



Consultation on Species Listing Eligibility and Conservation Actions

Sphyrna lewini (Scalloped Hammerhead)

You are invited to provide your views and supporting reasons related to:

- 1) the eligibility of *Sphyrna lewini* (Scalloped Hammerhead) for inclusion on the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) threatened species list in the Endangered category.

Note: for most species, the demonstration of eligibility leads to the species being listed under that category and the application of the protections of the EPBC Act. However, an alternative may apply for commercial fish species, allowing harvest to continue if it is managed to ensure sustainability. A fish species may be listed under subsection 179(6) of the EPBC Act as Conservation Dependent if it is the focus of a plan of management that provides for management actions necessary to stop the decline of, and support the recovery of, the species so its chances of long term survival in nature are maximised.

Inclusion of the Scalloped Hammerhead in the Conservation Dependent category may be considered by the Threatened Species Scientific Committee (the Committee). However, it is first necessary to establish if the species is eligible for one of the other threatened categories (Vulnerable, Endangered or Critically Endangered), and then to determine whether the species' management is sufficient to allow listing as Conservation Dependent. This advice addresses only the eligibility for threatened listing while the accompanying consultation questions provide the opportunity for stakeholders to provide input into how management may be designed if a Conservation Dependent listing is considered.

- 2) the necessary conservation actions for the above species.

The purpose of this consultation document is to elicit additional information to better understand the status of the species and help inform on conservation actions and further planning. As such, the below draft assessment should be considered to be **tentative** as it may change following responses to this consultation process.

Evidence provided by Traditional Owners, experts, stakeholders and the general public are welcome. Responses can be provided by any interested person.

Anyone may nominate a native species, ecological community or threatening process for listing under the EPBC Act or for a transfer of an item already on the list to a new listing category. The Committee undertakes the assessment of species to determine eligibility for inclusion in the list of threatened species and provides its recommendation to the Australian Government Minister for the Environment.

Responses are to be provided in writing by email to:

species.consultation@environment.gov.au . Please include the species' scientific name in the Subject field.

or by mail to:

The Director
Marine and Freshwater Species Conservation Section
Protected Species and Communities Branch
Biodiversity Conservation Division
Australian Government Department Agriculture, Water and the Environment
(Attention: species.consultation@environment.gov.au)
GPO Box 858
CANBERRA ACT 2601

Responses are required to be submitted by 10 December 2021.

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General background information about listing threatened species

The Australian Government helps protect species at risk of extinction by listing them as threatened under Part 13 of the EPBC Act. Once listed under the EPBC Act, the species becomes a Matter of National Environmental Significance (MNES) and must be protected from significant impacts through the assessment and approval provisions of the EPBC Act. More information about threatened species is available on the department's website at: <http://www.environment.gov.au/biodiversity/threatened/index.html>.

Public nominations to list threatened species under the EPBC Act are received annually by the department. In order to determine if a species is eligible for listing as threatened under the EPBC Act, the Committee undertakes a rigorous scientific assessment of its status to determine if the species is eligible for listing against a set of criteria. These criteria are available on the Department's website at: <http://www.environment.gov.au/system/files/pages/d72dfd1a-f0d8-4699-8d43-5d95bbb02428/files/tssc-guidelines-assessing-species-2018.pdf>.

As part of the assessment process, the Committee consults with the public and stakeholders to obtain specific details about the species, as well as advice on what conservation actions might be appropriate. Information provided through the consultation process is considered by the Committee in its assessment. The Committee provides its advice on the assessment (together with comments received) to the Minister regarding the eligibility of the species for listing under a particular category and what conservation actions might be appropriate. The Minister decides to add, or not to add, the species to the list of threatened species under the EPBC Act. More detailed information about the listing process is at: <http://www.environment.gov.au/biodiversity/threatened/nominations.html>.

To promote the recovery of listed threatened species and ecological communities, Conservation Advices and where required, Recovery Plans are made or adopted in accordance with Part 13 of the EPBC Act. Conservation Advices provide guidance at the time of listing on known threats and priority recovery actions that can be undertaken at a local and regional level. Recovery Plans describe key threats and identify specific recovery

actions that can be undertaken to enable recovery activities to occur within a planned and logical national framework. Information about recovery plans is available on the department's website at: <http://www.environment.gov.au/biodiversity/threatened/recovery.html>.

Privacy notice

Personal information means information or an opinion about an identified individual, or an individual who is reasonably identifiable.

The department collects your personal information (as defined by the *Privacy Act 1988*) in relation to information you provide as part of this consultation for the purposes of the nomination, assessment and listing process set out in Part 13 of the EPBC Act.

Personal information that you provide within, or in addition to, your comments in the threatened species assessment process may be used by the department for the purposes of its functions relating to threatened species assessments, including contacting you if we have any questions about your comments in the future.

The department may disclose your personal information to the Committee, the Australian Government Minister for the Environment, State and Territory Governments, and other Australian government agencies, persons or organisations where necessary for the above purposes, provided the disclosure is consistent with relevant laws, in particular the *Privacy Act 1988* (Cth) (Privacy Act).

Further, the Commonwealth, State and Territory governments have agreed to share threatened species assessment documentation (including comments) to ensure that all States and Territories have access to the same documentation when making a decision on the status of a potentially threatened species. This is also known as the '[Common Assessment Method](#)'. As a result, any personal information that you have provided in connection with your comments may be shared between Commonwealth, State or Territory government entities to assist with their assessment processes.

Your personal information will be used and stored in accordance with the Australian Privacy Principles.

See the [department's Privacy Policy](#) to learn more about accessing or correcting personal information or making a complaint. Alternatively, email the department at privacy@awe.gov.au.

Information about this consultation process

Responses to this consultation can be provided electronically or in hard copy to the contact addresses provided on Page 2. All responses received will be provided in full to the Committee and then to the Australian Government Minister for the Environment.

In providing comments, please provide references to published data where possible. Should the Committee use the information you provide in formulating its advice, the information will be attributed to you and referenced as a 'personal communication' unless you provide references or otherwise attribute this information (please specify if your organisation requires that this information is attributed to your organisation instead of yourself). The final advice by the Committee will be published on the department's website following the listing decision by the Minister.

Information provided through consultation may be subject to freedom of information legislation and court processes. It is also important to note that under the EPBC Act, the deliberations and recommendations of the Committee are confidential until the Minister has made a final decision on the nomination, unless otherwise determined by the Minister.

Consultation questions

Please note, this list of questions is provided as a guide only. Respondents are not required to address every question.

General

1. Do you agree with the current taxonomic position of the Australian Faunal Directory for this taxon (as identified in the draft conservation advice)?
2. Is the information used to assess the nationally threatened status of Scalloped Hammerhead robust? Have all the underlying assumptions been made explicit? Please provide justification for your response.
3. Can you provide additional data or information relevant to this assessment?
4. A fish species may be listed under subsection 179(6) of the EPBC Act as Conservation Dependent if it is the 'focus of a plan of management that provides for management actions necessary to stop the decline of, and support the recovery of, the species so its chances of long term survival in nature are maximised'.
If a suitable plan of management was in force under law, what do you consider to be the relative advantages or disadvantages of listing the Scalloped Hammerhead in the Endangered category compared to the Conservation Dependent category?
5. Can you provide input into how a plan of management may be designed if a Conservation Dependent listing is considered?
6. Have you been involved in previous state, territory or national assessments of Scalloped Hammerhead? If so, in what capacity?
7. Do you have comments on any other matters relevant to the assessment of Scalloped Hammerhead?

Do you have additional information on the ecology or biology of scalloped hammerhead? (if no, skip to next section)

8. Can you provide any additional information about stock structure for the Scalloped Hammerhead in Australian waters or more broadly?
9. Can you provide any additional or alternative references, information or estimates on longevity, average life span and generation length?
10. Do you have any additional information on the ecology or biology of Scalloped Hammerhead not in the current advice?

Are you aware of the status of the total national population of scalloped hammerhead? (if no, skip to next section)

11. Can you provide estimates of the current population size of mature adults in Australian waters? Importantly, for the purposes of the assessment against the listing criteria, is it likely that the population is greater or less than 10 000 individuals? Please provide any supporting justification or other information.

Are you aware of trends in the overall population of scalloped hammerhead? (if no, skip to next section)

12. Does the magnitude of decline used in the assessment seem reasonable? Do you consider that the way this estimate has been derived is appropriate? If not, please provide justification of your response.

13. Are you able to provide an estimate of the total population size during the early 1950s (*at or soon after the start of the most recent three generation period*)? Please provide justification for your response.

If, because of uncertainty, you are unable to provide a single number, you may wish to provide an estimated range. If so, please choose one of the ranges suggested in the table below of possible species/subspecies numbers, and also choose the level of confidence you have in this estimate.

Number of mature individuals is estimated to be in the range of:

☐ 250–2500 ☐ 2500–10 000 ☐ >10 000

Level of your confidence in this estimate:

- ☐ 0–30% - low level of certainty/ a bit of a guess/ not much information to go on
- ☐ 31–50% - more than a guess, some level of supporting evidence
- ☐ 51–95% - reasonably certain, information suggests this range
- ☐ 95–100% - high level of certainty, information indicates quantity within this range
- ☐ 99–100% - very high level of certainty, data are accurate within this range

14. Are you able to comment on the extent of decline in the species/subspecies' total population size over the last approximately 72 years (i.e. three generations)? Please provide justification for your response.

If, because of uncertainty, you are unable to provide an estimate of decline, you may wish to provide an estimated range. If so, please choose one of the ranges suggested in the table below of ranges of decline, and also choose the level of confidence you have in this estimated range.

Decline estimated to be in the range of:

☐ 1–30% ☐ 31–50% ☐ 51–80% ☐ 81–100% ☐ 90–100%

Level of your confidence in this estimated decline:

- ☐ 0–30% - low level of certainty/ a bit of a guess/ not much information to go on
- ☐ 31–50% - more than a guess, some level of supporting evidence
- ☐ 51–95% - reasonably certain, suggests this range of decline
- ☐ 95–100% - high level of certainty, information indicates a decline within this range
- ☐ 99–100% - very high level of certainty, data are accurate within this range

15. Please provide (if known) any additional evidence which shows the population is stable, increasing or declining.

Are you aware of information on the total range of scalloped hammerhead? (if no, skip to next section)

16. Is the distribution described in the assessment accurate? If not, please provide justification for your response and provide alternate information.
17. Do you agree with the estimates of the current extent of occurrence (EOO) and/or area of occupancy (AOO) in the advice? If not, can you provide alternative estimates, supported by information?

Are you aware of trends in the total range of the scalloped hammerhead? (if no, skip to next section)

18. Do you consider that the way the historic distribution has been estimated is appropriate? Please provide justification for your response.
19. Can you provide estimates (or if you disagree with the estimates provided, alternative estimates) of the former extent of occurrence and/or area of occupancy?

If, because of uncertainty, you are unable to provide an estimate of past extent of occurrence, you may wish to provide an estimated range. If so, please choose one of the ranges suggested in the table below of ranges of past extent of occurrence, and also choose the level of confidence you have in this estimated range.

Past extent of occurrence is estimated to be in the range of:

☐ <100 km² ☐ 100 – 5 000 km² ☐ 5 001 – 20 000 km² ☐ >20 000 km²

Level of your confidence in this estimated extent of occurrence

- ☐ 0–30% - low level of certainty/ a bit of a guess/ not much data to go on
- ☐ 31–50% - more than a guess, some level of supporting evidence
- ☐ 51–95% - reasonably certain, data suggests this range of decline
- ☐ 95–100% - high level of certainty, data indicates a decline within this range
- ☐ 99–100% - very high level of certainty, data is accurate within this range

If, because of uncertainty, you are unable to provide an estimate of past area of occupancy, you may wish to provide an estimated range. If so, please choose one of the ranges suggested in the table below of ranges of past area of occupancy, and also choose the level of confidence you have in this estimated range:

Past area of occupancy is estimated to be in the range of:

☐ <10 km² ☐ 11 – 500 km² ☐ 501 – 2000 km² ☐ >2000 km²

Level of your confidence in this estimated extent of occurrence:

- ☐ 0–30% - low level of certainty/ a bit of a guess/ not much data to go on
- ☐ 31–50% - more than a guess, some level of supporting evidence
- ☐ 51–95% - reasonably certain, data suggests this range of decline

- ☐ 95–100% -high level of certainty, data indicates a decline within this range
- ☐ 99–100% - very high level of certainty, data is accurate within this range

Do you have information on threats to the survival of scalloped hammerhead? (if no, skip to next section)

- 20. Do you consider that all major threats have been identified and described adequately?
- 21. To what degree are the identified threats likely to impact on Scalloped Hammerhead in the future?
- 22. Are the threats impacting on different populations equally, or do the threats vary across different populations?
- 23. Can you provide additional or alternative information on past, current or potential threats that may adversely affect Scalloped Hammerhead at any stage of its life cycle?
- 24. Can you provide supporting data/justification or other information for your responses to these questions about threats?

Do you have information on current or future management for the recovery of scalloped hammerhead? (if no, skip to next section)

- 25. What planning, management and recovery actions are currently in place supporting protection and recovery of Scalloped Hammerhead? To what extent have they been effective?
- 26. Can you recommend any additional or alternative specific threat abatement or conservation actions that would aid the protection and recovery of Scalloped Hammerhead?

Do you have information on cultural and community significance relating to scalloped hammerhead? (if no, skip to next section)

The Department of Agriculture, Water and the Environment recognises that Traditional Owners are the custodians of Indigenous Cultural and Intellectual Property (ICIP). We seek to preserve and protect the rights of Traditional Owners to ICIP by only collecting, storing or sharing ICIP with the free, prior and informed consent of Traditional Owners. If you intend to provide ICIP, please raise this with us so that we can ensure that the ICIP is appropriately managed.

- 27. Are you aware of any Aboriginal or Torres Strait Islander names for the species or places mentioned in the draft Conservation Advice document? If you would like to provide this information, please also provide the language origin/s so that information can be included.
- 28. Would you like to share any information that may help better understand population trends/fluctuations or important areas of habitat for hammerhead sharks?
- 29. Would you like to provide information about necessary conservation actions for the Scalloped Hammerhead?
- 30. Which individuals or organisations are, or potentially could be, involved in management and conservation of the Scalloped Hammerhead?
- 31. Would you like to provide information about the cultural significance of hammerhead sharks, or the Scalloped Hammerhead specifically?

32. Are there any hammerhead shark populations or habitats that are particularly important to your community?
33. Do you have any concerns about impacts that listing the Scalloped Hammerhead in a threatened category might have on the cultural values of the species, including traditional harvest?

Under the Native Title Act 1993, native title holders are not prohibited or restricted from exercising native title rights. Listing of the Scalloped Hammerhead as a threatened species under the EPBC Act would not change the rights of native title holders to fish the species for personal, domestic and non-commercial communal needs.

34. Do you have any other comments you would like to provide to inform the threatened species listing assessment?
35. Are you aware of any other individuals/groups who might be able to provide information?



Conservation Advice for *Sphyrna lewini* (Scalloped Hammerhead)

This document combines the draft conservation advice and listing assessment for the species. It provides a foundation for conservation action and further planning.



Sphyrna lewini. Kevin Lino, 2015. NOAA Photo Library: Coral Kingdom.

