and spatial patterns of movement, including potential 'hotspots'. Environmental DNA analysis involves the collection of waters samples followed by the extraction, amplification and sequencing of DNA that is naturally shed into the environment by all organisms (Harrison, Sunday et al. 2019) and has been used effectively to study the movement of large pelagic species like white sharks (Truelove, Andruszkiewicz et al. 2019).

The development and validation of a species-specific eDNA assay to understand temporal and spatial near shore movement of mako sharks in Victoria in relation to adjacent states (NSW, Tas and SA) was conducted by Rebecca Skurrie and Julia Gray as partial fulfilment of Deakin University requirements for the Degree of Bachelor of Environmental Science (Honours) under the supervision of Assoc. Prof. Craig Sherman. This work was partially funded by the recreational fishing grants program (https://vfa.vic.gov.au/recreational-fishing/recreational-fishing-grants-program). To achieve this aim, research was conducted in two components. Firstly, to develop a test a species-specific qPCR (quantitative polymerase chain reaction) assay and validate it for water samples sampled adjacent to mako sharks, and secondly, to use the species-specific assay to identify the presence of mako shark DNA on different spatial and temporal scales.

Skurrie (2021) found that mako shark qPCR assays amplifying DNA are highly species specific and did not cross amplify when tested against 14 other sharks naturally occurring in Australian waters. Seawater samples collected off the coast of Victoria showed that mako shark DNA was highly detectable. Rates of DNA decay indicated that mako sharks could be detected for up to 120 hours after their DNA was naturally shed. These methods are highly transferable for analysing water samples collected at different spatial and temporal scales to detect the presence/absence of mako sharks.

A time series of sea water samples collected off the coast of Victoria from January – September 2022 indicated that peak presence occurred in March–May (autumn), then declined through winter and spring. Water samples collected from Portland to Barwon Heads (Victoria) revealed the highest concentrations of mako shark DNA; however, detections were found at all locations sample along the open coast. However, monthly samples from Hobsons Bay, near the port of Melbourne within the large embayment of Port Phillip Bay, showed only a single detection over a 19 month period, indicating this species does not regularly migrate far, or remain resident for long in this large embayment. Movement patterns of mako shark #197610 were observed between Port Phillip Heads and Cape Otway and mako shark DNA was also detected in this region. Gray (2022) suggested that patterns of occurrence of mako shark off Victoria were seasonal; however, a broad spatial and temporal sampling region would be required to maximise the benefits of eDNA analysis. Nevertheless, the eDNA results were consistent with the tagging information obtained under the first aim of this study.

Management

Globally, mako shark have a broad geographical distribution inhabiting both hemispheres where they complete their full life cycle (Abascal et al. 2011). Mako shark comprises three known subpopulations: Atlantic, Eastern North Pacific and Indo-West Pacific (Cailliet, Cavanagh et al. 2019). They are found throughout Australian waters, with the exception of the Arafura Sea, Torres Strait and Gulf of Carpentaria (Last and Stevens 2009).

In a global context, a Memorandum of Understanding on the Conservation of Migratory Sharks (CMS), also referred to as the Sharks MoU, was developed under the auspices of the Convention on the Conservation of Migratory Species of Wild Animals. For Australia, the objective of the Sharks MoU is to achieve and maintain a favourable conservation status for seven shark species, that ensures healthy and viable populations remain in their existing habitats. Although the IUCN classify global stocks of mako shark as Endangered (2022 list) they also recognise that the South Pacific is the only region that has increasing numbers of mako shark. While data are not available for the Indo-West Pacific, a declining stock is likely given its high exploitation (www.fish.gov.au). In Australia, mako shark is considered to be Vulnerable "*due to contrasting situations in adjacent areas (declining in the Indian Ocean and increasing in New Zealand).*" (Kyne et al. 2021), but commercial catches in Australia are considered low as regulations of pelagic longline fisheries limit its retention (www.fish.gov.au) with the management of shark species being important to ensure the conservation and sustainability of global shark stocks (Stein, Mull et al. 2018).

