

Introduction

Since the 2009/10 meshing season, the Shark Meshing (Bather Protection) Program (SMP) has operated in accordance with Joint Management Agreements (JMAs) and an associated Management Plan authorised by the *Fisheries Management Act 1994*. The Management Plan contains a performance assessment and reporting framework to assess the performance of the Plan in achieving its objectives, and to communicate the results transparently. Achievement of those objectives is determined against performance indicators and trigger points, and is communicated by annual performance reports and review reports.

The annual performance report for 2016/17 (Dalton *et al.*, 2017) identified that the trigger point for the objective of '*minimising the impact on non-target species and threatened species*' was tripped for Greynurse Sharks, Hawksbill Turtles and Smooth Hammerheads. The trigger points relating to the other objectives of the Plan: '*reducing the risk to humans from shark attacks at meshed beaches*'; '*Work Health and Safety risks*'; and '*transparent monitoring and reporting*' were not tripped during the 2016/17 reporting period.

In accordance with the 2009 JMAs and Management Plan, both the JMAs and Management Plan were reviewed, amended and replaced with the current 2017 JMA and Management Plan. The 2016/17 SMP season therefore marked a transition from the original 2009 JMA and Management Plan to the 2017 JMA and Management Plan, including amended trigger points for threatened and non-target species.

This trigger point review report for the 2016/17 SMP season is a transition report and therefore also considers threatened and non-target species that would have tripped the trigger points from the 2009 JMA, which were Leatherback Turtle, Great Hammerhead Shark, and White Shark. From 2018/19 SMP season and beyond, trigger point review reports will only address threatened and non-target species in accordance with the 2017 JMA and Management Plan.

2016/17 Catch summary

In the 2016/17 SMP season, 373 animals were entangled in the nets (Table 7 in Dalton *et al.*, 2017), and 301 (81%) of those were threatened, protected, and/or non-target animals. The trigger point for the objective of '*minimising the impact on non-target species and threatened species*' was tripped in 2016/17 for six species. Two of these are listed as *endangered* species: Greynurse Shark and Leatherback Turtle; two are listed as *vulnerable* species: Great Hammerhead Shark and White Shark in NSW legislation; and two are other non-target species: Smooth Hammerhead Shark and Hawksbill Turtle. The trigger points are considered to be precautionary measures as they are related to the number of entanglements, not the number of animals that die as a result of entanglement.

Trigger Point Reviews

Endangered species

Greynurse Shark (*Carcharias taurus*)

Incident Description

Of the 17 Greynurse Sharks (*Carcharias taurus*) caught during the 2016/17 SMP season, 11 were released alive and six were retained for necropsy and contributed to the NSW DPI Fisheries database for this species.

Incident review

The SMP nets are generally set away from reef structure to minimise damage to reef habitats and nets and enhance ease of operations for the contractors. At these locations they are also considered less likely to capture predominantly reef-associated species such as Grey Nurse Sharks. The nets are generally set in similar positions throughout and between years, and the materials and other specifications have not changed, indicating that operational matters are unlikely to account for catch rates and tripping of the trigger point.

Grey Nurse Sharks were caught in all regions other than Sydney Central, but a substantial proportion (41%) were caught in the northern-most net off Stockton Beach. This is a large sandy bottom embayment and not generally considered prime habitat for Grey Nurse Sharks. In 2015/16, 12 of the 17 Grey Nurse Sharks were caught in the Central Coast regions of the SMP, with only three caught across the Hunter region, highlighting the inherent natural variability of catches in the SMP.

Grey Nurse Sharks were also caught throughout the meshing season, with no single month representing a notably higher entanglement rate.

Conclusions

The catches of 19 and 17 Grey Nurse Sharks in the 2015/16 and 2016/17 years, respectively, were more than three times the ten-year annual average catch in the SMP. Successive annual catches of that magnitude have not been reported since the 1970s, a time when the SMP season was operated for a full calendar year, rather than for eight months in the current SMP.

Although the trigger point was tripped following the capture of 17 Grey Nurse Sharks, this is likely due to two successive years of relatively high catches preceded by a long period of substantially lower reported catches for this species during the preceding decade rather than a function of the operation or management of the SMP. There are no readily identifiable deficiencies or issues to be addressed from an operational perspective of the 2017 JMA and Management Plan.