Conservation status

Sphyrna lewini (Scalloped Hammerhead) is listed in the Conservation Dependent category of the threatened species list under the *Environment Protection and Biodiversity Conservation Act 1999* (Cwth) (EPBC Act) effective from 15 March 2018.

The Scalloped Hammerhead is currently being assessed by the Threatened Species Scientific Committee (the Committee). The Committee's preliminary assessment is at Attachment A. The Committee's assessment of the species' eligibility against each of the listing criteria is:

- Criterion 1: A2bd: Endangered

The main factor that makes the species eligible for listing in the Endangered category is an inferred population reduction of greater than 50% over the last 3 generations (72 years). The Committee's inference is based on fishery-dependent catch information; a suite of candidate stock assessment models; standardised catch rates from the Queensland Shark Control Program; and fishery-independent shark surveys in the Java Sea. The cause of this reduction, i.e., mortality in commercial fisheries, is ongoing.

Attachment A addresses the eligibility of the species for listing as a threatened species. For most species, the demonstration of eligibility leads to the species being listed under that category and

the application of the protections of the EPBC Act. However, an alternative may apply for commercial fish¹ species, allowing harvest to continue if it is managed to ensure sustainability.

A fish species may be listed under subsection 179(6) of the EPBC Act as Conservation Dependent if it is the 'focus of a plan of management that provides for management actions necessary to stop the decline of, and support the recovery of, the species so its chances of long term survival in nature are maximised'.

Inclusion of the Scalloped Hammerhead in the Conservation Dependent category may be considered by the Committee. However, it is first necessary to establish if the species is eligible for one of the other threatened categories (Vulnerable, Endangered or Critically Endangered), and then to determine whether the species' management is sufficient to allow listing as Conservation Dependent. This advice addresses only the eligibility for threatened listing while the accompanying consultation questions provide the opportunity for stakeholders to provide input into how management may be designed if a Conservation Dependent listing is considered.

Species can also be listed as threatened under state and territory legislation. For information on the current listing status of this species under relevant state or territory legislation, see the [Species Profile and Threat Database](#).

Species information

Taxonomy

Conventionally accepted as *Sphyrna lewini* (Griffith & Smith, 1834).

Description

The eyes of hammerhead sharks (Family Sphyrnidae) are located at the tips of laterally expanded blades that resemble a hammer. They have fusiform bodies and ventrally placed mouths. The dorsal surface of the Scalloped Hammerhead is olive, bronze or grey. The ventral side is pale grey (Last & Stevens 2009).

The Scalloped Hammerhead is readily distinguished from all other Indo-Pacific hammerhead shark species based on the following key features: the head width being less than 40% of the total body length; the anterior margin of the head bulging forward in the middle; an indentation in the middle of the anterior margin of the head; and the first dorsal fin being only moderately high and semi-falcate (Last & Stevens 2009).

¹ Section 179 of the EPBC Act defines a fish as '...all species of bony fish, sharks, rays, crustaceans, molluscs and other marine organisms, but does not include marine mammals or marine reptiles'.

Distribution

The Scalloped Hammerhead is a coastal and semi-oceanic species with a circumglobal distribution in coastal warm-temperate and tropical seas (Compagno 1984). In Australia, the species is recorded around the northern coastline to approximately 34°S on both east and west coasts (Sydney, New South Wales (NSW) to Geographe Bay, Western Australia (WA); Last & Stevens 2009) (Figure 1). Bartes & Braccini (2021) reported occurrences of the species an additional 336 km east of Geographe Bay, WA. The species inhabits continental and insular shelves and adjacent deep water from the surface and intertidal areas to at least 275 m depth (Compagno 1984). The species has also been recorded at 1042 m depth (Moore & Gates 2015).

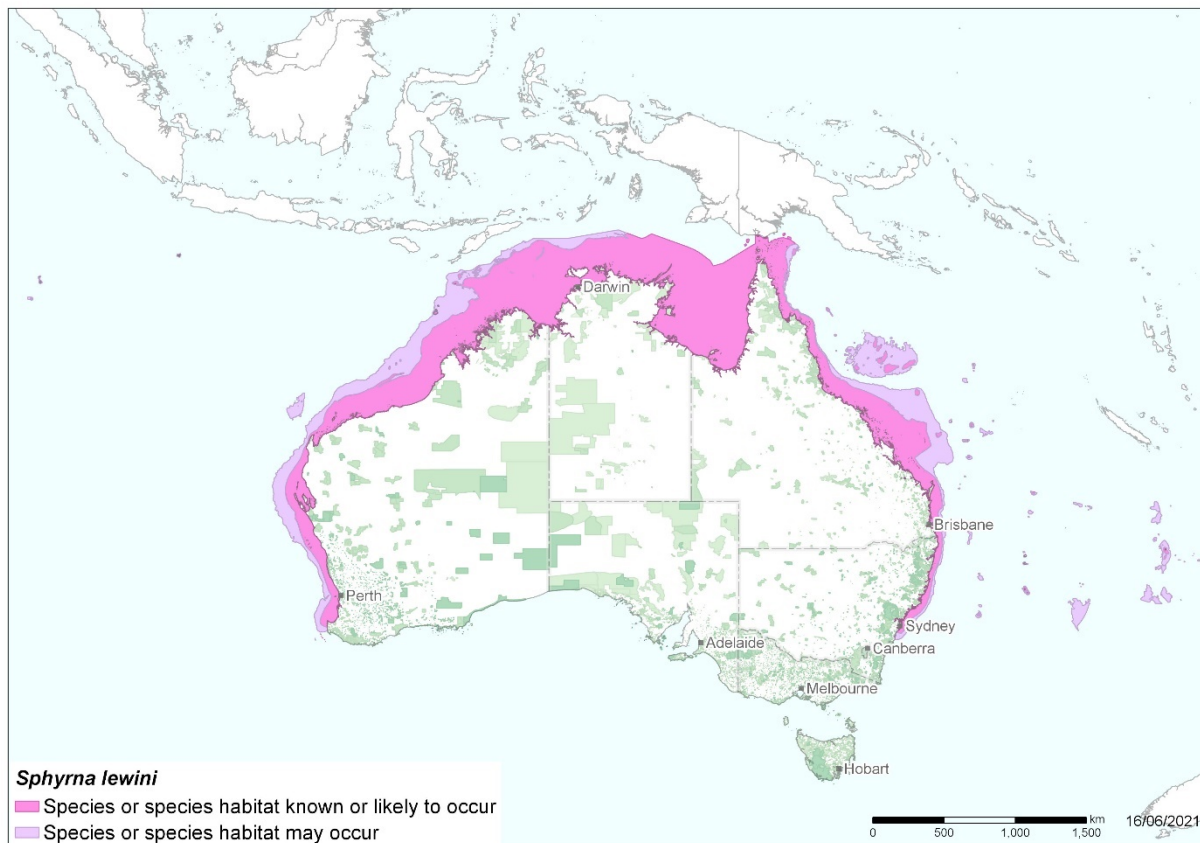


Figure 1 Modelled distribution of the Scalloped Hammerhead in Australian waters.

Source: Base map, Geoscience Australia; species distribution data, **Species of National Environmental Significance** database.

Caveat: The information presented in this map has been provided by a range of groups and agencies. While every effort has been made to ensure accuracy and completeness, no guarantee is given, nor responsibility taken by the Commonwealth for errors or omissions, and the Commonwealth does not accept responsibility in respect of any information or advice given in relation to, or as a consequence of, anything containing herein.

Species distribution mapping: The species distribution mapping categories are indicative only and aim to capture (a) the specific habitat type or geographic feature that represents to recent observed locations of the species (known to occur) or preferred habitat occurring in close proximity to these locations (likely to occur); and (b) the broad environmental envelope or geographic region that encompasses all areas that could provide habitat for the species (may occur). These presence categories are created using an extensive database of species observations records, national and regional-scale environmental data, environmental modelling techniques and documented scientific research.

Cultural and community significance

Sharks, including hammerhead sharks, are significant as totemic symbols and as food resources to some Aboriginal and Torres Strait Islander Peoples (McDavitt 2005). Hammerhead sharks are identified as a totem for many of the Torres Strait Island clans or families across the islands, and they are depicted in many of the lino-cut artworks that are unique to the Torres Strait (Gerhardt 2018). Information about the cultural significance of hammerhead sharks on mainland Australia is limited compared to the Torres Strait, although there are reports of small hammerheads being observed close to shore during the summer wet season and very few larger individuals seen inshore (Gerhardt 2018).

The purpose of this consultation document is to elicit additional information to better understand the species' status, including its cultural and community significance.

Relevant biology and ecology

Biology

The Scalloped Hammerhead's life history characteristics render the species vulnerable to exploitation in fisheries (White et al. 2008; Rigby et al. 2019). These characteristics include slow growth, late age-at-maturity and low fecundity compared to, for example, many teleost species. Reproduction is placental viviparous, with an annual or biennial reproductive cycle (reviewed by Rigby et al. 2019). It is hypothesised that mating generally occurs in deep water (Salinas-de-León et al. 2017). In Australia, the gestation period is 9–10 months and parturition occurs throughout the year, predominantly between October and January/February (Stevens & Lyle 1989; Harry et al. 2011a; Yates et al. 2015b). Reported litter sizes range between 12 and 41 pups (reviewed by Rigby et al. 2019), with a mean of 17 pups when pregnant females have been occasionally sampled in northern Australia (Stevens & Lyle 1989). Pups are born at 45–46 cm total length (TL) (Stevens & Lyle 1989; Harry et al. 2011a).

Males mature at 140–198 cm TL and females at 200–250 cm TL (Compagno 1984; Branstetter 1987; Stevens & Lyle 1989; Chen et al. 1990; White et al. 2008; Harry et al. 2011a; reviewed by Rigby et al. 2019). Age-at-maturity was calculated in Indonesian waters to be 8.9 and 13.2 years for males and females, respectively (Drew et al. 2015). Reported maximum sizes are 219–340 cm and 296–346 cm TL for males and females, respectively (reviewed by Simpfendorfer et al. 2019). Maximum age is estimated as 21 years for males (Harry et al. 2011a) and 35 years for females (Drew et al. 2015). Together, these characteristics mean that populations can be quickly depleted and once depleted can take a long time to recover.

Habitat use

The Scalloped Hammerhead is a coastal and semi-oceanic pelagic species (Compagno 1984). In northern Australia, juveniles inhabit shallow inshore environments whereas adults generally occur in deeper waters near the edge of the continental shelf (Stevens & Lyle 1989; Simpfendorfer & Milward 1993). Globally, populations demonstrate high levels of sexual segregation. For example, the Australian population is dominated by juveniles and small adult males, with few records of pregnant females (Stevens & Lyle 1989; Harry et al. 2011a; 2011b). In contrast, large adult and pregnant females are commonly reported in Indonesian and Papua New Guinean (PNG) waters (White et al. 2008; 2020). This could be the result of sampling bias or evidence of stock connectivity between Australia and Indonesia/PNG (Chin et al. 2017;

Thomson 2021). Considering that hammerhead sharks in other oceans move to shallow nursery areas to give birth (Duncan et al. 2006), the observed demographic structuring suggests that a proportion of adult females may migrate from Australian to Indonesia/PNG waters, and return to give birth to their young in nursery areas in coastal areas of northern Australia (Chin et al. 2017). This may also suggest that northern Australia may provide important nursery areas for the Indo-Pacific Scalloped Hammerhead stock.

Observations from the Queensland (Qld) coast indicate that at least a portion of males remain in inshore areas longer than females (Harry et al. 2011a; 2011b). It is hypothesised that two distinct male habitat-use strategies exist in Australian waters. Pelagic strategists are males that disperse from their natal grounds, migrating offshore like females and also ranging further into temperate waters. Coastal strategists, however, remain in inshore waters for their entire lives (Harry et al. 2011b).

The limited numbers of tagged Scalloped Hammerhead individuals in Australia have not been recorded undertaking long distance movements to and from other national jurisdictions. In other regions of the world, individuals appear to disperse readily across continuous habitat (continental shelves) and less-frequently across open oceans (Kohler & Turner 2001; Ketchum et al. 2014; Duncan et al. 2006). Tagging studies indicate movement of individuals between female-skewed aggregations of Scalloped Hammerheads at oceanic islands in the Eastern Tropical Pacific, although the sex ratio of sharks that undertook these movements was not reported (Bessudo et al. 2011; Nalesso et al. 2019). It is likely that females also migrate from these oceanic islands towards the Pacific coast of Central and South America at certain times of year to give birth (reviewed by Nalesso et al. 2019). Although neonates are caught in coastal waters of Central and South America throughout the year, catches seem to be higher in the months of April and May (Quintanilla et al. 2014; Nalesso et al. 2019), coinciding with the period of absence of large adults from oceanic islands (Bessudo et al. 2011; Nalesso et al. 2019).

Stock structure

At a global scale, Scalloped Hammerhead individuals occurring in the Indo-Pacific (which includes the Australian population) are genetically distinct from individuals occurring in the Northwest Atlantic, Caribbean Sea and Southwest Atlantic (Quattro et al. 2006; Simpfendorfer et al. 2019). Global phylogeography indicates high connectivity between nursery populations that are linked by continuous coastline, and that oceanic dispersal by females does occur but is rare (Duncan et al. 2006). At a global scale, females are reproductively philopatric (i.e., they return to the nursery area in which they were born to give birth) or adhere to coastal or shelf habitats, while males facilitate gene flow across oceanic expanses (Daly-Engel et al. 2012). If these traits are applicable to northern Australian populations, the shared continental shelf with New Guinea and the eastern margin of the Banda Sea (Indonesia) plausibly facilitates connectivity between Australia, Indonesia and PNG (Chin et al. 2017; Simpfendorfer et al. 2019).

Green et al. (in review) (a peer-reviewed publication of the genetics information in Heupel et al. 2020) proposed four major genetic stocks across the Pacific and Indian Oceans. These stocks were (1) West Indian (Seychelles), (2) Central Indo-Pacific (Papua New Guinea, Indonesia, Philippines, Taiwan, Australia, Fiji), (3) Central Pacific (Hawaii), and (4) East Pacific (Gulf of California). Green et al. (in review) also note some structure occurring within the central Indo-Pacific (i.e., for Western Australia and Fiji), but discussed that this was less clear, and slight compared to the aforementioned genetic stocks.

An important uncertainty concerning stock structure within the Central Indo-Pacific is the degree to which Scalloped Hammerhead individuals occurring in Indonesia and PNG are part of the same stock that occurs in Australian waters. Heupel et al. (2020) provided information to inform the stock structure and connectivity of the Scalloped Hammerhead across northern Australia and with adjacent countries using satellite tracking, genetic structure, and parasite fauna.

The genetic study used mitochondrial DNA (n=395 samples), microsatellites (n=354 samples), and single nucleotide polymorphisms (SNPs) (n = 310 samples). SNPs identified more population subdivision compared to the other methods and were identified as the preferred stock structure assessment method due to the larger number of markers (loci) and greater statistical strength compared to microsatellites (Green 2019; Heupel et al. 2020). Using SNP data, Discriminant Analysis of Principal Components and estimates of pairwise genetic differentiation (F_{ST}) identified Scalloped Hammerhead individuals from WA, Fiji and Philippines/Taiwan as genetically distinct from those from Northern Territory (NT), Qld, Indonesia and Papua New Guinea (PNG) (Figure 2) (Heupel et al. 2020). The central cluster of individuals in Figure 2 indicates similarity in the genetic information – and hence connectivity – across NT, Qld, NSW, Indonesia, and PNG. These similarities were verified by the F_{ST} values (Figure 3). Distance also appeared to play a significant role in genetic connectivity, with isolation-by-distance plots detecting a significant correlation ($r = 0.73$) between F_{ST} and geographic distance (Green 2019; Heupel et al. 2020). Isolation-by-distance may explain variability in the degree of similarity/dissimilarity of genetic information between samples from NSW and other locations in the central Indo-Pacific (Figure 3).

