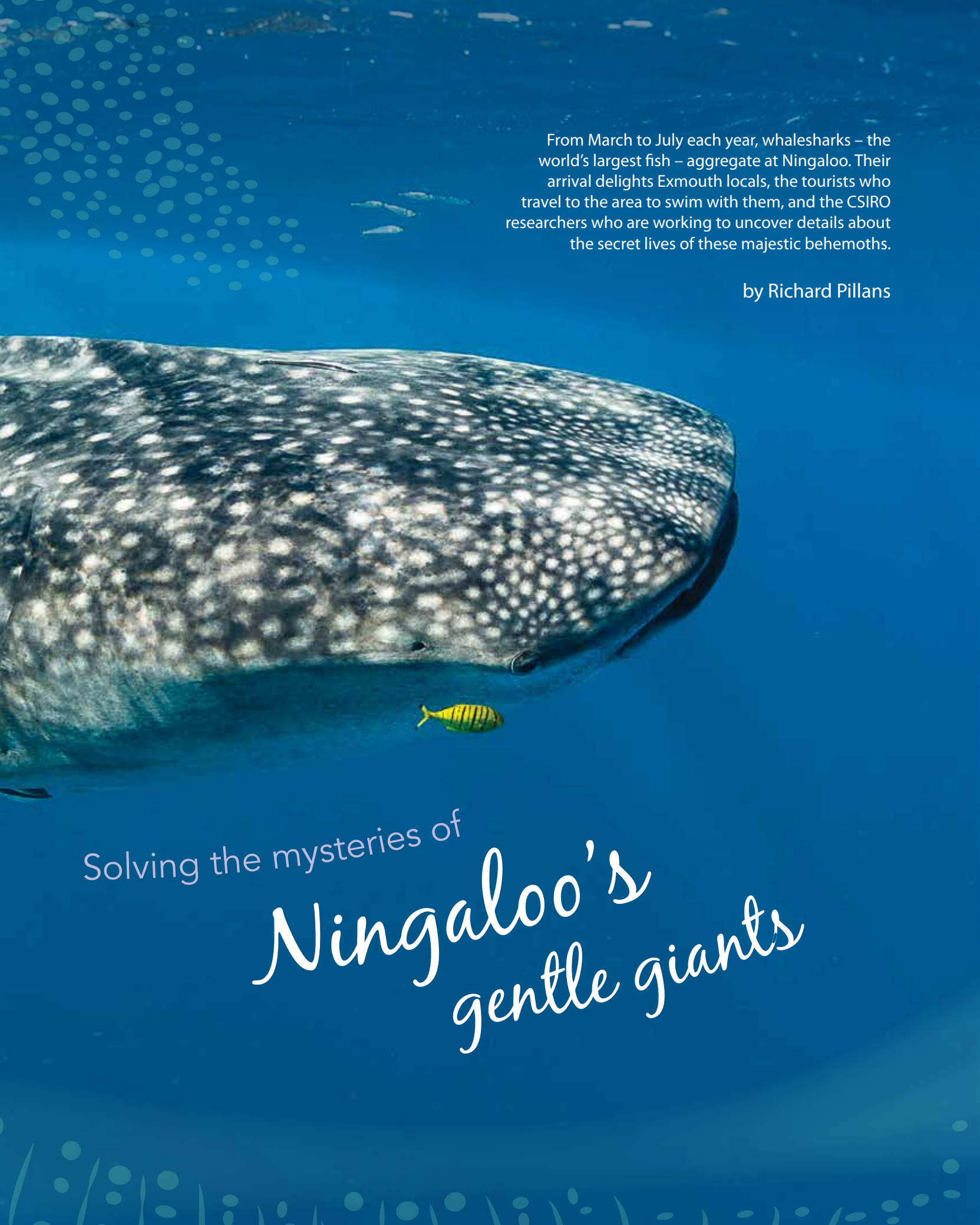


From March to July each year, whalesharks – the world's largest fish – aggregate at Ningaloo. Their arrival delights Exmouth locals, the tourists who travel to the area to swim with them, and the CSIRO researchers who are working to uncover details about the secret lives of these majestic behemoths.

by Richard Pillans

Solving the mysteries of

Ningaloo's gentle giants

While individual whale sharks (*Rhincodon typus*) are found off the Ningaloo coast year round, the aggregation of large numbers of sharks begins in March when they can be regularly seen until about July–August. Their arrival coincides with an increased abundance of zooplankton, which occurs as a result of stronger Leeuwin Current flow and increased upwelling (when deep, colder water rises to the surface) as the southward flowing Leeuwin Current meets the northward flowing Ningaloo Current.