The National Plan of Action for the Conservation and Management of Sharks 2012 (Shark-Plan 2) is an initiative that provides guidance for meeting internationally recognised targets for shark management and conservation in Australia. As such their effective management is dependent on implementation of effective strategies at a domestic level (Rigby, Barreto et al. 2019, Kyne et al. 2021). On 15 July 2010, an amendment was made to the

Environment Protection and Biodiversity Conservation Act 1999 (the *EPBC Act* Cwth) that allows recreational fishing of shortfin mako in Commonwealth waters (Government 2010, Kyne et al. 2021) and in Victoria the recreational bag limit for mako sharks is one.

Unlike findings from this study, mako sharks previously tagged off the coast of Australia travelled much more extensive distances, implying that their habitat preference is not only linked to topographical features of the continental slope and shelf but deep oceanographic waters. Mako sharks tagged in the Great Australian Bight migrated to the tropical NE Indian Ocean and the Coral Sea with one individual travelling 25,550 km across the Indian Ocean (Rogers et al. 2015). Although such extraordinarily long distances were not observed in this study it illustrates the importance in broad-scale management and rather than confining investigations to within Victoria's jurisdiction. In other words, projects should be national involving collaboration with research agencies in other jurisdictions.

Best practice principles for recreational angling

If ongoing management of mako sharks if going to be effective in rebuilding and maintaining populations, then responsibility for its prosecution not only resides within state and federal legislation, but in stewardship fostered by improving recreational angler interaction. This present research contributed to a larger FRDC project that aimed to create 'best-practice capture, handling, and release guidelines' for recreational fishing of sharks and rays. A survey of over 1000 recreational fishers was conducted to assess current behaviours and attitudes of the community fishing for sharks and rays which then informed the Shark Mates extension campaign. The educational resources created for Shark Mates facilitated improved outcomes during capture and release of sharks and rays.

Williamson et al. (2023) opined that "*In 2019, the vulnerability risk analysis was completed (Walker et al., 2021) along with the national workshop (Reina et al., 2020). The results of the recreational fisher survey highlight that a large proportion of respondents, 84%, are concerned with the behaviour of other fishers. In 2020, we designed the best-practice guidelines and educational materials and completed filming of a series of six informational videos accessible online. The Shark Mates extension campaign was launched in early 2021, involving the development of a website and social media accounts including instructional YouTube videos. These useful informational resources remain available to the recreational fishing community. There has been some good initial support for the extension campaign by members of the recreational fishing community. The most successful platform used by the campaign at the moment is Instagram, with 130 followers of Shark Mates on that platform. The continued upkeep of communications about best- practice guidelines for shark and ray fishing, achieved specifically by regular maintenance and updating of the Shark Mates website and social media channels is advised. Further effort to disseminate the information to a larger proportion of the recreational fishing community is also encouraged. With adoption and championing of best-practice behaviours within the recreational fishing community outcomes from interactions with sharks and rays during fishing will continue to improve*."

A downloadable Shark Mates booklet can be found at:

https://sharkmates.com.au/wp-content/uploads/2021/07/21092_SharkMates_HandlingBooklet_Final_Web.pdf