Localised movements were observed from all satellite tagged individuals (n = 8), with the furthest latitudinal distance moved being less than 250 km, and the longest distance between tagging and release locations of 169 km. Results also indicated connectivity between Qld, NT, PNG, and Indonesia. Parasite assemblages (n = 209 samples) from Australian waters were significantly different between the NT, Qld and NSW. Comparison between Australian and Indonesian (n = 27) parasite faunas was restricted only to internal parasites but showed some level of differentiation suggesting limited connectivity. Inference about stock structure using parasite data is confounded by differences in shark body sizes between sampling locations. Body size appeared to affect parasite assemblages with a considerable change in parasites found in animals larger than 2 m TL (Heupel et al., 2020).

Synthesis of these findings suggests that there are varying levels of stock structuring occurring between Australia, Indonesia, and PNG, but this finding is subject to uncertainty (Heupel et al., 2020). The uncertainty is driven largely by the failure to sample large (i.e., more than 3 m length) individuals that are most likely to move the greatest distances and create connectivity (Heupel et al. 2020). Tracking and parasite fauna data suggest limited movement for individuals up to c. 2.8 m. Genetic data indicate stock connectivity for Scalloped Hammerhead individuals occurring in Australian waters, with a stock divide likely occurring near the WA/NT border. Based on the information currently available, one stock likely occurs east of the WA/NT border and is connected to Indonesian and PNG waters. The other stock likely occurs west of the WA/NT border, and may be connected throughout WA waters and potentially further to the west into the eastern Indian Ocean (Green 2019; Heupel et al. 2020). The boundaries of this western stock are poorly defined, and Green et al. (in review) describe this as a potential ‘subtle population structure’ with a ‘small break’ in gene flow between the western Australian stock and

the north/eastern Australia, PNG, and Indonesian stock. For the purposes of this assessment, and in accordance with the Intergovernmental Memorandum of Understanding Agreement on a Common Assessment Method for the Listing of Threatened Species and Ecological Communities (the CAM MOU), this stock is therefore not considered geographically isolated or able to be defined or assessed in a way that differentiates it from the Central Indo-Pacific stock.

Other studies (that used some of the same samples as Heupel et al. 2020) have also concluded that populations in Australia, Indonesia and PNG cannot be genetically differentiated, suggesting they are the same stock (Ovenden et al. 2009; 2011). Based on the current genetic, tagging and parasite information, it is not possible to confirm or rule out the possibility that large cohorts of Scalloped Hammerheads are moving between regions consistently (Chin et al. 2017; Heupel et al. 2020). With the genetics methods used, it is also not possible to determine when movements have occurred or are occurring (Lowe & Allendorf 2010). For sharks, results based on SNPs are indicative of connectivity at a temporal scale anywhere between (1) within the last ~10 generations and (2) 10,000+ generations ago (Green et al. in press). In summary, the current genetics information indicates connectivity between Australia, Indonesia and PNG, but the timeframes and magnitude of this connectivity are unknown.

Biogeographic barriers in the Indo-Pacific region may be important for structuring the population. For example, the Torres Strait Land Bridge may form a barrier between stocks on the east coast of Queensland and the rest of northern Australia, as has been reported for other species of coastal sharks (e.g., Common Blacktip Shark (*Carcharhinus limbatus*)) and coastal/pelagic teleosts (e.g., Grey Mackerel (*Scomberomorus semifasciatus*)) (Flood et al. 2014). However, there are no data supporting a divide at the Torres Strait Land Bridge for the Scalloped Hammerhead. The Committee considers that the parasites and satellite tagging data in Heupel et al. (2020) cannot be used to test with high confidence hypothesis relating to stock structure (Table 1).

Various stock structure hypotheses were tested against these results (outlined in Table 1). The most supported hypothesis was continental shelf movements but with a stock divide around the WA/NT border.

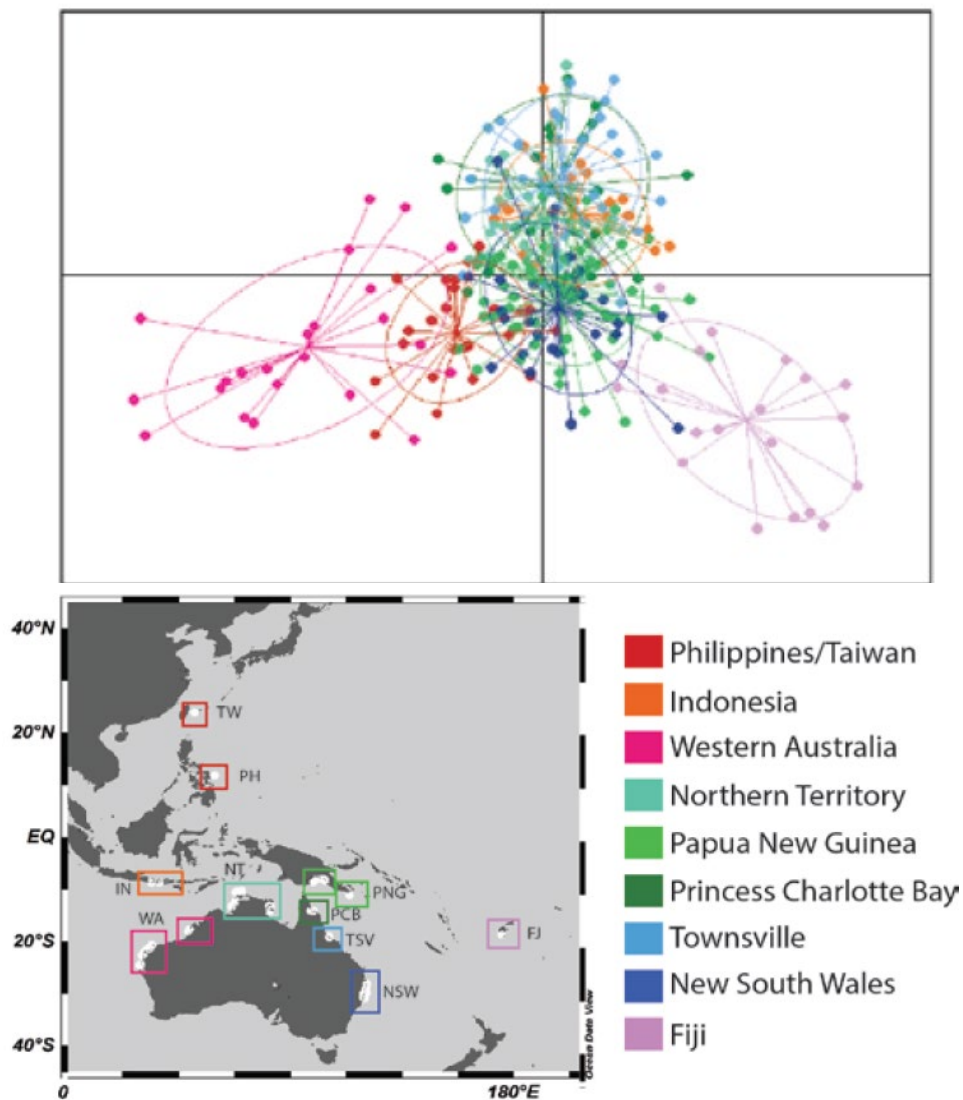


Figure 2 Scatterplot generated using Discriminant Analysis of Principal Components showing Single nucleotide polymorphisms (SNP) variation between Scalloped Hammerhead individuals (dots) and regions (colours) (top panel) with accompanying map of sampling locations in the central Indo-Pacific (bottom panel) (from Heupel et al. 2020).

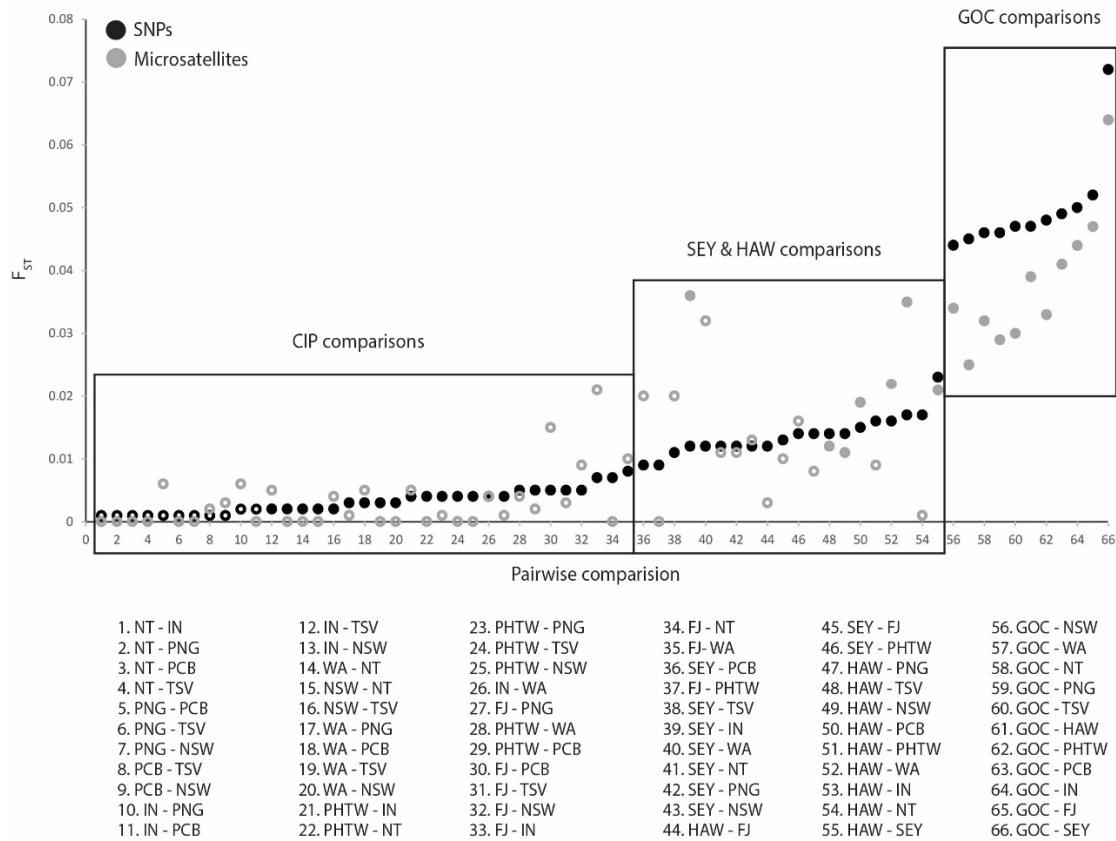


Figure 3 Estimates of pairwise genetic differentiation (F_{ST}) between all sampled locations for the Scalloped Hammerhead using Single nucleotide polymorphism (SNP) (black) and microsatellite (grey) loci (from Heupel et al. 2020).

NT = Northern Territory, PNG = Papua New Guinea, PCB = Princess Charlotte Bay, TSV = Townsville, NSW = New South Wales, IN = Indonesia, WA = Western Australia, PHTW = Philippines/Taiwan, FJ = Fiji, CIP = central Indo-Pacific, SEY = Seychelles, HAW = Hawaii and GOC = Gulf of California. Comparisons are arranged in ascending order of SNP F_{ST} values (x-axis). Filled circles indicate significant p-values where $p \leq 0.001$ and boxes represent pairwise comparisons between grouped locations.

Table 1 Support for various Scalloped Hammerhead stock structure hypotheses based on three methodological approaches (adapted from Chin et al. 2017 and Heupel et al. 2020). Scenarios indicated with asterisks* were considered in the stock assessments by Saunders et al. (2021).

Method	Stock structure hypothesis						Comments
	Panmictic across the Indo-Pacific region	Panmictic across northern Australia, Malay Archipelago and Taiwan	Continental shelf movements (CSM)	Continental shelf movements but with stock divide around the WA/NT border*	Continental shelf movements but with stock divides at (1) the Torres Strait land bridge and (2) around the WA/NT border*	Limited movement*	
	Adults move freely throughout the Indo-Pacific, including beyond continental shelves. Adult females are likely to return to natal nursery areas in northern Australia, PNG and Indonesia to give birth.	Panmictic movements, including beyond continental shelves, spanning waters from northern Australia to Taiwan.	The continental shelves of Australia, PNG and Indonesia provide well connected habitat enabling movements between these countries (but not with Fiji)	Similar to the CSM hypothesis, but there is limited connectivity between WA and all other regions (Figure 4).	Similar to the CSM hypothesis, but the Torres Strait land bridge also divides stocks to the east and west, with adults moving northwards into Indonesia (from NT only) and PNG (from Qld only) (Figure 5).	Adults remain in restricted geographic areas and there is no international connectivity (Figure 6).	
Satellite tracking	No	No	Partial/uncertain	Partial/uncertain	Partial/uncertain	Partial/uncertain	Sampling limitations complicate inference about stock structure using tagging information. No large adults were tagged. Locations of adult females in Australian waters remains unknown. Movements on the continental shelf were recorded, however no tagged individuals crossed jurisdictional boundaries or the Torres Strait land bridge.

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Genetics	Partial (i.e., not for some locations, e.g., WA and Fiji)	Partial (i.e., not for some locations, e.g., WA and Fiji)	Partial	Yes WA differs from NT, Qld, NSW, Indonesia, and PNG. Fiji samples were genetically distinct.	Partial Numerous estimates of pairwise genetic differentiation indicated connectivity between some sampling locations in (1) eastern Qld compared to NT, (2) eastern Qld compared to Indonesia, and (3) NT compared to PNG)	No	Current genetic analysis provides evidence of a connection on evolutionary time scales, although it does not discount connections at shorter time scales.
Parasites	No	No	Yes	Partial/ uncertain	Partial/ uncertain	Partial	Inference about stock structure is confounded by differences in shark body sizes between sampling locations. Body size appeared to affect parasite assemblages with a considerable change in parasites found in animals > 2 m TL.
Synthesis	Genetics information suggests stock structure in the region. No long-distance movements beyond the continental shelf were recorded.	Genetics information suggests stock structure in the region. No long-distance movements beyond the continental shelf were recorded.	Continental shelf movements are well supported by genetic and demographic information. However, the WA population is genetically distinct from NT, QLD, NSW, Indonesia, and PNG.	The hypothesis most supported by the available evidence. Continental shelf movements are well supported by genetic and demographic information. Division of the western stock is well supported by genetic information.	Continental shelf movements are well supported by genetic and demographic information. However, genetic information indicates connectivity across the Torres Strait land bridge. Division of the western stock is well supported by genetic information.	Limited support given (1) sampling limitations in tracking and parasite studies, and (2) results of multiple studies indicating genetic connectivity at a broader spatial scale (Ovenden et al. 2009, 2011; Heupel et al. 2020).	