Large aggregations of actively feeding whale sharks can often be seen, with feeding activity peaking at dusk. Genetic barcoding has identified tropical krill *Pseudeuphausia latifrons* in the faecal samples of whale sharks at Ningaloo.

How many whale sharks visit the area depends on the Southern Oscillation Index; more sharks are observed during El Niño years when upwelling is enhanced.

VIEWING THE VISITING WHALE SHARKS

Ningaloo Marine Park and the adjacent Cape Range National Park provide many nature-based activities for visitors to enjoy. The pristine beaches, turquoise waters and diverse and abundant marine life draw thousands of visitors to the area each year.

The regularity and predictability of the whale shark aggregation led to Ningaloo becoming one of the first places to offer in-water interactions with whale sharks. Whale sharks, manta rays and humpback whales play a key role in Ningaloo's ecotourism industry, which is an important component of the regional economy.

Established in 1989, the industry grew quickly and the number of people swimming with whale sharks each year has increased to nearly 32,000 in 2018. The total direct expenditure by tourists in the whale shark industry in 2014 was estimated to be more than $11.5 million per year with an additional $12.5 million spent in the region by tourists for whom the opportunity to snorkel with whale sharks was the primary motivation for their trip.

The management of whale shark watching at Ningaloo is widely recognised as a world-leading example of good practice ecologically sustainable whale shark ecotourism. Only 15 licences are issued for whale shark watching vessels along Ningaloo and there are strict conditions imposed. These conditions regulate how many vessels are permitted near each whale shark (one), how many people can be in the water (maximum of 10), how close they can get to the whale shark (no closer than three metres, and no diving underneath the animal), how people can interact with them (no flash photography and no blocking their path) and regulates appropriate boat positioning, speed and track of vessels relative to the whale shark. A user fee for each customer ($18 per ticket for adults) is used to facilitate management of the industry and support sustainable ecotourism.

Anatomy of a giant

The whale shark (*Rhincodon typus*) is the only member of the family *Rhincodontidae*. As the largest fish in the world, they can grow to more than 16 metres. Whale sharks are distributed throughout tropical and warm temperate seas and feed exclusively on zooplankton including krill, copepods and fish larvae. Their large size, slow growth rates, long life and late maturity make them particularly susceptible to anthropogenic impacts. Globally, whale shark populations have declined and, in 2016, the IUCN Red List changed the species' status from 'Threatened' to 'Endangered' . The decline has been largely attributed to direct harvest of whale sharks in targeted fisheries. However, ship strike is also an ongoing threat. Nearly 10 per cent of the whale sharks that visit Ningaloo Reef carry scars believed to have been caused by boat strike. It is not known how many die as a result of their injuries.