There are currently no known effective methods to completely mitigate bycatch of Grey Nurse Sharks from shark nets like those used in the SMP.

Recommendations

The NSW SMP nets have generally caught small numbers of Grey Nurse Sharks over the past decade. However, the release of over 50% of all Grey Nurse Sharks since the implementation of the first JMA in 2009 highlights the efficacy of reducing the number of hours between checks of nets to a maximum of 72 hours (previously 96 hours). It is anticipated that these released individuals will survive, but it is recommended that released Grey Nurse Sharks are fitted with pop-up archival tags to measure post-release survivorship. Similar tags are being used in the shark tagging and tracking programs under the NSW Shark Management Strategy.

Alternative bather protection devices, such as SMART Drumlines which are showing promising trial results in NSW, could achieve reduced impacts on threatened species such as Grey Nurse Sharks whilst still providing bather protection from shark interactions. A trial of their use at some beaches of the SMP, particularly those with relatively high catches of Grey Nurse Sharks, could determine the practicalities of incorporating them into the NSW Shark Meshing Program.

Leatherback Turtle (*Dermochelys coriacea*)

Incident description

The entanglement of one Leatherback Turtle (*Dermochelys coriacea*) during the 2016/17 SMP season tripped the trigger point for threatened species entanglements, as it was preceded by two entanglements in each of

the 2013/14 and 2015/16 meshing seasons after a decade of no reported catches for this species.

The Leatherback Turtle caught in 2016/17 was released alive.

Incident review

Leatherback Turtles are the largest of all sea turtles, but are rarely found close to shore in NSW as they are considered to be a pelagic species primarily found in tropical and sub-tropical waters throughout the world (Marquez 1990). However, their physiological adaptation allowing them to maintain elevated body temperatures in cold water enable them to extend their range into temperate waters. Although a few Leatherback Turtle nests have been reported for the far north coast of NSW, no major nesting has been recorded in Australia (Department of Environment and Energy, 2017).

While Leatherback Turtles are considered to occupy pelagic waters, they are caught in the Queensland Shark Control Program and very rarely in the SMP. The southern waters of Australia are one of five identified foraging grounds (where area restricted behaviour occurs) (Bailey *et al.*, 2012), so their movement through NSW waters could primarily represent a 'corridor' between nesting sites and primary foraging sites.

There is no evidence that Australian populations are currently in decline (Cogger, 2001) so occasional capture of this species in the SMP is likely to continue.

Conclusions

Although the trigger point was tripped following the capture of a single Leatherback Turtle, this is due to catches of two individuals in 2013/14 and 2015/16 preceded by a long period of zero reported catch for this species during the preceding decade. It should be noted that this entanglement did *not* result in mortality of the Leatherback Turtle.

The SMP has maintained an active policy of ensuring nets are set sub-surface in an attempt to enable air-breathing marine mammals, reptiles and birds to swim over the top of the net.

Recent studies into reducing turtle bycatch in passive net fisheries have highlighted the potential to use LED lamps to illuminate nets and reduce bycatch (Gilman *et al.*, 2010; Ortiz *et al.*, 2016).

Recommendations

The SMP nets have caught a few Leatherback Turtles over the past decade, however, it is anticipated that catches for this species may increase with increasing temperature of nearshore waters and subsequent movement of warm-water species into central NSW waters.

While it is unlikely that the current rate of SMP-induced mortality of Leatherback Turtles will negatively affect the population, it is imperative that ongoing efforts to further reduce bycatch be continually reassessed by the DPI and OEH and incorporated into subsequent trigger point review reports.

Vulnerable species

Great Hammerhead Shark (*Sphyrna mokarran*)

Incident description

The entanglement of one Great Hammerhead Shark (*Sphyrna mokarran*) during the 2016/17 SMP season tripped the trigger point for non-target species as it was preceded by one entanglement in the 2015/16 meshing season and numerous preceding years of zero catch.

The whole animal carcass was retained for research purposes.