Habitat critical to the survival

It was not possible to define habitat critical to the survival of the Scalloped Hammerhead as there is insufficient data. No Critical Habitat as defined under section 207A of the EPBC Act has been identified or included in the Register of Critical Habitat.

In general, inshore nursery areas are critical to the species' survival, and contributions from a diverse range of inshore areas may enhance population stability and resilience (Yates et al. 2012). Catch rates of immature Scalloped Hammerheads in fisheries-independent surveys along northeast Qld increased with increasing turbidity, indicating that turbid waters may provide important nursery habitat (Yates et al. 2015a). However, longer time series would be required to delineate areas that meet the criteria for classification as nurseries (Heupel et al. 2007).

Habitats that support reoccurring aggregations of juveniles and subadults, like those observed during summer in the Shoalwater Islands Marine Park, WA (López et al. in review) are also likely to provide population-level benefits. Habitats utilised by subadult and adult females in Australian waters remain poorly understood. It will be critical to link early life stage conservation with protection of older individuals if effective management is to be achieved (Kinney et al. 2009).

Threats

Globally, the current main threat to the Scalloped Hammerhead is widespread, high-effort, targeted commercial fishing for the species throughout much of its range. The species is taken by trawl, purse seine, gillnet, fixed-bottom longline, pelagic longline and inshore artisanal fisheries (Simpfendorfer et al. 2019).

In Australia, there is continued take of Scalloped Hammerhead as bycatch and byproduct primarily in commercial fisheries operating off Qld and the NT (Kyne et al. 2021). Most of the Australian catch is of juveniles of both sexes and adult males (Harry et al. 2011a; 2011b). There is also a small but notable catch of the species in the Qld Shark Control Program and it is likely taken in Illegal, Unreported and Unregulated (IUU) fishing activity in waters off northern Australia. The species is also taken by Indonesian vessels permitted to operate with traditional fishing methods within an area of the Timor Sea known as the MOU Box. The Australian population of the species is likely linked as part of the same stocks that occur in Indonesia, PNG, and potentially more broadly in the Indian Ocean; and in some parts of these regions there is intense fishing pressure. Cumulatively, these threats have resulted in population size reduction for the Australian population of Scalloped Hammerhead (Attachment A) (Simpfendorfer et al. 2019; Saunders et al. 2021).

Based on current evidence, Australian occurrences of the Scalloped Hammerhead may make critical contributions to the viability of the central Indo-Pacific population(s) through pupping areas, nurseries, juvenile foraging grounds and (if managed appropriately) refuges from overharvest. These contributions could be critical to the flux of new reproductive adults into the central Indo-Pacific population. Conversely, the viability of the central Indo-Pacific population(s) also depends critically on management of fisheries in foreign and international waters.

In 2014, the total annual commercial catch of Scalloped Hammerhead in Australian waters was estimated to be c. 200–250 tonnes (Simpfendorfer 2014). The Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) Scientific Authority of Australia

made a Non-Detriment Finding reporting that this magnitude of catch was sustainable and unlikely to be detrimental to the species (DOE 2014), however this finding was based on scientific advice that this level of catch was appropriate ‘while work to quantify the status of stocks and sustainable take levels is undertaken’ (Simpfendorfer 2014). It is important to note that (1) the CITES Non-Detriment Finding and (2) stock assessments undertaken since for Indo-Pacific populations (Saunders et al. 2021) are considered data limited, mainly due to the poor taxonomic resolution of reported catch information and absence of reliable abundance indices (Thompson 2021).

The unique head morphology of hammerhead sharks makes all life-history stages vulnerable to capture in large- and small-mesh nets (Harry et al. 2011b; Leigh 2015). Furthermore, individuals quickly die if not freed from any fishing gear (Butcher et al. 2015; Dapp et al. 2016). Hammerhead sharks are also particularly susceptible to mortality after being released, with estimates ranging within 83–90% (DOE 2014; Gallagher et al. 2014; Eddy et al. 2016). Impacts of fisheries interactions are further exacerbated by pups frequently being aborted during the process of capture (Stevens 1984).

Some habitat-use characteristics of the Scalloped Hammerhead influence the species’ susceptibility to fishing pressure. For instance, spatial and seasonal segregation by size and sex can increase vulnerability of certain demographics to fishing, and thereby have population-level implications (Kinney et al. 2009). If Australian populations are connected more broadly across the Indo-Pacific, heavy fishing pressure on the species in areas outside the Australian EEZ (such as within Indonesia and PNG waters) poses a threat to Australian populations. This threat would be exacerbated by the higher catches of pregnant females in Indonesia compared to Australia (White et al. 2008; White et al. 2020). Conversely, within Australian waters, juveniles are particularly at risk due to their presence in large numbers in nearshore nursery habitats (Simpfendorfer & Milward 1993). The species is known to form aggregations in Australian waters, comprised of juveniles and subadults (López et al. in review), which may also increase the species’ vulnerability to fisheries (Simpfendorfer et al. 2019).

The major historical and ongoing threats to the Scalloped Hammerhead are outlined in Table 2. The following threats are poorly understood or of minor consequence to the species and as such they have not been considered in Table 2. There is ongoing uncertainty surrounding the cumulative impacts from multiple threats associated with this species.

WA fisheries: Reconstructed annual catches of Scalloped Hammerhead from WA peaked at c. 56 tonnes in 2004 (Saunders et al. 2021). The Northern Shark Fishery (NSF) (WA North Coast Shark Fishery, WANCSF; and Joint Authority Northern Shark Fishery, JANSF) historically caught Scalloped Hammerheads, although no catch has been reported since the NSF ceased operations in 2008-09 (Molony et al. 2013). Small amounts of the species are captured along the southwestern and southern coasts of WA in the Temperate Demersal Gillnet and Demersal Longline fisheries. During 2015–2021, an average of c. 44 tonnes per year of hammerhead shark was reported. Observer data indicated that 3% of those catches were Scalloped Hammerhead and Great Hammerhead (combined) (M Braccini 2021. pers comm 28 June). An Ecological Risk Assessment was undertaken in March 2021 and categorised hammerhead sharks (pooled) as medium risk (i.e., acceptable with current risk control measures in place) (Watt et al. in press).

NSW fisheries: In 2012, the Scalloped Hammerhead and the Great Hammerhead were listed as threatened species under the NSW Fisheries Management Act 1994 (Endangered and Vulnerable, respectively). The total catch of hammerhead sharks recorded during 1990–2019 in NSW (c. 130 tonnes) is small compared to catches in other jurisdictions (Saunders et al. 2021). The NSW Ocean Trap and Line Fishery (OTLF) captures some large Scalloped Hammerheads, and the catch is mostly males (Macbeth et al. 2009). Scalloped Hammerheads represent c. 3% of commercial catch by demersal longlines in the Large Shark Fishery (a sub-sector of the OTLF) (Macbeth et al. 2009), which ceased operations by 2015. Discarded hammerhead shark catch is not reported, and capture mortality is high in all NSW fisheries (Butcher et al. 2015).

Commonwealth fisheries: Commonwealth managed fisheries rarely interact with the Scalloped Hammerhead. During 2014–2020, the Commonwealth fishing operators recorded a total of 35 individuals as Scalloped Hammerhead across all Commonwealth fisheries (R Murphy 2021. pers comm 28 June). No species-specific management measures are in place. Commonwealth fisheries have a range of legislative measures in place to manage and monitor interactions with all shark species. The Scalloped Hammerhead has not been identified as a high-risk species in any of Australian Fisheries Management Authority's (AFMA) Ecological Risk Assessments (R Murphy 2021. pers comm 28 June).

Recreational fishing: Scalloped Hammerheads are captured, but rarely targeted, by recreational fishers across northern Australia, although species-specific data is scarce. Scalloped Hammerheads contribute almost 7% of recreational catch in north Qld (De Faria 2012). Reconstructed annual catch of Scalloped Hammerhead along the east coast of Qld was less than 10 tonnes during 1981–2012, but then increased steadily to 24 tonnes in 2019 (Saunders et al. 2021). Reconstructed annual catches of Scalloped Hammerhead across WA, NT and the Gulf of Carpentaria remained under 10 tonnes during c. 1950–2019 (Saunders et al. 2021).

Habitat degradation: Scalloped Hammerheads rely on coastal habitats, particularly as nursery areas for juveniles. This reliance on coastal habitats exposes them to a variety of anthropogenic threats (e.g., coastal development, dredging, construction, pollution and land reclamation) (Knip et al. 2010).

Climate change: Ongoing changes are expected in precipitation patterns in northern Australia, including more-intense heavy rains (Brown et al. 2016) coupled with longer dry spells (Trenberth et al. 2013). These changes may influence turbidity, water temperature and salinity regimes, which are drivers of Scalloped Hammerhead abundance within inshore nursery areas along north-eastern Qld (Yates et al. 2015a). Population-level resilience of the species to climate change may be enhanced by its widespread distribution, occurrence in a variety of habitats and reliance on a variety of prey types (Yates et al. 2012; Chin et al. 2017).

Table 2 Major threats impacting the Scalloped Hammerhead

Threat	Status and severity ^a	Evidence
Commercial fishing in Australian waters. Of the total area of the species' range spanning Indonesia, East Timor, PNG and Australia, approximately 33% is within Australian waters (based on species range in Rigby et al. 2019).		
Qld managed fisheries	<ul style="list-style-type: none"> • Status: historical and current • Confidence: known • Consequence: moderate compared to fisheries outside Australia • Trend: static • Extent: across part of its range 	<p>Status: The Queensland Fish Board began recording commercial landings of sharks (unspecified) in Qld managed fisheries in the 1974–75 fishing season (Leigh 2015). Most of Qld's commercial shark catch, and therefore hammerhead shark catch, is taken by the East Coast Inshore Fin Fish Fishery (ECIFFF) and the Gulf of Carpentaria Inshore Fin Fish Fishery (GOCIFFF) (Leigh 2015). Scalloped Hammerhead is a bycatch/byproduct species in these fisheries (Kyne et al. 2021).</p> <p>Confidence: High-confidence and species-specific records of catch and discards are not available, especially prior to 2004 (Leigh 2015; Saunders et al. 2021). Catch rate and size composition data for sharks are mainly obtained through the commercial logbook system (1988 to present). Data on shark species composition in catches from the ECIFFF and GOCIFFF are mainly from a voluntary observer program that operated during 2006–12 (Leigh 2015).</p> <p>Consequence: Scalloped Hammerhead was the species at second-most risk of overfishing in a Qld-wide stock assessment, mainly due to its long lifespan, low natural mortality rate and vulnerability to the gillnet fishery throughout most of its size range (Leigh 2015). Large declines in standardised catch rates of hammerhead sharks are reported using data from the Qld Shark Control Program (Attachment A) (Simpfendorfer et al. 2011; Roff et al. 2018).</p> <p>Trend: Total annual reconstructed catch of Scalloped Hammerhead from Qld's east coast peaked at > 400 tonnes in 2003 (Saunders et al. 2021). Management reforms in 2009 led to a decrease in the reported catch of hammerhead sharks. Reconstructed annual catches of Scalloped Hammerhead in Qld commercial fisheries were less than 150 tonnes during 2009–2019 and less than 20 tonnes in 2019 (Saunders et al. 2021).</p> <p>Extent: Qld represents approximately 40% of the species' distribution within the Australian EEZ (based on species range in Rigby et al. 2019).</p>
NT managed fisheries	<ul style="list-style-type: none"> • Status: historical and current • Confidence: known • Consequence: moderate compared to fisheries outside Australia • Trend: static • Extent: across part of its range 	<p>Status: The NT Offshore Net and Line Fishery (ONLF) commenced operations around 1986. Scalloped Hammerhead is a bycatch/byproduct species as part of its total shark catch. Annual shark catches rarely exceeded 500 tonnes during the 1990s, before peaking at > 1000 tonnes in the 2000s (NT Government 2014; Saunders et al. 2021). In 2011, the ONLF took 141 tonnes of hammerhead sharks (Simpfendorfer 2014).</p> <p>There have been no reported catches of hammerhead sharks in the NT Barramundi Fishery since 2010, and prior to 2010 annual catches were sporadic, not exceeding 400 kg (unpublished raw data, NT Government, 28 June 2021).</p> <p>Confidence: Species specific catch information for hammerhead sharks in the NT is not available prior to 2014 (Simpfendorfer 2014), but species-specific reporting of Scalloped Hammerhead is now mandatory in all ONLF Catch Disposal Records (CDR) and paper logbooks. The current on-board observer program in the ONLF aims to achieve 10% coverage. Electronic monitoring (cameras) is now compulsory for pelagic and demersal longlining.</p> <p>Consequence: The Scalloped Hammerhead was categorised at 'moderate' risk in the 2020 Ecological Risk Assessment for the ONLF (NT Government 2020). Post release mortality of Scalloped Hammerheads is assumed to be 'very high' (NT Government 2020).</p> <p>Trend: Reconstructed catches of Scalloped Hammerhead in the NT and the Gulf of Carpentaria (GOC) (i.e., including Qld catch from within the GOC) steadily increased to a peak in 2005 (Saunders et al. 2021). There has been limited targeting of sharks in the ONLF since 2012, mainly due to declines in shark fin prices (NT Government 2020). A transition to targeting Grey Mackerel also lead to a reduction in the total shark catch to</p>