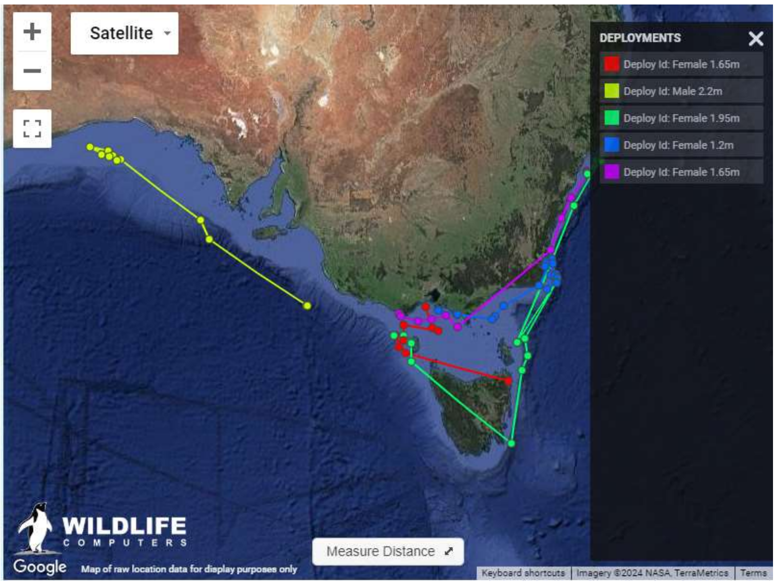
Conclusion

This project validated that mako sharks caught off the coast of Victoria can travel through multiple state jurisdictions and Commonwealth waters. Both migratory behaviour and site fidelity appear to be highly individually specific; however, there was commonality in an association with the continental slope particularly when travelling. Several areas of increased site fidelity were identified (GAB slope, western Victoria during active Bonney Upwelling, eastern Victorian slope including the head of the Bass Canyon, and central/northern NSW continental shelf-break). Analysis of eDNA showed its high potential for identifying important habitats (hotspots) at a varying spatial and temporal scales. With ongoing management that supports sustainability principles complemented by advocating for the importance of 'best practice' capture (and release) of sharks and rays there will be tangible benefits for the recreational fishing community in the future.

Media extension

Project updates were regularly provided though online content including,

- VFA website (https://vfa.vic.gov.au/science-in-fisheries/mako-shark-tagging)
- Interactive mako shark location map (https://my.wildlifecomputers.com/data/map/?id=604ff334e9b351183d273a64)



- The Pody Mullet VFA Podcast

(https://podcasters.spotify.com/pod/show/poddy-mullet/episodes/Episode-14---Mako-Shark-Tagging-e11hm3f/a-a5m2f7h).

– Social network posts

Victorian Fisheries Authority
April 9, 2021

A project to learn more about shortfin mako sharks is moving along - nearly as quickly as the sharks themselves!

The tagging program is funded by your fishing licence fees and is helping our scientists learn more about the movement and habitat preference of makos.

So far, four sharks have been tagged with the satellite transmitting devices, which transmit location data each time the shark surfaces.... See more

Victorian Fisheries Authority
August 14, 2019

With help from your fishing licence fees, we're working with scientists from Deakin University to track the whereabouts of mako sharks using DNA technology!

By analysing eDNA (environmental DNA) in conjunction with satellite tagging, scientists are able to identify mako shark 'hot spots' along our coastline.

Rather than taking physical DNA samples from the sharks themselves, eDNA enables scientists to determine the presence of the sharks from samples that are sh... See more

Renée, Grant and 40 others 3 comments 2 shares

Victorian Fisheries Authority
August 8, 2022

It's amazing what technology can see in water from the sea!

Thanks to your fishing licence fees, we've been working with Deakin University on a project to learn about the movement of mako sharks.

We know makos make for good rec fishing offshore but less is clear about their prevalence and where and when they move. ... See more

– Television (Channel 31)

– SharkMates

www.sharkmates.com.au

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Investigating genetic connectivity of mako sharks in Victoria in relation to adjacent states (NSW, Tas and SA) was conducted by Rebecca Skurrie and Julia Gray as partial fulfilment of the Deakin University requirements for the Degree of Bachelor of Environmental Science (Honours) under the supervision of Assoc. Prof. Craig Sherman of.

Gaining a greater understanding of catch and release practices of shark anglers and develop 'best practice' principles for recreational angling was conducted by Dr. Sean Williamson (see Williamson, S., Huveneers, C., Walker, T., Green, C., Reina, R. 2023 Improving outcomes of fisher interactions with sharks, rays, and chimaeras, Melbourne, Australia, as a part of a larger research project supported by the Fisheries Research and Development Corporation (FRDC) with supplemented funding provided by the Recreational Fishing Grants Program associated with this research project. The full report can be found here https://www.frdc.com.au/sites/default/files/products/2018-042-DLD.pdf).

Social media content was managed by Marc Ainsworth VFA with photos provided by Luke McCredden and Aaron Habgood.