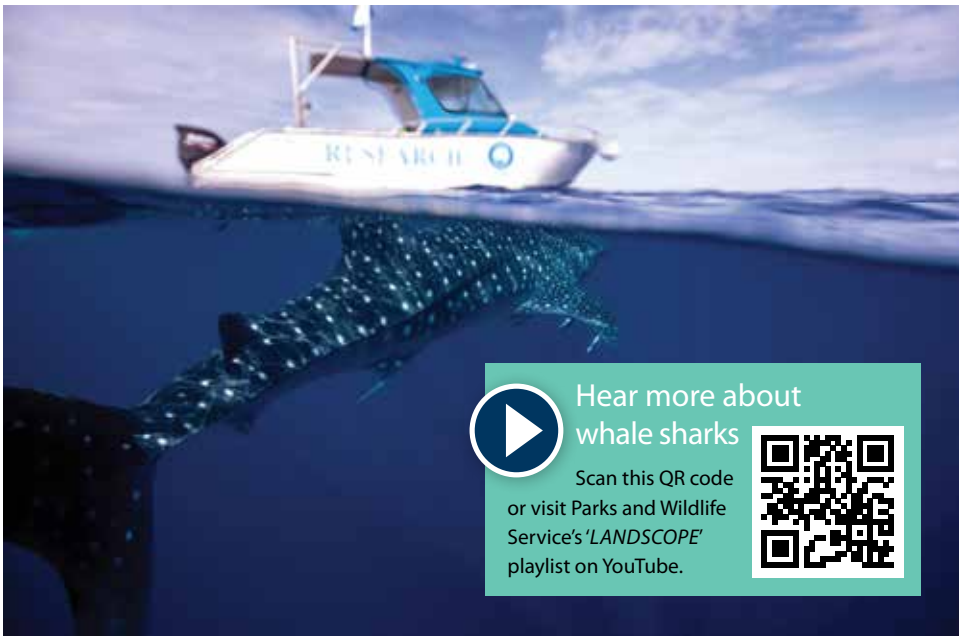
WHO'S WHO IN THE ZOO

In any given year, several hundred whale sharks will visit Ningaloo; the exact number remains a mystery with more sharks seen in some years than others. Male sharks and rays have external reproductive organs (claspers), which means they can be visually sexed. This enables researchers to determine how many of the visiting whale sharks are male, and how many are sexually mature.

Sexually mature males have long, calcified claspers that extend well past the ventral fin. Based on visual observations, the whale sharks that visit Ningaloo are

Previous page
Main A gentle giant at Ningaloo.
Photo – Matt Kleczkowski

Above Whale sharks can grow more than 16 metres, making them the largest fish in the world.
Photo – Geoff Taylor/Lochman Transparencies



Hear more about whale sharks

Scan this QR code or visit Parks and Wildlife Service's '*LANDSCOPE*' playlist on YouTube.

"The regularity and predictability of whale shark aggregation led to Ningaloo becoming one of the first places to offer in-water interactions with whale sharks ... The management of whale shark watching at Ningaloo is widely recognised as a world-leading example of good practice ecologically sustainable whale shark ecotourism."

primarily male (80 per cent), of which most are immature (74–85 per cent); only about 10 per cent of the males are sexually mature.

Mature females make up fewer than one per cent of the visiting population. These females are typically encountered in open sea environments and reported sightings of pregnant females usually originate from oceanic islands surrounded by deep water, such as the Galapagos and Saint Helena islands.

Size and sex segregation in whale sharks has been observed globally and suggest that both ontogenetic and sex-specific habitat or dietary shifts are present in the species. Where mating and birthing occurs remain two of the mysteries of whale shark biology. However, a large mature male whale shark was recently observed trying to mate with a smaller immature female shark (see 'A love story. Or not?' on page 33). While the immature female was exhibiting escape or avoidance behaviour, and so it was not a successful mating union, the event indicates that male whale sharks at Ningaloo will attempt to mate.

SPOTTING INDIVIDUALS

Each whale shark's spot and stripe pattern is unique, which means individuals can be identified from photographs. The *Wildbook for Whale Sharks* database (www.whaleshark.org) is a platform where photographs can be uploaded and individual sharks identified.

Researchers, including from CSIRO, have used this technique to identify more than 1000 individuals at Ningaloo over the past 20 years, with many individuals returning year after year.

Identifying individuals by their unique patterns has also enabled researchers to estimate population trends. However, results from different studies vary, with some suggesting a decline and others an increase. Regardless of the results, these studies only provide information about the whale sharks that return to the same area;