Threat	Status and severity ^a	Evidence
		<p>52 tonnes in 2018 (NT Government unpublished, cited in Saunders et al. 2021).</p> <p>Extent: NT represents approximately 17% the species' Australian distribution within the Australian EEZ (based on species range in Rigby et al. 2019). ONLF licence holders generally operate within 20 km of the coastline (NT Government 2014), which is a largely separate area to where the Taiwanese fishery was active (Saunders et al. 2021) (see below under 'Foreign fleets in Australian waters').</p>
Shark Control Programs (Qld and NSW)	<ul style="list-style-type: none"> • Status: historical and current • Confidence: known • Consequence: moderate (predominantly Qld) • Trend: static • Extent: across part of its range 	<p>Status: The Qld Shark Control Program (QSCP) commenced in 1962 and uses both large-mesh gillnets and drumlines to target and kill sharks (Leigh 2015). Total annual reconstructed catch of Scalloped Hammerhead was 0.7 tonnes during 1988–2019 (Saunders et al. 2020).</p> <p>The NSW Shark Meshing Program (NSW SMP) commenced in 1937 in Sydney, and in 1949 in Newcastle and Wollongong (Reid & Krogh 1992). Since accurate species identification was initiated in the NSW SMP, less than one individual Scalloped Hammerhead has been caught per annum (Dalton & Peddemors 2019). Ninety-five percent of total hammerhead shark catch in the NSW SMP is <i>Sphyrna zygaena</i> (Smooth Hammerhead) (Dalton et al. 2020).</p> <p>Confidence: Accuracy of species identification for hammerhead sharks over the duration of the QSCP has been variable. As a result, analyses have pooled data across all hammerhead shark species (Simpfendorfer et al. 2011; Roff et al. 2018). Species-specific reporting in the NSW SMP commenced in 2010 (Reid et al. 2011; Lee et al. 2018).</p> <p>Consequence: Large reductions in the catch of hammerhead sharks by the QSCP (Attachment A) (Simpfendorfer et al. 2011; Roff et al. 2018) are in contrast with the increasing relative biomass trajectories shown by stock assessment models (Saunders et al. 2021). It is unclear whether the declines in QSCP catches, coupled with other sources of mortality, are indicative of localised depletion, widespread depletion, or a contraction near the edge of the species' range (Thomson 2021).</p> <p>Trend: Catches are ongoing. The QSCP initially used nets, which contributed most of the hammerhead catch during the early 1990's (Simpfendorfer et al. 2011). Due to high levels of bycatch and declines in the number of sharks caught in nets, they were incrementally partially replaced with drumlines, especially during 1990–1995 (Simpfendorfer et al. 2011; Roff et al. 2018). No information on the trend for Scalloped Hammerheads in the NSW SMP is available, presumably due to the low catches of the species.</p> <p>Extent: The QSCP spans tropical and sub-tropical coastal waters along 1760 km of coastline between Cairns and Gold Coast (Roff et al. 2018). Gillnets and drumlines are deployed in 8–10 m of water and positioned 300–1000 m from the beach (Noriega et al. 2011).</p> <p>The NSW SMP spans 51 beaches between Stockton and South Wollongong (Reid et al. 2011). Beaches of South Sydney and Illawarra are outside of the Scalloped Hammerhead's distribution.</p>
Foreign fleets in Australian waters	<ul style="list-style-type: none"> • Status: historical and current • Confidence: known • Consequence: severe • Trend: static • Extent: across part of its range 	<p>Status: A Taiwanese fishery operated off northern Australia (WA, NT and Qld) using pelagic gillnets during 1974–1986 and using longlines during 1990 and 1991. It captured a variety of shark species including the Scalloped Hammerhead (Stevens & Lyle 1989; Stevens 1999).</p> <p>Since 1974, Indonesian fishers have been permitted to operate with traditional fishing methods within an area of the Timor Sea known as the MOU Box. This is subject to a 1974 memorandum of understanding and subsequent agreements between Australia and Indonesia.</p> <p>A Soviet trawl fishery has also operated across northern Australia. Data on shark catches are not available. Data on red snapper catches during 1966–1977 indicate that most of the Soviet fishing took place in WA and NT waters, and very little in Qld (Leigh 2015).</p> <p>Confidence: Data on shark catches in the Taiwanese fishery are available for 1974–1992 (Stevens & Davenport 1991; Stevens 1999). Hammerhead</p>

Threat	Status and severity ^a	Evidence
		<p>sharks were among the main shark species captured although data collected were not species specific (Stevens & Davenport 1991). The annual shark catches in the early to mid-1980s were 2300–4500 t (all species) (Stevens 1999). Reconstructed annual catches of Scalloped Hammerhead in the MOU box during 1975–2018 peaked at 7.8 tonnes in the 2005-06 financial year, and were < 2 tonnes from 2010-11 (Marshall et al. 2016; Jaiteh et al. 2017; Saunders et al. 2021).</p> <p>Consequence: The development of the Taiwanese fishery in the 1970s was the beginning of significant fishing of Scalloped Hammerheads in Australian waters. Catches by the Taiwanese fishery are a primary driver of declining biomass in stock-assessment models (Saunders et al. 2021). Total catches across NT and the GOC were dominated by the high catches (i.e., 1000s of tonnes of shark in the 1970s and 1980) by the Taiwanese gillnet fleet during 1975–1984 (Stevens 1999; NT Government 2020; Saunders et al. 2021). In WA, reconstructed catches of Scalloped Hammerhead in the Taiwanese fishery peaked at > 30 tonnes in 1980 (Saunders et al. 2021). OECD (2004) reported that approximately 53 fishing trips took place in the MOU box each year and the average shark catch per trip was 2600 kg (OECD 2004).</p> <p>Trend: Large catches of shark by the Taiwanese gillnet fishery effectively ceased in 1986 in the NT/GOC due to stringent management measures making the operations uneconomical (Saunders et al. 2021). Effort from the Taiwanese gillnet fishery in Qld waters was considered negligible from November 1979 onwards (Leigh 2015). Fishing by Indonesian fishers in MOU box is ongoing.</p> <p>Extent: The Taiwanese fishery took most of its catch in waters > 40 nm offshore in NT (Saunders et al. 2021). Effort in the Taiwanese pelagic gillnet fishery was concentrated north of the Wessel Islands (Stevens & Davenport 1991).</p>
Commercial fishing outside Australian waters		
Indonesian fisheries	<ul style="list-style-type: none"> • Status: historical and current • Confidence: known • Consequence: severe • Trend: unknown • Extent: across part of its range 	<p>Status: Indonesia has the largest chondrichthyan fishery in the world, with annual reported catches of approximately 110 000 tonnes (White et al. 2006; Lack & Sant 2009; Tull 2014). Elasmobranch catches increased rapidly from the 1970s (Tull 2014; Simeon et al. 2021). Hammerhead sharks are caught as target species and bycatch in numerous fisheries including shark bottom-longline, shark drift/surface longline, drift gillnet, and tuna longline (Jaiteh et al. 2017; Simeon et al. 2021). Sharks are reportedly caught by 46 targeted fishing fleets in Indonesia (Simeon et al. 2021).</p> <p>In 2010, Indonesia established the National Plan of Action (NPOA) for Sharks and Rays 2010–2014 (Simeon et al. 2021). Existing measures under the NPOA are considered difficult to enforce because of the nature of small-scale fisheries in Indonesia and limited government resources to enforce regulations (Loneragan et al. 2021).</p> <p>In 2014, three species of hammerhead shark were included in Appendix II of CITES. In response, the Indonesian Government's Ministry of Marine Affairs and Fisheries (MMAF) issued a regulation prohibiting the export of all forms of hammerhead shark products and derivatives (MMAF Ministerial Decree No 5/2018). This decree has expired and was not extended. Harvest of hammerhead sharks for domestic trade and use is still allowed (Simeon et al. 2021).</p> <p>Confidence: Total shark catches reported in Indonesia are likely to be underestimates of the total catch (Saunders et al. 2021). Fisheries in Indonesia are largely unregulated and catches are likely to be largely unreported. Data that is available often has poor taxonomic resolution and accuracy (White & Kyne 2010). IUU fishing is substantial and further complicates understanding of total mortality (White & Kyne 2010).</p> <p>Inferred declines are corroborated by reports from fishers of decreasing abundance and body size, and changes to species' distributions (Jaiteh et al. 2017a; 2017b; Simeon et al. 2021). Furthermore, low genetic diversity</p>

Threat	Status and severity ^a	Evidence
		<p>detected around Lombok may be driven by intense fishing pressure (Hadi et al. 2019; 2020).</p> <p>Consequence: Fishery-independent catch rates of elasmobranchs in the Java Sea declined by at least one order of magnitude during 1976–1997 (Blaber et al. 2009). Catches by Indonesian fisheries are a primary driver of declining biomass in stock-assessment models (Saunders et al. 2021).</p> <p>Trend: The number of shark fishing boats increased significantly toward the end of the 1990s, and the high value of hammerhead shark fins has driven an increase in targeting in some areas (Simeon et al. 2021). The exploitation rate at Tanjung Luar in east Lombok increased from 0.51 in 2018 to 0.76 in 2019 (Simeon et al. 2021). Anna et al. (2020) report increasing total catch and CPUE of hammerhead sharks during 2006–2018, based on data from Indramayu’s fisheries Agency and West Java fisheries Agency. These reports contrast with dramatic declines in reconstructed annual catch from c. 2010 by Saunders et al. (2021).</p> <p>Extent: The spatial distribution of reported shark catches within Indonesian waters is not available (Saunders et al. 2021). Of the total area of the species’ range spanning Indonesia, East Timor, PNG and Australia, approximately 60% is within Indonesian waters (based on species range in Rigby et al. 2019).</p>
Papua New Guinea fisheries (PNG)	<ul style="list-style-type: none"> • Status: historical and current • Confidence: known • Consequence: presumed severe • Trend: unknown • Extent: across part of its range 	<p>Status: Sharks are caught in a variety of fisheries in PNG, including the Commercial Purse Seine and Prawn Trawl fisheries, and by artisanal coastal fisheries. These coastal fisheries vary in method by province and location and include gillnet, dropline, seine net, trap net and spear gears (White et al. 2020). There is also a small bycatch of Scalloped Hammerhead in the Demersal Prawn Trawl Fishery in the Gulf of Papua in the order of hundreds of kilograms annually since the inception of this fishery in 1969 (White et al. 2019; Saunders et al. 2021).</p> <p>The Shark Longline Fishery developed in the mid-1990s and catches peaked at just below 1500 tonnes in the early-2000s but ceased in 2014 amid concerns over shark sustainability (White et al. 2020).</p> <p>A drift net fishery for shark and other species operated in the Gulf of Papua during the early 1980s but has since ceased (Kumoru 2003).</p> <p>Confidence: The level of observer misidentification in the Shark Longline Fishery of PNG was low (< 10%), which reflected the use of region-specific identification guides by well-trained fisheries observers (White et al. 2020). Seventy-seven percent of Scalloped Hammerhead caught in the Shark Longline Fishery were either dead, injured or dying (White et al. 2020). Scalloped Hammerhead sharks comprised 3.1% of the catch mass in this fishery based on observer data collected during May–June 2014 (White et al. 2020).</p> <p>More broadly, coastal fisheries catches are poorly documented in PNG and total national landings are difficult to estimate (White et al. 2020). Reported total shark catches are likely to be underestimates (Saunders et al. 2021).</p> <p>Consequence: White & Kyne (2010) suggest that a decline in the PNG shark population, similar to what has been observed in Indonesia, is likely to have occurred. Although the PNG human population density is much lower than in Indonesia, destructive practices such as dynamite fishing and poisoning are widespread (White & Kyne 2010).</p> <p>Trend: Fishing for sharks is ongoing but poorly understood.</p> <p>Extent: The spatial distribution of reported shark catches within PNG waters is not available (Saunders et al. 2021). Of the total area of the species’ range spanning Indonesia, East Timor, PNG and Australia, approximately 7% is within PNG waters (based on species range in Rigby et al. 2019).</p>

Threat	Status and severity ^a	Evidence
Illegal, Unregulated and Unreported (IUU) fishing		
IUU fishing	<ul style="list-style-type: none"> • Status: primarily historical • Confidence: known • Consequence: severe • Trend: decreasing to static • Extent: across part of its range 	<p>Status: Illegal fishing by foreign vessels for sharks along northern Australia was most prevalent between the late-1990s and the late -2000s (ANAO 2010; Saunders et al. 2021). IUU fishing remains a concern in Indonesia and PNG but it is poorly defined and the extent is largely unknown (White & Kyne 2010). Domestic compliance issues are considered relatively minor.</p> <p>Confidence: The quantity and species composition of sharks taken by IUU fishing along northern Australia are largely unknown. Numbers of sightings and apprehensions alone do not provide a reliable indication of the level of fishing effort or of the level of catch (Lack & Sant 2008; Marshall 2011).</p> <p>Consequence: The scale of IUU shark fishing in 2006 may have been equivalent to, or more than, the largest commercial shark fisheries operating at the time in the region (Marshall 2011) and as such has likely been a primary driver of population decline (Saunders et al. 2021).</p> <p>Trend: During 2003–2006 there was a significant increase in the number of foreign vessels illegally fishing in Australia’s northern waters (ANAO 2010). This number then declined from 367 in the 2005/06 fishing season to seven in the 2012/13 season (AFMA 2013). Saunders et al. (2021) used total days of illegal fishing effort per month during 2005–2006 (Salini et al. 2007), annual proportions of illegal fishing effort during 1975–2019 (Fox 2009; ANAO 2010; OECD 2004), and daily catch rates (Marshall et al. 2016) to reconstruct a time series of IUU catch in the NT. Annual reconstructions peaked at 80 tonnes in 2005 and were less than 5 tonnes per year during 2010–2019.</p> <p>Extent: IUU catch is believed to have occurred in WA, NT and the GOC based on surveillance information across northern Australia (Salini et al. 2007). Comparatively, the IUU catch that has occurred along the east coast of Qld is considered negligible by Saunders et al. (2021).</p>

Status—identify the temporal nature of the threat;

Confidence—identify the extent to which we have confidence about the impact of the threat on the species;

Consequence—identify the severity of the threat;

Trend—identify the extent to which it will continue to operate on the species;

Extent—identify its spatial content in terms of the range of the species.

Each threat has been described in Table 2 in terms of the extent that it is operating on the species. The risk matrix (Table 3) provides a visual depiction of the level of risk being imposed by a threat and supports the prioritisation of subsequent management and conservation actions. In preparing a risk matrix, several factors have been taken into consideration, they are: the life stage they affect; the duration of the impact; and the efficacy of current management regimes, assuming that management will continue to be applied appropriately. The risk matrix and ranking of threats has been developed in consultation with in-house expertise and using available literature.

Table 3 Scalloped Hammerhead risk matrix.

Likelihood	Consequences				
	Not significant	Minor	Moderate	Major	Catastrophic
Almost certain	Low risk	Moderate risk	Very high risk	Very high risk	Very high risk
Likely	Low risk	Moderate risk Shark Control Programs	High risk Qld fisheries; NT fisheries	Very high risk Indonesian fisheries; PNG fisheries	Very high risk
Possible	Low risk	Moderate risk	High risk IUU fishing; Foreign fleets in Australian waters	Very high risk	Very high risk
Unlikely	Low risk	Low risk	Moderate risk	High risk	Very high risk
Unknown	Low risk	Low risk	Moderate risk	High risk	Very high risk

Priority actions have then been developed to manage threats particularly where the risk was deemed to be ‘very high’ or ‘high’. For those threats with an unknown or low risk outcome it may be more appropriate to identify further research or maintain a watching brief.

Conservation and recovery actions

Primary conservation outcome

The primary conservation outcomes are to (1) prevent further population decline for the Scalloped Hammerhead and (2) recover the species across its range. Approximately 33% of the species’ range in Indonesia, East Timor, PNG and Australia is within Australian waters (based on species range in Rigby et al. 2019). Based on current evidence, pupping areas, nurseries, juvenile foraging grounds and habitats utilised by males within Australian waters may make critical contributions to the viability of the central Indo-Pacific population. Although the population declines outlined in Attachment A can be attributed in part to fishing outside of Australian waters, management actions in Australia will be critical to achieving the primary conservation outcomes. Conversely, the viability of the central Indo-Pacific population(s) also depends on management of fisheries in foreign and international waters. International co-operation and conservation instruments will be vital to the recovery of the species in Australia and regionally.

Conservation and management priorities

- [If the Scalloped Hammerhead is listed in an EPBC Act threatened category: Prohibit catch and retention of Scalloped Hammerheads in all Australian commercial and recreational fisheries, and revise the Australian CITES Non-Detriment Finding for the Scalloped Hammerhead appropriately.]
- Develop a species-specific mitigation strategy for incidental interactions with Scalloped Hammerheads, particularly for subadults and adults. This may include spatiotemporal closures, interaction limits, move-on provisions, fishing effort controls, gear restrictions and gear modifications.