This study was conducted in accordance with Deakin University's Animal Ethics Committee. Approval for research was granted on 11 May 2020 (Application Number B07-2020)

This project would not be possible without support by the recreational fishing and charter boat sectors. A big thank you to the Salty Dog Fishing Charters, Ocean Grove Fishing Charters, and Gone Fishing Charters for locating, capturing, and tagging mako sharks including. The mako shark tagging cradle was designed and engineered by Calvin Baker (www.creativestainless.net.au).

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Appendix 1. The development and validation of eDNA protocols for detecting the presence and movement of mako sharks in Victoria

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Submitted in partial fulfilment of the degree of Bachelor of Science (Honours). May 2021

Abstract:
Sharks play an important role in marine ecosystems by being apex predators that feed on animals lower down the food web. This helps to regulate and maintain an ecosystem by balancing the food web, as they directly limit populations of prey below them. When an apex predator is removed from the community, the entire ecosystem is at risk of collapse. Due to centuries of overfishing, sharks are now deemed as critically endangered. In many parts of the world there has been little action by fisheries regulators in managing targeted and accidental shark captures, and remote fishing communities that have high levels of poverty make it difficult to track capture rates due to poorly recorded data. In Australia, the shortfin mako shark, *Isurus oxyrinchyus*, is increasingly being targeted as a recreational fisheries species. However, there is currently a lack of information on patterns of movement and near shore visitation rates for this species, which are urgently needed to inform effective management. In south-eastern Australia, *I. oxyrinchyus* are currently being monitored and tracked for fisheries via baiting, hooking, and tagging, however this is costly and can only be done for a limited number of individuals. Environmental DNA (eDNA) is an emerging technology that provides a rapid, targeted, and cost-effective tool for detecting the presence of a species and can provide crucial information on the movement and near shore visitation rates of sharks to better inform management. In this study, I test and validate a qPCR assay designed to be specific to *I. oxyrinchyus*. The qPCR assay was shown to be highly species specific and did not cross amplify with 14 other Australian shark species tested. Analyses on the limits of detection (LOD) showed that the assay was highly sensitive and could reliably detect DNA concentrations as low as 1.31 pg/µl. A controlled laboratory eDNA decay trial showed that after approximately 48-hours, the concentration of eDNA reaches the LOD and becomes increasing difficult to reliably detect. This indicates that sharks may be detectable within an area up to two days after a visitation. Finally, the assay was shown to reliably amplify field water samples collected from around a shortfin mako shark capture. The results from this study demonstrate that this qPCR assay is highly species specific and sensitive for detecting *I. oxyrinchyus* in the field and provides a new tool to help current tracking of this species and understanding movement and near shore visitation rates.

Appendix 2. Assessing nearshore visitation of shark species in Victorian waters using environmental DNA

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Abstract

Knowledge of spatial and temporal movements of migratory sharks is crucial for informing effective management on local, national and global scales. *Isurus oxyrinchus*, *Carcharodon carcharias*, *Galeocerdo cuvier* and *Carcharhinus leucas* distributions and movements within nearshore waters of western Victoria are unknown, with all species of significant interest in Victoria and throughout Australia. *I. oxyrinchus* is popular within Victorian commercial and recreational fisheries, and *C. carcharias*, *G. cuvier* and *C. leucas* are of most concern due to their role in the rising frequency of negative shark-human interactions. I use a time series of environmental DNA (eDNA) samples collected between January 2022 to September 2022 together with species-specific assays to determine and compare species presence within western Victoria on spatial and temporal scales. *I. oxyrinchus* was largely present within samples, with statistical significance in the likelihood of detections between seasons ($p = 0.015$) and locations ($p < 0.001$). Peak presence occurred in autumn, with a gradual decline in winter and the lowest proportion of detections in summer and spring. Spatially, *I. oxyrinchus* was detected at all locations, with the most detections within the Point Roadknight to Barwon Heads region. C*. carcharias, G. cuvier and C. leucas* were not detected within any samples. This study shows that eDNA sampling for shark DNA can be effectively applied, which may reduce the reliance on traditional methods. Mako shark presence has been verified in nearshore western Victorian, with significant annual occupancy. This highlights the need for future research into understanding the life stages and biology of individuals within the region, to better tailor management to their needs. While C. carcharias DNA was not detected, their presence in Victoria is known and future studies should focus on their nearshore movements within western Victoria. The absence of *G. cuvier and C. leucas* DNA was expected, however poleward shifts are expanding their populations globally. These species are expected to move into Victoria in the near future and it is important to understand when these shifts occur.