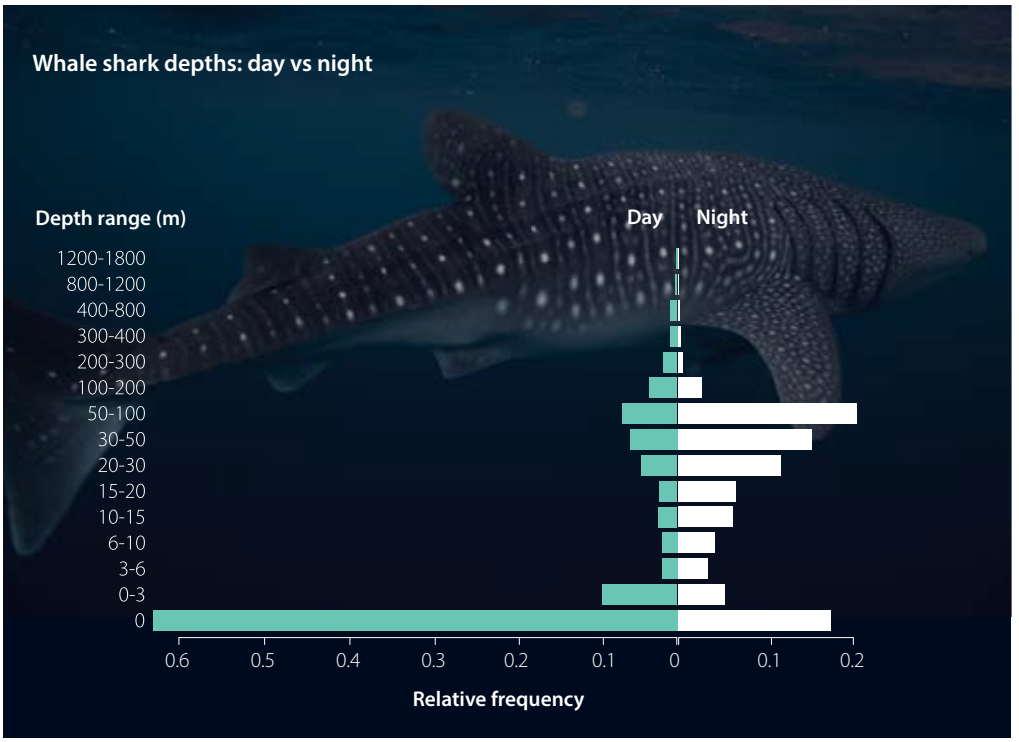
World recognition for Ningaloo

Ningaloo Reef is contained within the Ningaloo Coast World Heritage Area, which includes terrestrial and marine habitats and was inscribed in part because of the high diversity of iconic megafauna including sharks, whales, turtles and whale sharks. Predictable aggregations of whale sharks along the Ningaloo coast were one of the 'outstanding universal values' that the Ningaloo Coast World Heritage Area was listed to protect.

Top left Claspers on a 8.5-metre male whale shark at Ningaloo Reef indicate this animal is approaching sexual maturity.

Top A four-metre-long juvenile whale shark takes an interest in CSIRO's research vessel. *Photos – Richard Pillans/CSIRO*

Above A diverse range of iconic megafauna inhabit the waters of Ningaloo Marine Park. *Photo – Guy Skillen*



Above left Scarring on a juvenile whale shark hit by a small fast-moving vessel. The size of the scars can provide information about the type of vessel involved.

Above Summarised data from the recovered tag from 'Big Mumma' shows the proportion of time spent at different depths during the day and at night. Whale sharks spend more time at the surface during the day and dive deepest at dawn and dusk. At night they spend more time between 30 and 100 metres. *Photos – Richard Pillans/CSIRO*

they do not provide insight into whale sharks that do not visit Ningaloo during their life or only visit infrequently.

CSIRO researchers have developed a method to study whale shark genetics that may help estimate population sizes, which will help determine the trajectory of the population. Researchers recently used this method to estimate the number of white sharks (*Carcharodon carcharias*) in Australia and have been collecting tissue samples, sex and length measurements from hundreds of whale sharks over the past three years as part of the CSIRO-BHP Ningaloo Outlook Partnership in order to conduct similar research on whale sharks at Ningaloo and the Indian Ocean. The data collected about the population sizes will help determine whether the whale shark population is continuing to decline following the IUCN listing to Endangered.