- Implement independent data collection and validation programs in all Australian fisheries that interact with Scalloped Hammerheads, including a combination of on-board observers or electronic catch monitoring.
- Implement and further develop bycatch reduction devices and methodologies to reduce interactions with, and catches of, Scalloped Hammerheads.
- Introduce best practice catch handling to optimise post-release survival and fitness in commercial fisheries.
- Improve species-specific information on fisheries interactions (including weight, size, fate and release condition).
- Undertake Cumulative Ecological Risk Assessments (ERAs) for the Scalloped Hammerhead. Cumulative ERAs assess risks from cumulative fishing mortality from multiple fisheries (e.g., Zhou et al. 2019).
- Implement spatiotemporal protection of known nursery areas and aggregation sites in Australian waters, coupled with measures to manage public interaction with the species to avoid disturbance of aggregations.
- Implement rebuilding targets and timeframes for the Scalloped Hammerhead and establish a process for their ongoing review.
- Restrict spatial expansion of the commercial fisheries that interact with Scalloped Hammerheads, unless informed by comprehensive research into the impacts on the species.
- Accurate species-level identification and reporting for all hammerheads captured in shark control programs. Where possible, consider transition of shark control programs from nets to drumlines and/or non-lethal bather protection techniques.
- Develop regional partnerships to enhance the conservation and management of the Scalloped Hammerhead across borders and international jurisdictions and to improve understanding of total mortality outside of Australia. Utilise the mechanisms established within relevant Regional Fisheries Management Organisations and the Convention on the Conservation of Migratory Species Memorandum of Understanding on the Conservation and Management of Migratory Sharks to facilitate such initiatives. Work with governments of Indonesian and PNG to reduce IUU fishing of Scalloped Hammerheads in Australian waters.
- Identify areas of Critical Habitat and Habitat Critical to the Survival of Scalloped Hammerhead.

Stakeholder engagement/community engagement

- Continue refining state/territory partnerships to enhance the conservation and management of the Scalloped Hammerhead across Australian jurisdictions.
- Implement an education program for recreational and game fishers to practise best practice handling and release for incidental interactions with Scalloped Hammerheads.
- *[If the Scalloped Hammerhead is listed in an EPBC Act threatened category: In collaboration with Indigenous communities, develop and implement a community level program to promote Scalloped Hammerhead conservation and enhance cooperation and understanding between government agencies and Indigenous communities.]*

Information and research priorities

- Develop an overarching research and monitoring plan for the Scalloped Hammerhead including performance indicators, monitoring mechanisms and timeframes, and a process for ongoing review of the plan.
- Investigate the implications of cumulative threats including exposure to multiple fisheries, habitat degradation and climate change.
- Continue research on stock structure and connectivity:
 - Expand sample sizes, geographic extent, and sampling of larger individuals of both sexes. Conduct targeted sampling to investigate occurrence and habitat use of females (e.g., near undersea ridges or steep drop-offs along the edge of continental shelves) and juveniles/neonates (e.g., inshore coastal areas used as nursery and pupping areas).
 - Incorporate Indigenous knowledge (e.g., reports that large schools of hammerhead sharks congregate regularly to the east of the Torres Strait islands and move through the middle section of the straits during the wet season) (Gerhardt 2018).
 - Research to identify where and when reoccurring aggregations occur (such as those observed in Shoalwater Islands Marine Park, WA) (López et al. in review).
 - Evaluate the utility of targeted citizen science programs that use photographic verification.
 - Apply new information to inform the delineation of habitat critical to the survival of the Scalloped Hammerhead in Australian waters.
- Implement a program to collect tissue samples for genetic sequencing and kin finding. Conduct close kin mark recapture (CKMR) estimation of abundance, mortality and fecundity. Provide information on stock structure on a more contemporary time scale than that offered by population genetic techniques.
- Collect data required for future age-structured stock assessment models (see Thomson 2021).
- Evaluate and collect alternative indices of abundance, potentially including fisheries-independent sources such as baited remote underwater video (BRUV) or standardised surveys using multiple gears.
- Estimate levels of capture/handling stress and post-release mortality in commercial and recreational fisheries, and test methods to reduce mortality associated with fisheries interactions.
- Undertake research to evaluate the impact of incidental capture by recreational and game fishers.
- Meta-analyses of existing and new spatial/depth fishing closures and their capacity to protect different life stages of the Scalloped Hammerhead.
- Investigate potential southward shifts in the Australian distribution of the Scalloped Hammerhead, and the potential for increased interaction with fisheries that have not historically captured large quantities of the species.

Recovery plan decision

No recovery plan is in place for the Scalloped Hammerhead. A decision about whether there should be a recovery plan for this species has not yet been determined. The purpose of this consultation document is to elicit additional information to help inform this decision.

Links to relevant implementation documents

- CITES Appendix II Non-Detriment Finding. Available at: <https://www.environment.gov.au/biodiversity/wildlife-trade/publications/non-detriment-finding-five-shark-species>
- CMS Appendix II. Available at: https://www.cms.int/sites/default/files/document/COP11_Doc_24_1_16_Rev1_Prop_II_7_Sphyrna_lewini_%28Hammerhead_Shark%29_CRI%26ECU_E_corr2.pdf
- Listed as Endangered (Fisheries Management Act 1994 [New South Wales]: November 2019 list)

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THREATENED SPECIES SCIENTIFIC COMMITTEE

Established under the *Environment Protection and Biodiversity Conservation Act 1999*

The Threatened Species Scientific Committee finalised this assessment on DD Month Year.

Attachment A: Listing Assessment for *Sphyrna lewini*

Reason for assessment

This assessment follows prioritisation of a nomination from the Threatened Species Scientific Committee.

Assessment of eligibility for listing

This assessment uses the criteria set out in the [EPBC Regulations](#). The thresholds used correspond with those in the [IUCN Red List criteria](#) except where noted in criterion 4, sub-criterion D2. The IUCN criteria are used by Australian jurisdictions to achieve consistent listing assessments through the Common Assessment Method (CAM).

The text below addresses the eligibility of the species for listing as a threatened species. Inclusion of the Scalloped Hammerhead in the Conservation Dependent category may also be considered by the Committee.

Key assessment parameters

Table 4 includes the key assessment parameters used in the assessment of eligibility for listing against the criteria.

Table 4 Key assessment parameters

Metric	Estimate used in the assessment	Minimum plausible value	Maximum plausible value	Justification
Number of mature individuals	>10 000			The number of mature individuals has not been estimated but is most plausibly > 10 000 mature individuals.
Trend	Potentially some recent recovery following historic declines			Based on relative biomass trajectories in Saunders et al. (2021).
Generation time (years)	24			The generation length was calculated as the median age of adults of current cohort: (Maximum age – age at maturity)/2 + age at maturity, with female age at maturity of 13 years, and female maximum observed age of 35 years (Drew et al. 2015; Kyne et al 2021).
Extent of occurrence	> 8 000 000 km ²			Based on species distribution mapping by the Department of Agriculture, Water, and the Environment. These are created using a database of species observation records, national and regional-scale environmental data, environmental modelling techniques and documented scientific research.
Trend	Unquantified			

Metric	Estimate used in the assessment	Minimum plausible value	Maximum plausible value	Justification
Area of Occupancy	> 15 000 km ²			Same as for EOO, above.
Trend	Unquantified			
Number of subpopulations	2	2	3	Genetic information indicates two possible subpopulations: (1) in waters of WA and potentially more broadly across the Indian Ocean, and (2) the rest of northern Australia, connected to Indonesia and PNG (Heupel et al 2020). Limited gene flow suggests that very little exchange or movement of individuals to or from WA is occurring. The possibility of >2 subpopulations is discussed above under 'Relevant biology and ecology' and in Attachment A.
Trend	Unquantified			
Basis of assessment of subpopulation number	Genetic, tagging and parasite information (Heupel et al. 2020).			
No. locations				Not applicable. The Scalloped Hammerhead is a wide-ranging marine species with a large distribution throughout the Indo-Pacific.
Trend				
Basis of assessment of location number	See above justification from number of locations.			
Fragmentation	Unquantified			
Fluctuations	Not known to be subject to extreme fluctuations in EOO, AOO, number of subpopulations, locations, or mature individuals.			

Criterion 1 Population size reduction

Reduction in total numbers (measured over the longer of 10 years or 3 generations) based on any of A1 to A4			
	Critically Endangered Very severe reduction	Endangered Severe reduction	Vulnerable Substantial reduction
A1	≥ 90%	≥ 70%	≥ 50%
A2, A3, A4	≥ 80%	≥ 50%	≥ 30%
<p>A1 Population reduction observed, estimated, inferred or suspected in the past and the causes of the reduction are clearly reversible AND understood AND ceased.</p> <p>A2 Population reduction observed, estimated, inferred or suspected in the past where the causes of the reduction may not have ceased OR may not be understood OR may not be reversible.</p> <p>A3 Population reduction, projected or suspected to be met in the future (up to a maximum of 100 years) [(a) cannot be used for A3]</p> <p>A4 An observed, estimated, inferred, projected or suspected population reduction where the time period must include both the past and the future (up to a max. of 100 years in future), and where the causes of reduction may not have ceased OR may not be understood OR may not be reversible.</p> <p>Based on any of the following</p> <ul style="list-style-type: none"> (a) direct observation [except A3] (b) an index of abundance appropriate to the taxon (c) a decline in area of occupancy, extent of occurrence and/or quality of habitat (d) actual or potential levels of exploitation (e) the effects of introduced taxa, hybridization, pathogens, pollutants, competitors or parasites 			

Criterion 1 evidence

Eligible under Criterion 1 A2bd for listing as Endangered

2018 Listing Advice

In its 2018 listing advice, the Committee considered that the information available at the time was sufficient to infer a population size reduction for the Scalloped Hammerhead (TSSC 2018). The main uncertainties were: (1) the relative original sizes of the Australian and Indonesian components of the population at the beginning of the three-generation period, (2) the decline in the Australian component of the population, and (3) the decline in the Indonesian component of the population. Based on published indications of decline (Table 5, below), the population size reduction in Australian waters across three generations was inferred to exceed 60% and was modelled across a range from 40 to 80%. The concurrent reduction in Indonesia and PNG (combined) was estimated to range from 60 to 90% (Blaber et al. 2009). To account for uncertainty in the level of international connectivity, the 2018 assessment considered multiple scenarios representing a range of relative original sizes of the Australian and Indonesian/PNG components of the stock. The assessment concluded that the overall population size reduction was most plausibly between 50 and 80%, and that the Scalloped Hammerhead met the criteria for listing in the Endangered category under the EPBC Act. Although they have not been used quantitatively to inform the conclusion under Criterion 1, the studies in Table 5 provide additional context to help evaluate the uncertainty within the stock assessment results in Saunders et al. (2021).

Table 5 Published indications of population size reduction for Scalloped Hammerhead that were considered in TSSC (2018). QSCP = Queensland Shark Control Program. Although they have not been used quantitatively to inform the conclusion under Criterion 1, these studies provide additional context to help evaluate the uncertainty within the stock assessment results in Saunders et al. (2021).

Jurisdiction	Decline (percent)	Spatial extent	Temporal extent	Comments	Reference
Australia	a. 66.6 b. 83.5	North Qld beaches around Townsville and Cairns	a. 1964–1990 (up to the period when replacement of nets with drumlines started to occur) b. 1995–2004 (just after most gear changes were completed)	Nets accounted for most of hammerhead shark catch. Annual catches (net data only) of all hammerhead species pooled were standardised using zero-inflated delta-negative binomial models to account for the effect of year, sex, effort, and beach. Predicted catches decreased steadily through the 1960s and 1970s, remained stable through the 1980s and fell to almost zero in the late 1990s. Female hammerhead sharks were rarely caught. The authors concluded that most of the hammerhead shark catch was of the Scalloped Hammerhead, based on body-size and species level identification in later years.	Simpfendorfer et al. (2011)
	58–76	North West Marine Region, WA	1998/99–2005/06	Calculated using a time-series of unstandardised annual CPUE for hammerhead species pooled in the WA North Coast Shark Fishery (WANCSF) and the Joint Authority Northern Shark Fishery (JANSF). Hammerhead catch rates fell rapidly from their 0.18–0.19 kg hook ⁻¹ maxima in 1997/98 and 1998/99 and then fluctuated between 0.05 and 0.11 kg hook ⁻¹ until 2005/06. Due to the relatively short temporal extent of these data compared to the reconstructed catches in Saunders et al. (2021), the results presented in Heupel & McAuley (2007) have not been used quantitatively to inform the conclusion under Criterion 1. More recently, standardisation of the data used by Heupel & McAuley (2007) using Generalised Additive Models indicated a reduction of 45% between 1999 and 2005 (95% confidence interval = 12–96%) (Braccini et al. 2020).	Heupel & McAuley (2007)
	60–70	NT and Arafura Sea	At least 1974–1986 (duration of the Taiwanese gillnet fishery; Stevens and Davenport 1991)	Inferred from an unpublished stock assessment for blacktip sharks (<i>Carcharhinus limbatus</i> and <i>C. tilstoni</i>). The Gulf of Carpentaria stock component probably did not decrease by more than 30% during this period (Stevens 1999). A more recent assessment estimated that in 2013 the biomass of <i>C. limbatus</i> and <i>C. tilstoni</i> was at 81 and 90% of the unfished biomass, respectively (Grubert et al. 2013). Due to the large amount of uncertainty in the application of stock assessments for different species to the Scalloped Hammerhead, the	Stevens (1999) citing unpublished stock assessment in Walters & Buckworth (1998)

Sphyrna lewini (Scalloped Hammerhead) Conservation Advice

				assessments in Walters & Buckworth (1998) and Grubert et al. (2013) have not been used to inform the conclusion under Criterion 1.	
Indonesia	60–90	Java Sea	1976–1997	Catch rates of elasmobranchs (unspecified) from research surveys. There is a large amount of uncertainty in the use of multi-species data to make inference about the Scalloped Hammerhead.	Blaber et al. (2009)

2021 Stock Assessment

Since the 2018 assessment, a stock assessment has been developed by the National Stock Assessment Working Group for Scalloped Hammerhead (Saunders et al. 2021), which has been independently reviewed by the Commonwealth Scientific and Industrial Research Organisation (CSIRO) (Thomson 2020; 2021).

Thomson (2021) concluded that the information available to Saunders et al. (2021) was insufficient to support models capable of providing advice on population depletions for the Scalloped Hammerhead, and that future efforts towards stock assessment should focus on improving data collection. The review highlighted the following challenges to understanding the status of Scalloped Hammerhead in Australian waters:

- Uncertainty about stock structure and connectivity across the Indo-Pacific.
- Scarce reported species-specific catch and discard information.
- Absence of high-confidence indices of abundance for some stocks, and the short temporal extent of the indices that are available.
- Models did not include QSCP data as an abundance index, which indicated large reductions in hammerhead shark abundance off eastern Qld (Simpfendorfer et al. 2011; Roff et al. 2018).
- Catch-Maximum Sustainable Yield (MSY) models require a long, accurate, time series of catches that include a period of decline resulting from a reduction in abundance. Such time series are not available for the Scalloped Hammerhead because the greatest reductions in catches have plausibly resulted from changes in fishing practices rather than changes in abundance (Thomson 2021).
- The Catch-MSY approach could be applied with an age-structured rather than Surplus Production model at its core. This would provide more realistic results for the Scalloped Hammerhead given that basic biological parameters (such as growth and fecundity) have been estimated (e.g., White et al. 2008; Drew et al. 2015).