Incident review

Historically, Great Hammerhead Sharks are rarely caught in the SMP, with only one mature female caught in 2015/16 at Maroubra Beach, and the 2016/17 capture of a 3.64m mature male occurring at Palm Beach. Great Hammerhead Shark was not reported from the SMP during the preceding nine seasons. A potential factor behind the recent captures over the last two seasons of this tropical species may be due to the changes in ocean circulation, leading to the increasing intensity and warming of the East Australian Current (EAC) (Hughes *et al.*, 2016).

Conclusions

The capture of a single Great Hammerhead Shark precludes detailed analysis to determine potential environmental factors leading to this incident, albeit over two consecutive years. However, movement of warm water eddies and/or the EAC closer to the coast may contribute to tropical species such as the Great Hammerhead Shark interacting with the SMP nets.

Recommendations

Due to the rare nature of Great Hammerhead Shark interaction within the SMP, the 10 year average of 0.2 interactions, and large litter sizes (6-33 pups; Last *et al.*, 2009), it is unlikely that SMP-induced mortality will negatively impact the population. Research into spatio-temporal and environmental drivers of Great Hammerhead Shark movements will complement existing life history information.

White Shark (*Carcharodon carcharias*)

Incident description

Of the 22 White Sharks (*Carcharodon carcharias*) caught during the 2016/17 season, eight sharks were released alive and 14 individuals were dead and retained. Eleven carcasses were kept for research purposes, while vertebrae (for ageing) and genetic samples were collected from the remaining three carcasses.

Incident review

White Sharks were caught throughout the region, but a substantial proportion (32%) were caught in the northern-most net off Stockton Beach. Stockton is a large sandy bottom embayment and is considered prime habitat for juvenile White Sharks, and is at the southern portion of the recognised juvenile nursery ground for this species (Bruce and Bradford, 2012).

Although White Sharks were caught throughout the SMP season, peak catches occurred in October and November, which aligns with known juvenile White Shark use of the nursery grounds off Port Stephens and with historical catches of White Sharks in that region.

Currently, it is believed that the eastern Australasian population of White Sharks numbers approximately 5,460 individuals (range of 2,909 to 12,802) (Bruce *et al.*, 2018) following development of new genetic techniques to determine population size using 'close-kin mark-recapture' techniques developed by the CSIRO (Hillary *et al.*, 2018). The adult shark population was calculated at 750 for which the trend in abundance was calculated not to be significantly different from zero (i.e. no trend and thus a stable population where births = deaths) (Bruce *et al.*, 2018).

However, White Shark catches in the SMP have been slowly increasing in the past two decades (Reid *et al.*, 2011). The 2016/17 catch was the fourth greatest catch of White Sharks in the SMP, with the previous year (2015/16) catch of 31 White Sharks representing the greatest reported SMP catch. These increased catches

may represent an early indication of a population growth of juvenile sharks since protection in Australian waters in the late 1990s.

Conclusions

Although the trigger point was tripped following the capture of 22 juvenile White Sharks, approximately one-third were successfully released alive from the nets. Greater numbers of live animals released from the nets have been a consistent outcome since the 2009 JMA reduced net checking frequency from 96 hours to a maximum 72 hours.

The NSW SMP nets have consistently caught White Sharks over the past decade. As juvenile White Sharks appear to regularly use near-shore waters in the SMP region they are most likely to interact with nets.

Recommendations

White Sharks are both a threatened species and a target species of the SMP, so their ongoing capture is an expected outcome of the SMP. It is, however, recommended that all sharks released alive from the nets should be tagged with acoustic and/or pop-up archival satellite tags to determine post-release survivorship and provide more robust information with respect to the impact of the shark nets on White Sharks.

Other non-target species

Smooth Hammerhead Shark (*Sphyrna zygaena*)

Incident description

The entanglement of 71 Smooth Hammerhead Sharks (*Sphyrna zygaena*) during the 2016/17 SMP season tripped the trigger point for non-target species as it was preceded by 113 entanglements in the 2015/16 meshing season.

Genetic samples and vertebrae were collected from 68 of the 71 deceased animals, to be used for confirmation of species identification and for ageing purposes, respectively.