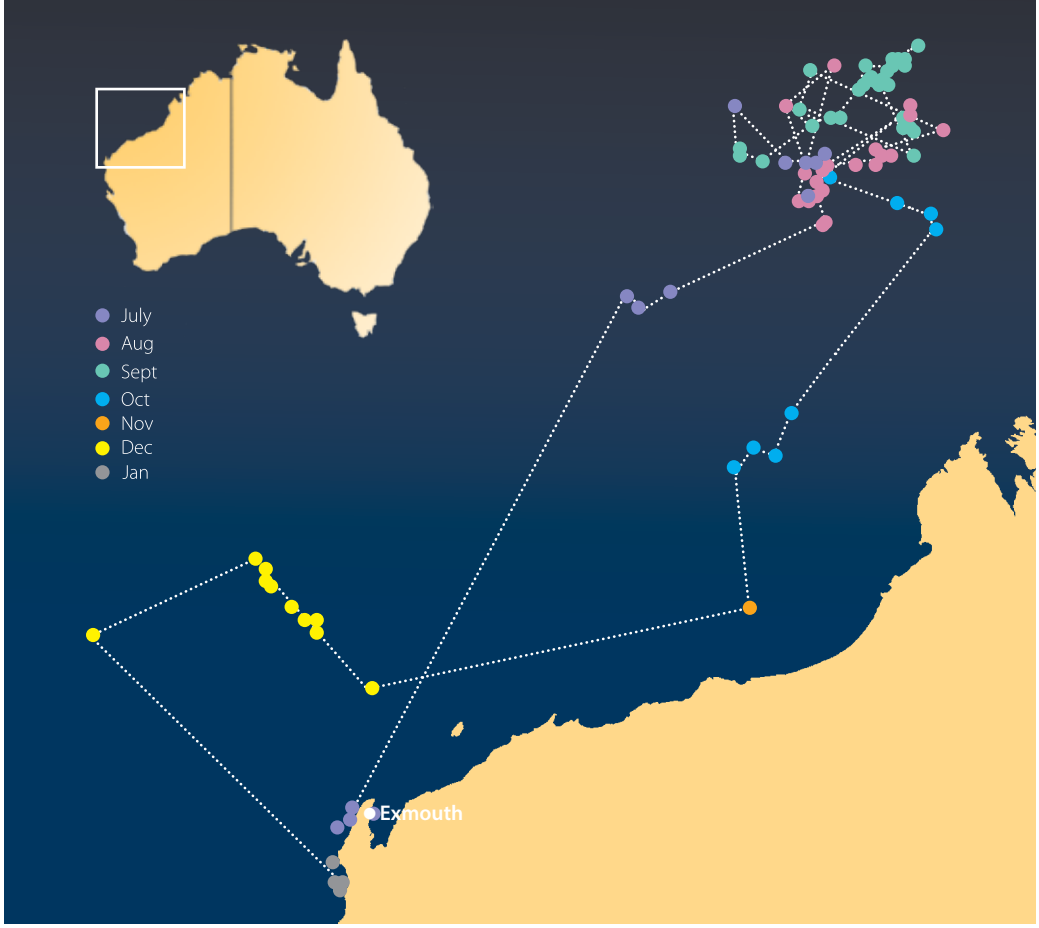
FAMILY MATTERS

The population of whale sharks at Ningaloo Reef is genetically identical to animals sampled throughout the Indian and Pacific oceans, which suggests there is mixing within the region. Despite genetic similarities, studies suggest that animals tagged at Ningaloo are confined to the eastern Indian Ocean, and the Arafura and Timor seas. Whale sharks tagged at Ningaloo as part of the Ningaloo Outlook Partnership show long-distance movements, including to Indonesia and Timor Leste. However, most satellite-tagged whale sharks have stayed within 300 to 400 kilometres of Ningaloo. Any long-distance movements away from Ningaloo have been primarily northwards, towards Christmas Island, as well as east as far as the Arafura Sea and Gulf of Carpentaria. Southwards movements are less common, but some individuals have been recorded as far south as Perth during the summer months.

For all published records of satellite-tagged animals at Ningaloo, the extent spans 26.5 degrees of latitude (5.5° to 32°S) and 55 degrees of longitude (85° to 145°E). Tagging has demonstrated that individuals vary their movement patterns once they depart Ningaloo Reef. This suggests that individuals have developed their own strategy of finding sufficient food resources that involves swimming thousands of kilometres in different directions. Data from satellite tags show that some animals swim continuously at speeds of between two to four kilometres per hour in one direction for up to four weeks before reaching an area where they spend a few weeks to months before moving on. These long-distance treks in one direction suggest that whale sharks are guided by past experiences or an inherited ability to find sporadic and ephemeral patches of abundant zooplankton resources. Very little is known about why this occurs but it seems that the movements are independent of surface currents and only weakly correlated with sea-surface chlorophyll-a concentrations.

TAG: YOU'RE IT

Satellite tags are very useful for obtaining broadscale data on the



Above 'Big Mumma' was tracked off Ningaloo.
Data – CSIRO

Right DBCA's Dani Rob and Joe Morgan with 'Big Mumma's' satellite tag.
Photo – Dani Rob/DBCA

Far right Mating behaviour between a male and female shark was observed at Ningaloo in June 2019 for the first time.
Photo – Tiffany Klein/Ningaloo Aviation

movement and diving behaviour of marine animals. However, an animal's location can only be tracked when they are at the water's surface for long enough that orbiting satellites overhead can detect them, which is usually limited to a few times each day.