Modelled stock-structure scenarios

Saunders et al. (2021) developed a suite of models that, in various combinations, comprised three stock-structure scenarios (described below and visually depicted in Figure 4–Figure 6):

Continental shelf movements but with stock divide around the WA/NT border

This scenario assumes that adults move along the margins of continental shelves, including northwards from Australia into Indonesia and PNG. Western Australia is the exception, and hence the models assume zero connectivity between WA and any other jurisdiction (Table 1 ; Figure 4). Fiji appears to be strongly separated from the other central Indo-Pacific locations indicating little to no movement of individuals occurs between these locations and no gene flow from the central Indo-Pacific to the eastern Pacific (Heupel et al. 2020).

The Committee considers this scenario as the most supported and precautionary until further data can be collected to support or refute this hypothesis. Given that Indonesia has the largest global landings of sharks (Blaber et al. 2009), including significant amounts of hammerhead sharks (White et al. 2008), if there are significant levels of exchange then some of the decline observed in Australia would be the result of fishing in Indonesia (Simpfendorfer 2014; Thomson et al. 2021).

Continental shelf movements but with stock divides at (1) the Torres Strait land bridge and (2) around the WA/NT border

In this scenario, adults move along the margins of continental shelves, but the Torres Strait land bridge divides the 'Northern' and 'Eastern' components. The Northern component includes waters of NT and the entire GOC. The Eastern component includes the east coast of Qld and NSW. This scenario accounts for movement of adults (1) between the Northern component and Indonesia, and (2) between the Eastern component and PNG. It assumes no movement between Indonesia and PNG. Catch time series from Indonesia and PNG were reduced in magnitude by 90%, to represent low levels of exchange of individuals between national jurisdictions.

The Committee considers that elements of this scenario are not consistent with current genetics information (Table 1) (Figure 10 in Heupel et al. 2020). Heupel et al. (2020) considered that connectivity between Australia and Indonesia/PNG was limited because not all the spatial pairwise comparisons spanning the Torres Strait land bridge were genetically indistinct, and because WA was genetically distinct. Heupel et al. (2020) were unable to confirm whether large cohorts of individuals are moving between regions consistently.

Limited movement

This scenario assumes that immature and mature individuals remain in restricted geographic areas (Figure 6). The Committee considers that the level of scientific support for this scenario is low compared to the scenarios involving continental shelf movements (Table 1).

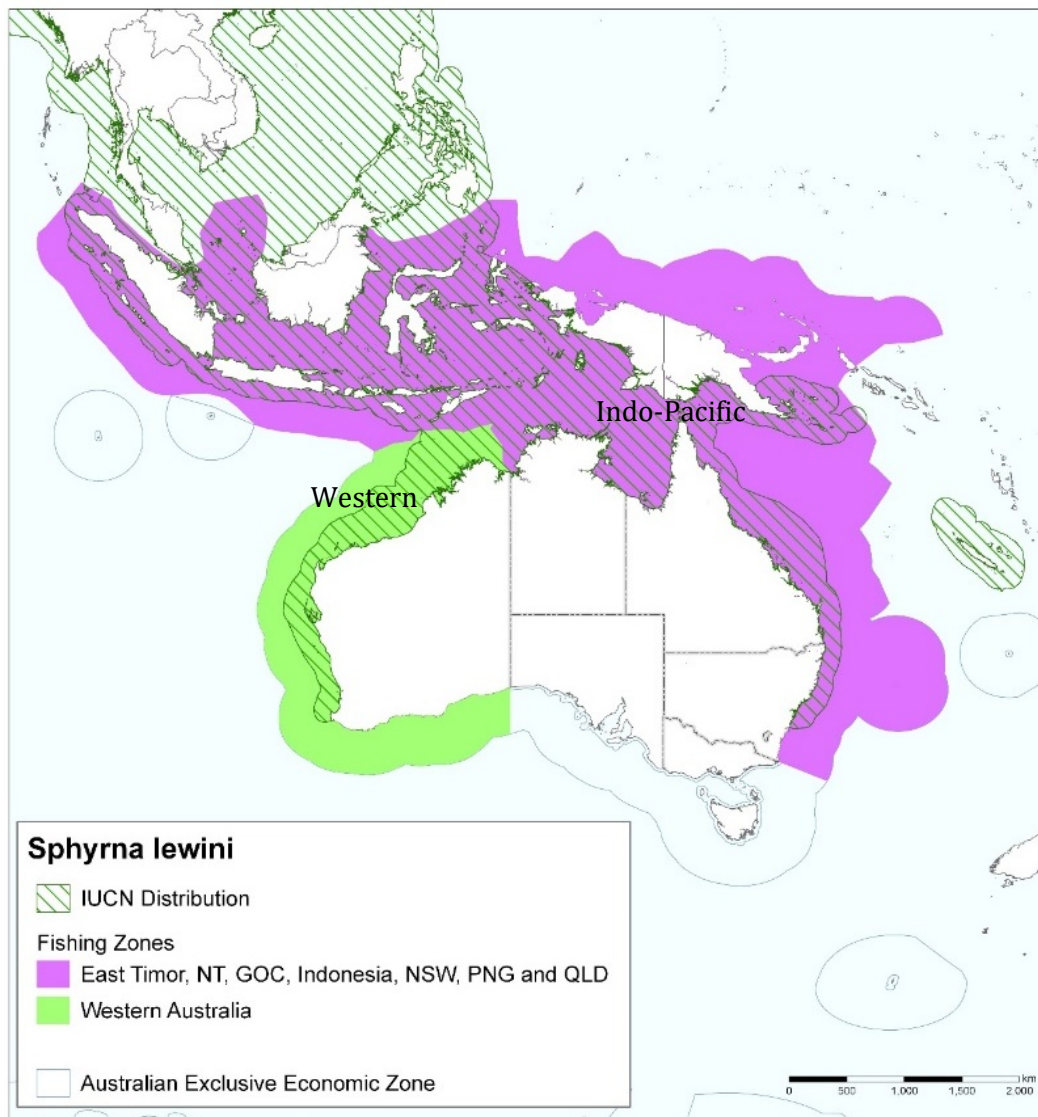


Figure 4 Map of the scenario ‘continental shelf movements but with stock divide around the WA-NT border’.

The species distribution (green hatching) is from Rigby et al. (2019), compiled by the IUCN Shark Specialist Group in 2018. The boundaries of the Western and Indo-Pacific stocks are poorly defined and are considered indicative only. Here, the boundaries are plotted as a visual representation of the how stocks were delineated in stock assessment models (Saunders et al. 2021). Contextual data were sourced from the Department of Agriculture, Water and the Environment, Geosciences Australia and PSMA Australia. The western boundaries of the WA component are poorly defined and should be considered indicative only.

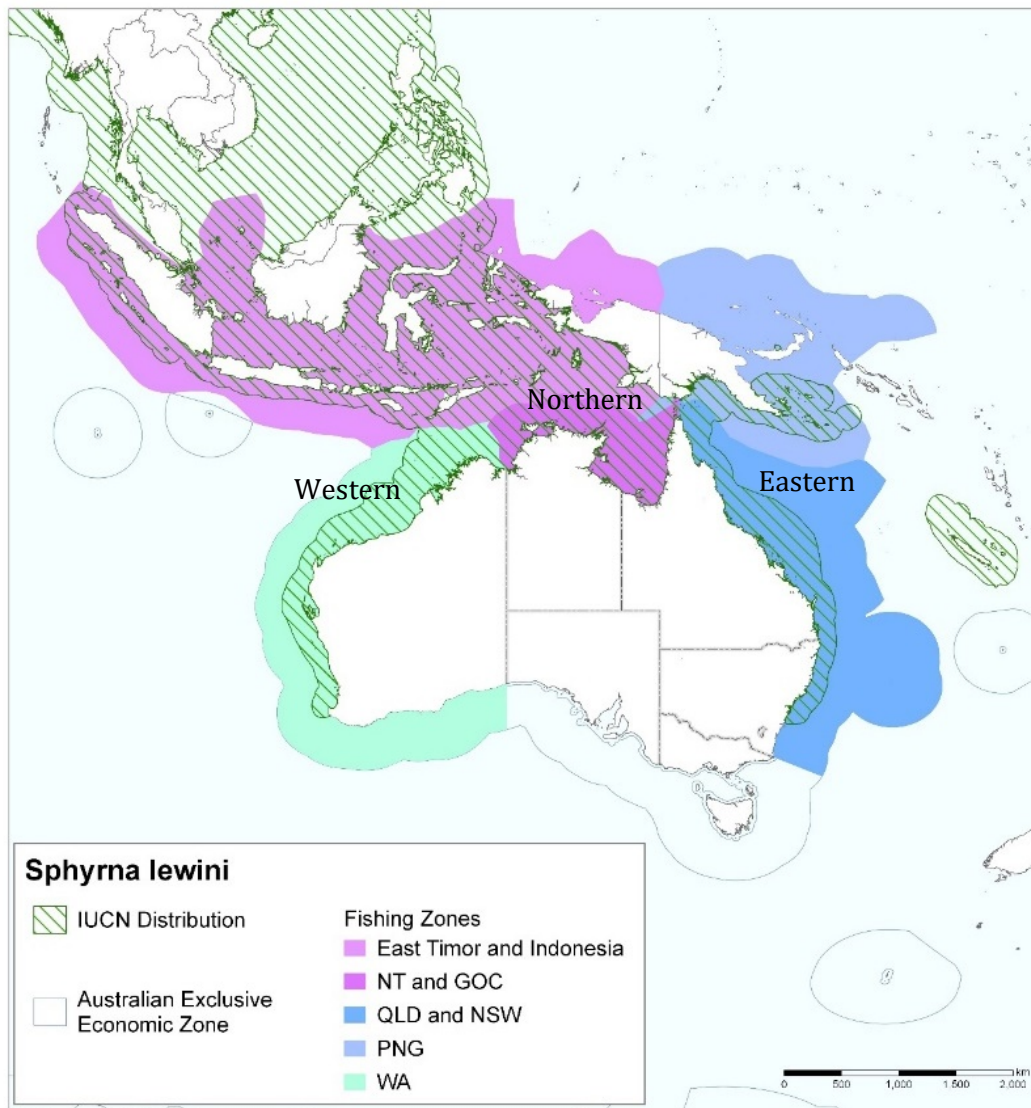


Figure 5 Map of scenario ‘continental shelf movements but with stock divides at (1) the Torres Strait land bridge and (2) around the WA-NT border’.

Catches in Indonesia and PNG are included in the Northern and Eastern models, respectively, but with magnitude reduced by 90%. The species distribution (green hatching) is from Rigby et al. (2019), compiled by the IUCN Shark Specialist Group in 2018. The boundaries of the Western, Northern and Eastern stocks are poorly defined and are considered indicative only. Here, the boundaries are plotted as a visual representation of the how stocks were delineated in stock assessment models (Saunders et al. 2021). Contextual data were sourced from the Department of Agriculture, Water and the Environment, Geosciences Australia and PSMA Australia. The western boundaries of the WA component are poorly defined and should be considered indicative only.

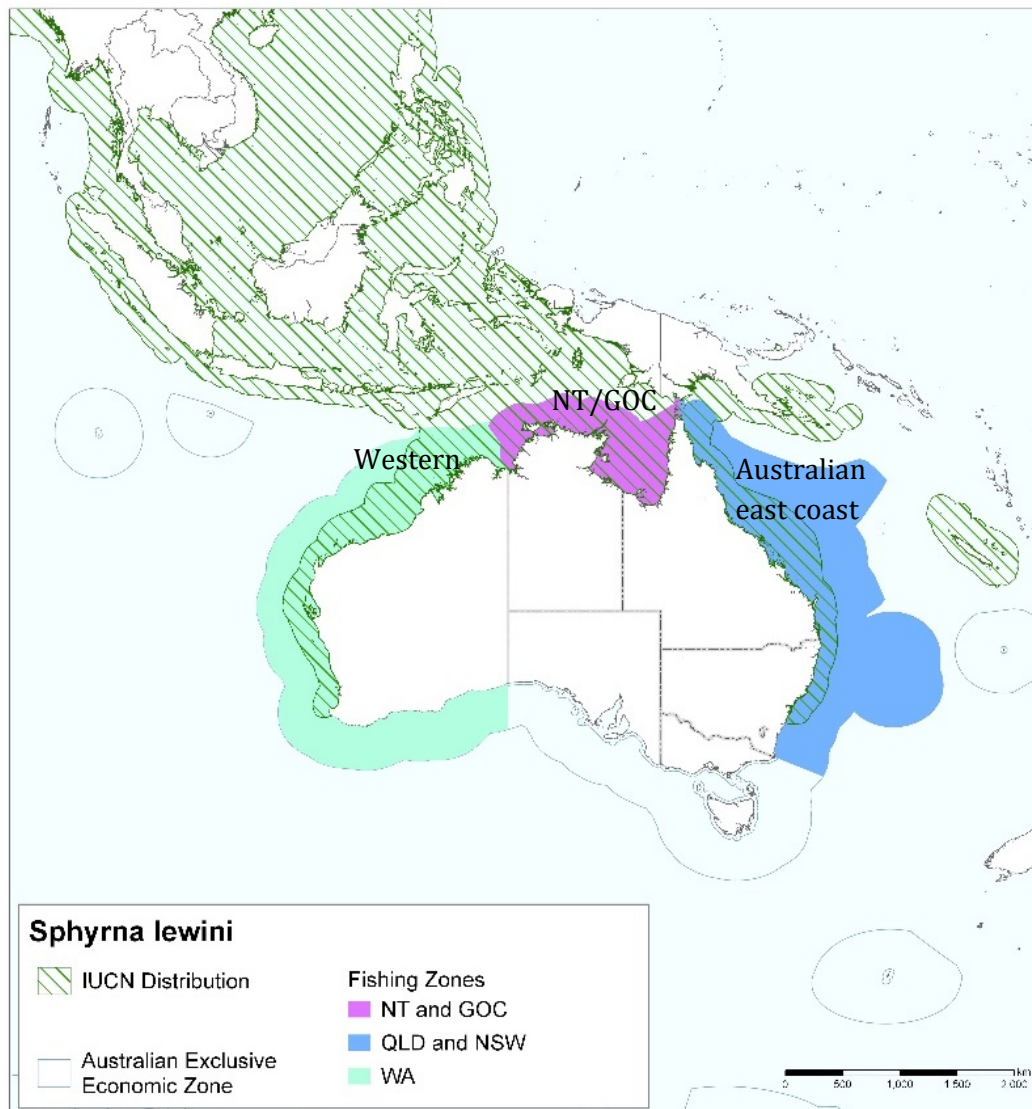


Figure 6 Map of scenario ‘limited movement’.

No catches from Indonesia and PNG are included and hence the models assume zero international connectivity. The boundaries of the Western, NT/GOC and Australian east coast stocks are poorly defined and are considered indicative only. Here, the boundaries are plotted as a visual representation of the how stocks were delineated in stock assessment models (Saunders et al. 2021). The species distribution (green hatching) is from Rigby et al. (2019), compiled by the IUCN Shark Specialist Group in 2018. Contextual data were sourced from the Department of Agriculture, Water and the Environment, Geosciences Australia and PSMA Australia.