Appendix 3. Improving outcomes of fisher interactions with sharks, rays, and chimaeras

Authors: Sean Williamson, Charlie Huveneers, Terence Walker, Corey Green, Michael Burgess, Ben Scullin, and Richard Reina

Fisheries Research and Development Corporation Project No 2018-042

January 2023

Executive Summary

A consortium of recreational fishing advocates, fisheries managers, and marine scientists from Monash

University, Victorian Recreational Fishing Peak Body (VRFish), Flinders University, and the Victorian Fisheries Authority collaborated to create best-practice capture, handling, and release guidelines for recreational fishing of sharks and rays. The guidelines were communicated to the recreational fishing community in southern Australia by creating of a multi-media extension campaign called *Shark Mates*. Informational resources, such as a best-practice guidelines booklet, six YouTube videos, a website, stickers and brochures, are now available to the public and are being promoted through the peak recreational fishing body in Victoria, VRFish. Prior to the creation of the guidelines and subsequent extension activities, a national workshop was conducted in collaboration with SARDI in Adelaide to discuss current knowledge related to handling and post-release survival of sharks and rays (Reina *et al.*, 2020). Priority species were identified at the workshop and a vulnerability analysis was conducted to assess all anthropogenic risks to these species. A survey of over 1000 recreational fishers was then conducted to assess current behaviours and attitudes of the community fishing of sharks and rays which then informed the *Shark Mates* extension campaign. The educational resources created for *Shark Mates* enable improved outcomes during capture and release of sharks and rays.

A need for fisher behavioural change in the capture of sharks and rays in recreational fisheries was identified after a series of ethical incidents impacting the social licence of fishing in southern Australia. The goal of this project was to develop and further refine best-practice capture, handling, and release guidelines for sharks and rays to ensure safety of fishers and improved outcomes for sharks and rays.

The objectives of this project were to:

1. Cause behavioural change of fishers in their interactions with captured sharks, rays and chimaeras in Victoria.
2. Form an expert steering committee to oversee and guide this project and the SARDI project addressing recreational fisheries' impact on sharks, rays and chimaeras.
3. Execute an informed, comprehensive, cost-effective and targeted communications strategy leading to behavioural change in Victorian fishers.
4. Complete a vulnerability risk analysis of chondrichthyan species impacted by recreational fishing in Victorian waters.
5. Co-host a multi-jurisdictional workshop with SARDI to identify species of importance, develop and agree upon capture, handling and release protocols for chondrichthyans across states to ensure high post-release survival and humane treatment of these sharks and rays and the safety of fishers.

In 2019, the vulnerability risk analysis was completed (Walker *et al.*, 2021) along with the national workshop (Reina *et al.*, 2020). The results of the recreational fisher survey highlight that a large proportion of respondents, 84%, are concerned with the behaviour of other fishers. In 2020, we designed the best-practice guidelines and educational materials and completed filming of a series of six informational videos accessible online. The *Shark Mates* extension campaign was launched in early 2021, involving the development of a website and social media accounts including instructional YouTube videos. These useful informational resources remain available to the recreational fishing community. There has been some good initial support for the extension campaign by members of the recreational fishing community. The most successful platform used by the campaign at the moment is Instagram, with 130 followers of *Shark Mates* on that platform. The continued upkeep of communications about best practice guidelines for shark and ray fishing, achieved specifically by regular maintenance and updating of the *Shark Mates* website and social media channels is advised. Further effort to disseminate the information to a larger proportion of the recreational fishing community is also encouraged. With adoption and championing of best-practice behaviours within the recreational fishing community outcomes from interactions with sharks and rays during fishing will continue to improve.