Other data, such as depth, temperature and light level, are recorded every 10 seconds and stored within the tags. However, only a tiny fraction of this information is transmitted back to the researcher via the satellite network and only in a highly summarised form. Therefore, recovering a tag and the data it stores is like hitting the jackpot for researchers.

CSIRO researchers from the Ningaloo Outlook team have recovered five satellite tags that were attached to whale sharks for up to 311 days. The data within these recovered tags are providing valuable new insight into both the horizontal and vertical (dive behaviour) movements throughout their journey along Ningaloo Reef and the whale sharks move as far away as Indonesia and Timor Leste.

Two of the tags that were recovered were found in the Ningaloo Marine Park by DBCA rangers. The first tag to be recovered had been attached to a seven- to eight-metre female whale shark known as 'Big Mumma' for seven months before it washed ashore north of Coral Bay. Much

A love story. Or not?

Two of the many mysteries of whale sharks are where mating and pupping occurs. In June 2019, mating behaviour between a male and female shark was observed at Ningaloo for the first time. This encounter was captured on film by Ningaloo Aviation's Tiffany Klein. Photographs from the air as well as images taken by CSIRO enabled the two sharks to be identified and their lengths accurately measured. The male was a 9.5-metre mature shark with fully calcified claspers, however the female shark was only 6.5 metres long – about two metres shorter than whale sharks typically are at maturity.

Therefore, the female was too small to be reproductively active and, although growth rates in whale sharks are uncertain, it is likely that it would be at least another 10 years before the female is large enough to have offspring. These observations reflect attempted mating and it was not surprising that the female did not reciprocate the male's advances. It is unusual for sharks to attempt to mate with females that are not sexually mature. In many species, sexually mature males and females aggregate at specific times of the year with little evidence of mating occurring outside these times.

Right CSIRO scientist Richard Pillans collecting a small tissue from a whale shark at Ningaloo Reef as part of the BHP-CSIRO Ningaloo Outlook Partnership.
Photo – Richard Pillans/CSIRO

Below Whale sharks have unique patterns, which enable researchers to identify and record individuals.
Photo – Guy Skillen

Below right Whale sharks are filter feeders.
Photo – Gary Bell/Oceanwide Images

to the excitement of the CSIRO researchers, the tag was found by DBCA staff who were tasked with the job of scouring the remote beach, which was covered in seaweed from a recent cyclone.

Data from the recovered tags showed that whale sharks moved between Ningaloo and offshore areas such as Ashmore Reef and Indonesia, diving to depths in excess of 1700 metres, where the water is a very chilly 3.5 degrees Celsius. The majority of these deep dives are fast, with the animal swimming down at a rate of 0.4 metres per second and then back up the surface at similar speeds. The reason for these deep, rapid dives is unknown but may be used to navigate the open ocean. Most deep dives occur at dawn and dusk. Whale sharks dive much more often at night so their average depth at night is greater than during the day, when they are more likely to be at the surface and dive less frequently (see 'Whale Shark depths: day vs night' on page 32). Recovered tags have also revealed that whale sharks behave very differently when they are moving between areas (fast horizontal movement), compared with when they spend days to months in a confined area (slow horizontal movement). During sustained, long-distance swimming, the animals are mainly close to the surface with fewer slow dives. However, when they are within a confined area they dive more often and faster.

Data on the horizontal and vertical (dive) patterns of whale sharks in conjunction with data on shipping activity in north-west Australia are being used by CSIRO researchers to investigate the risk of ship strike to whale sharks (where and when whale sharks are more susceptible to being hit by vessels). Detailed data on dive behaviour are also being used to better understand why whale sharks travel to different places at different times of the year with the dive data used to see which parts of the water column are being used. Temperature logged within the tag also provides valuable oceanographic data to aid in the analysis and interpretation of the whale shark's complex behavioural patterns.

Richard Pillans is a marine ecologist and is currently leading aspects of Theme 3 of CSIRO's Ningaloo Outlook, including tagging and tracking of sharks and turtles.

Richard would like to acknowledge the work of the field team: Mat Vanderklift, Anthea Donovan, Mick Haywood, Russ Bradford, Kinam Salee, Emma Westlake, Ningaloo Aviation and Sue Pillans, as well as those who worked from the CSIRO Hobart office, including geneticists and modellers.