Incident review

Historically, Smooth Hammerhead Shark captures in the SMP are substantial and spread throughout the region, with interactions occurring at 37 beaches in 2015/16 and 24 beaches in 2016/17. However, in those two seasons, 46% (2015/16) and 48% (2016/17) of Smooth Hammerhead Shark interactions were reported at four of the 51 beach nets. These beaches are located near to estuary mouths, which act as nursery habitat for Scalloped Hammerhead Sharks (*Sphyrna lewini*) (Bush and Holland, 2002; Clarke, 1971; Duncan and Holland, 2006; Holland *et al.*, 1993; Lowe, 2002) and for Smooth Hammerhead Sharks (Francis, 2016).

The apparent concentration of Smooth Hammerhead Shark captures at potential nursery sites is corroborated by the size frequencies of those individuals. All Smooth Hammerhead Sharks caught in the SMP are sexually immature, with the size at capture indicating their age to span between newborns and ten year old animals (mode three years) (Wray-Barnes, 2017).

Conclusions

Although there is an ongoing catch of Smooth Hammerhead Sharks in the SMP it is unlikely that the catch negatively affects the overall population status for this species, given the majority of captures are juveniles less than five years old, the age at sexual maturity is 26.5 years for females and 16.9 years for males (Wray-Barnes, 2017), and the large litter sizes of between 20-49 pups (Last *et al.*, 2009). Smooth Hammerhead

Shark interactions are almost entirely non-adult animals, with a 10 year average of 37 interactions.

Recommendations

Further research into age and growth, age at maturity, and population estimates in an eastern Australian would assist in providing confidence in the assessment that the SMP is not detrimental on Smooth Hammerhead Shark populations.

Hawksbill Turtle (*Eretmochelys imbricata*)

Incident description

The entanglement (and subsequent death) of two Hawksbill Turtles (*Eretmochelys imbricata*) during the 2016/17 SMP tripped the trigger point for threatened species entanglements, as it was preceded by five entanglements in the 2015/16 meshing season and one in the 2014/15 season after a decade of no reported catches for this species. Both Hawksbill Turtles caught were retained and provided to Taronga Zoo for necropsy and sampling for inclusion into the Australian Registry of Wildlife Health.

Incident review

SMP nets are set away from reef structure to minimise reef habitat damage, damage to nets, and to enhance ease of operations for the contractors. Therefore, they are considered less likely to capture reef-associated species such as Hawksbill Turtles.

Hawksbill Turtles generally occupy shallow waters (< 30m) and are infrequently caught in the both the SMP and the Queensland Shark Control Program. Although Hawksbill Turtles occur in NSW waters, none of their key nesting and inter-nesting areas (where females live between laying successive clutches in the same season) are in NSW (Department of the Environment and Energy, 2017). A review of their strandings along NSW beaches highlighted a skewed stranding frequency to northern NSW beaches (Ferris, 2016). The SMP is considered outside of their preferred range.

The size range of 62-70cm curved carapace length (CCL) corresponds to the size at recruitment onto reef habitat from the pelagic environment (Limpus, 1992; Limpus *et al.*, 2008). The months of capture in the SMP reflect increased periods of strandings in NSW waters (Ferris, 2016) and may reflect changes in the strength and seasonal variation of the East Australian Current (EAC).

One of the animals was thought to be severely malnourished at the time of death, but no obvious signs for this could be determined at the Taronga Zoo necropsy. The second animal was in good health.

Conclusions

Although the trigger point was tripped following the capture of these two Hawksbill Turtles, this is likely due to the previous years of five and one catches preceded by a long period of zero reported catch for this species during the preceding decade.

The SMP has maintained an active policy of ensuring nets are set sub-surface in an attempt to enable air-breathing marine mammals, reptiles and birds to swim over the top of the net.

Recommendations

The SMP nets have caught few Hawksbill Turtles over the past decade, however, it is anticipated that catches for this species could increase with increasing temperature of nearshore waters and subsequent movement of warm-water species into central NSW waters.

Although it is unlikely that the current rate of SMP-induced mortality of Hawksbill Turtles will negatively affect the population, it is imperative that ongoing efforts to reduce any bycatch be continually reassessed. Alternative bather protection devices, such as SMART Drumlines which are showing promising trial results in NSW, could achieve reduced impacts on threatened species such as Hawksbill Turtles whilst still providing bather protection from shark interactions. A trial of their use at some beaches of the SMP, particularly those with relatively high catches of Hawksbill Turtles, could determine the practicalities of incorporating them into the NSW Shark Meshing Program.

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