Base-case model outputs

Results from stock assessment models across three generations for the Scalloped Hammerhead are presented in Table 6. Based on a generation length of 24 years, the three-generation period is from the start of 1950 until the end of 2021 (72 years) (Kyne et al. 2021). In lieu of reconstructed catches for years 2020 and 2021 (Table 6), biomass trajectories during 1950–2019 are considered as adequate proxies, albeit slightly precautionary, for the biomass trajectories over the past three generations. Catch-MSY models do not include parameter estimation and instead calculate all possible stock abundance trajectories that are consistent with prior assumptions (e.g., about intrinsic rate of population increase and carrying capacity). Hence, although Table 6 includes mean relative biomass levels, each of the greater than 50 000 biomass trajectories are equally probable (Thomson 2021).

Relative biomass (i.e., as a proportion of the model's starting biomass) of the base-case Indo-Pacific stock was 0.80–0.99 in 1950 (the *a priori* starting depletion range), then declined to its minimum (based on mid-point) of 0.07–0.52 in 2013, before increasing to 0.04–0.69 (5th and 95th quantiles) in 2019. Note that the 5th quantile decreased marginally between 2013 and 2019, indicating that the lower bound of the envelope of possible biomass trajectories did not increase during 2013–2019. In 2019, 94.5% of trajectories were at ≤ 0.70 relative biomass (i.e., $\geq 30\%$ depletion), and 42.6% of trajectories were within 0.50–0.21 relative biomass (i.e., 50–79% depletion) (Table 6).

Relative biomass of the base-case Western stock was 0.95–1.00 in 1950 (the *a priori* starting depletion range), then declined to its minimum of 0.41–0.82 in 2008, before increasing to 0.49–0.91 in 2019 (5th and 95th quantiles). In 2019, 54.5% of trajectories were at ≤ 0.70 relative biomass (i.e., $\geq 30\%$ depletion), and 49.5% of trajectories were within 0.70–0.51 relative biomass (i.e., 30–49% depletion) (Table 6).

Relative biomass of the base-case Northern stock was unconstrained (1.00) in 1950, then declined to its minimum of 0.32–0.51 in 2012, before increasing to 0.49–0.68 in 2019 (5th and 95th quantiles). In 2019, 98.2% of trajectories were at ≤ 0.70 relative biomass (i.e., $\geq 30\%$ depletion), and 81.7% of trajectories were within 0.70–0.51 relative biomass (i.e., 30–49% depletion) (Table 6).

Relative biomass of the base-case Eastern stock was unconstrained (1.00) in 1950, then declined to its minimum of 0.34–0.65 in 2009, before increasing to 0.54–0.86 in 2019 (5th and 95th quantiles). In 2019, 57.2% of trajectories were at ≤ 0.70 relative biomass (i.e., $\geq 30\%$ depletion), and 54.6% of trajectories were within 0.70–0.51 relative biomass (i.e., 30–49% depletion) (Table 6).

Trajectories from the NT/GOC and Australian east coast base-case models indicated smaller changes in relative biomass through time. For both, most trajectories finished in 2019 with relative biomass within 1.00–0.71 (i.e., less than 30% decline) (Table 6). However, the Committee considers that there is low support for the limited movement scenario (defined in Table 1).

Recent reconstructed catches of the Scalloped Hammerhead (i.e., from around 2015) have been lower than past catches (i.e., in the 1940s to the 1980s, Table 6), which suggests that the national population may be in a state of recovery (Saunders et al. 2021; Thompson 2021).

However, catch-MSY models are heavily influenced by catch data inputs (Smith et al. 2021), are not designed to detect tipping points, and cannot rule out the possibility that the stock components were not depleted to such low levels by large historic catches that even current low catches are too high (Thomson et al. 2021). Indications of recovery for the western stock in Saunders et al. (2021) are not strongly supported by fluctuating but stable catch rates for Scalloped Hammerhead in fisheries-independent surveys spanning 15 years (2002–2017) in northwest Australia (Braccini et al. 2020; although the authors noted low statistical power of the analyses and that some years were excluded to allow model convergence). It is important to note that the fisheries-dependent data used in the stock assessment models (Saunders et al. 2021) and the fisheries-independent surveys in Braccini et al. (2020) are from operations that were not targeting Scalloped Hammerheads specifically. A space-for-time investigation of potential recovery of shark populations in northwest Australia using Baited Remote Underwater Videos (BRUVs) showed no evidence of recovery of the Scalloped Hammerhead in open water just beyond the reef drop off at Ashmore Reef despite almost 20 years of protection from fishing (Meekan et al. 2006). Although the comparison in Meekan et al. (2006) is of limited spatiotemporal scope and predates the putative period of recovery from around 2015, it does suggest that recovery of the Scalloped Hammerhead may be slow. Furthermore, the extent to which mortality in Indonesia and PNG will continue to inhibit recovery of Australian populations remains unclear (Table 2). Given the complex spatial ecology of the Scalloped Hammerhead (i.e., migration, reproductive philopatry, size/sex segregation), re-population of depleted areas from neighbouring regions is expected to be a slow and complex process (Simpfendorfer et al. 2019). Overall, the Committee considers that collection of better data to support future age-structured models, informed by reliable indices of abundance, is required to strengthen confidence in hypothesised recovery of the Scalloped Hammerhead in Australian waters.

Sensitivity test outputs

For the scenario ‘Continental shelf movements but with stock divide around the WA/NT border’, to account for uncertainty in the level of contemporary connectivity between national jurisdictions, a variety of models were developed with a range of proportions of Indonesia/PNG catch included (25, 50, 75, 100%). Resulting depletion trajectories were almost identical when plotted as a decline in the relative biomass (Appendix 1). Therefore, it can be inferred that uncertainty and variability in the level of movement between Australia and Indonesia/PNG does not substantially influence estimated depletions (when $\geq 25\%$ of catch from Indonesia and PNG is included). The Maximum Sustainable Yield levels depended on the proportions of Indonesia/PNG catch included (Table A1.1).

Sensitivities were undertaken in the Western, Northern and Eastern assessments for the most uncertain catch time series: IUU catches, foreign catches in Australian waters, Australian commercial discards, and Australian recreational catch (Table 6). For the Northern and Eastern stocks, sensitivity tests had a greater percentage of depletion trajectories with biomass ≤ 0.70 (i.e., $\geq 30\%$ depletion) in 2019 compared to their respective base cases (Table 6). For the Northern stock, the percentage of depletion trajectories within 0.50–0.21 (i.e., 50–79% depletion) in 2019 increased to 43.3% given double the illegal and Indonesian catches (Table 6). Overall, these alternative catch scenarios have little influence on inferred declines (Table 6).

For all stock components, models were repeated with the relative biomass in the final year of the time series (2019) constrained to 0.01–0.1 (see 90% depletion fields under ‘Sensitivity’ in Table 6). This was to test the plausibility of depletions around 92% that were inferred by Roff et

al. (2018). This magnitude of decline was not supported by the models, because less than 8% of the simulated population trajectories finished with relative biomass ≤ 0.10 (Table 6). Therefore, a 92% decline in biomass during 1950–2019 is highly unlikely (Saunders et al. 2021).

Table 6 Results of stock assessment models across approximately three generations for the Scalloped Hammerhead (72 years; Kyne et al. 2021). All depletions correspond to years 1950–2019. DIF = sensitivity test with double illegal and foreign catches. DDR = sensitivity test with double commercial discards and recreational catch. HF = sensitivity test with double the illegal and foreign catches. DD = sensitivity test with double commercial discards. MSY = maximum sustainable yield. SRA = stock reduction analysis.

Stock	Catch time series		Model	Sensitivity	Relative biomass (proportion of starting biomass) with 5 th and 95 th quantiles					Percent of depletion trajectories between EPBC & IUCN listing thresholds (expressed as percentage population reduction)					Lowest relative biomass during 1950–2019 with 5 th and 95 th quantiles			
					1950 (starting range)		2019			2019								
	Start	End			Lower	Upper	5 th	Mean ³	95 th	0–29	30–49	50–79	80–89 ¹	90–99 ¹	Year	5 th	Mean ³	95 th
Indo-Pacific	1950	2019	Catch-MSY	Base	0.80	0.99	0.04	0.36	0.69	5.5	22.0	42.6	15.2	14.1	2013	0.07	0.26	0.52
				90% depletion ¹	0.98	0.99	NA	NA	NA	NA	NA	NA	NA	7.7	NA	NA	NA	NA
Western	1941-1942	2017-2018	Catch-MSY	Base ²	0.95	1.00	0.49	0.81	0.91	45.5	49.5	5.0	0	0	2008	0.41	0.72	0.82
				DIF	0.95	1.00	0.42	0.80	0.89	43.5	49.0	7.5	0	0	2008	0.37	0.69	0.83
				DDR	0.95	1.00	0.43	0.80	0.89	43.5	49.0	7.5	0	0	2008	0.39	0.70	0.83
				90% depletion ¹	0.98	0.99	NA	NA	NA	NA	NA	NA	NA	0.006	NA	NA	NA	NA
Northern	1950	2019	Catch-MSY	90% depletion ¹	0.98	0.99	NA	NA	NA	NA	NA	NA	NA	1.2	NA	NA	NA	NA
			Stochastic SRA	Base	1.00 ⁴	1.00 ⁴	0.49	0.57	0.68	1.8	81.7	16.5	0	0	2012	0.32	0.41	0.51
				HF	1.00 ⁴	1.00 ⁴	0.43	0.51	0.63	0.4	56.3	43.3	0	0	2011	0.28	0.37	0.50
Eastern	1981	2019	Catch-MSY	90% depletion ¹	0.98	0.99	NA	NA	NA	NA	NA	NA	NA	1.34	NA	NA	NA	NA
			SRA	Base	1.00 ⁴	1.00 ⁴	0.54	0.69	0.86	42.8	54.6	2.6	0	0	2009	0.34	0.46	0.65

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				DD	1.004	1.004	0.51	0.65	0.83	32.2	62.2	5.6	0	0	2009	0.36	0.47	0.65
NT/GOC	1974	2019	Catch-MSY	Base	0.80	0.99	0.32	0.78	0.97	75.4	13.7	8.2	1.5	1.3	1987	0.16	0.32	0.51
				90% depletion ¹	0.98	0.99	NA	NA	NA	NA	NA	NA	NA	0.01	NA	NA	NA	NA
Aust. East Coast	1981	2019	Catch-MSY	Base	0.50	0.70	0.06	0.44	0.77	59.6	21.4	14.0	2.9	2.2	2009	0.25	0.59	0.84
				90% depletion ¹	0.98	0.99	NA	NA	NA	NA	NA	NA	NA	1.7	NA	NA	NA	NA

¹ The '90% depletion' scenario was conducted to provide context to published reports of significant declines in Scalloped Hammerhead stocks in Northern Australia. These scenarios were not designed to generate estimates of biomass or MSY. Figures provided are the percentage of model runs resulting in a 2019 biomass that was 10% of virgin biomass levels compared to total trials conducted. Only runs resulting in relative biomass between 0.01 and 0.1 were retained.

² The base case Catch-MSY model for the Western Stock was constrained by the assumption that the 2019 biomass was above 20% virgin biomass. This was considered a reasonable assumption given this stock has experienced limited recent fishing mortality and historic catches peaked at approximately 60 tonnes.

³ Each of the > 50 000 biomass trajectories within the upper and lower limits are equally probable.

⁴ Stochastic SRA approach is not constrained by initial depletion levels, reasonable bounds of biological input parameter uncertainty are provided to enable model exploration of possible biomass trajectories using MCMC.

Overall depletions in Australian waters

The Committee has assessed the species at its national extent. Accordingly, this listing assessment integrates the results of multiple models. The combinations of models that comprise the various scenarios are illustrated in Figures 4–6. Table 7 integrates the results of multiple models (depending on the scenario) to inform inference across the national extent, while also taking into consideration potential interactions with shared Scalloped Hammerhead stock(s) outside of Australian waters.

For each model, the range of plausible depletions between 1950 and 2019 was calculated. Minimum depletion was calculated as the biomass 5th-quantile in 1950 minus the biomass 95th-quantile in 2019. Maximum depletion was calculated as biomass 95th-quantile in 1950 minus biomass 5th-quantile in 2019. Minimum and maximum depletions were scaled according to the species' range (km²) within the underlying model's geographic range (km²), as a proportion of the species' total range for the given scenario. This maintained continuity in the geographic scale being considered and was similar in principle to the scaling-by-area in Rigby et al. (2019). Geographic areas were calculated using the species' distribution in Rigby et al. (2019) (see Figures 4–6). Scaled depletions were summed to estimate overall minimum and maximum depletions for each scenario (Table 7).

For models that included data from Indonesia or PNG, those areas were used in the scaling of the depletion estimates, which were subsequently used to calculate scenario-wide depletions for the Australian Scalloped Hammerhead population. This approach ensured that the geographic extent of the area calculations matched the geographic extents of the data included in the underlying stock-assessment models. However, this approach assumes that (1) population density is equal between the modelled areas and (2) relative depletions are homogenous throughout the modelled areas. Therefore, the stock-wide depletions and depletions in Australian waters are presumed to be the same. Given it is plausible that depletion is greater in Indonesia and PNG, this represents a precautionary approach until more information is available.

Table 7 Scaling of depletion levels and estimation of total depletions of Scalloped Hammerhead for each scenario. All depletions correspond to years 1950–2019. Only base case models are included. MSY = maximum sustainable yield. SRA = stock reduction analysis. Negative values indicate an increase in relative biomass.

Scenario	Component	Model type	Depletion (1950–2019)		Area (km ²) ¹	Proportion of total area (km ²)	Scaled depletion		Scenario-wide depletion		
			Min ²	Max ³			Min	Max	Min	Max	Mid
Continental shelf movements but with stock divide around the WA-NT border	Indo-Pacific	Catch-MSY	0.11	0.95	6256591	0.87	0.10	0.83	0.10	0.89	0.50
	Western	Catch-MSY	0.04	0.51	902585	0.13	0.01	0.06			
Continental shelf movements but with stock divides at (1) the Torres Strait land bridge and (2) around the WA-NT border	Western	Catch-MSY	0.04	0.51	902585	0.13	0.01	0.06	0.25	0.50	0.38
	Northern	Stochastic SRA	0.32	0.51	5047240	0.71	0.23	0.36			
	Eastern	SRA	0.14	0.46	1209351	0.17	0.02	0.08			
Limited movement	Western	Catch-MSY	0.04	0.51	902585	0.38	0.02	0.19	-0.12	0.60	0.24
	NT/GOC	Catch-MSY	-0.17	0.67	738857	0.31	-0.05	0.21			
	Australian East Coast	Catch-MSY	-0.27	0.64	723990	0.31	-0.08	0.20			

¹ Areas were calculated using the global distribution for the Scalloped Hammerhead in Rigby et al. (2019).

² Minimum depletion was calculated as the biomass 5th-quantile in 1950 minus the biomass 95th-quantile in 2019.

³ Maximum depletion was calculated as biomass 95th-quantile in 1950 minus biomass 5th-quantile in 2019.

Queensland Shark Control Program

Standardised catch rates for hammerhead sharks (all species) in the QSCP declined by 66.6–83.5% from year 1964 (Simpfendorfer et al. 2011) (Table 5). Subsequent analyses of the same standardised catches yielded annual rates of reduction of 8.4%, consistent with an estimated median reduction of 99.8% over three generation lengths (72.3 years), with the highest probability of more than 80% reduction over three generation lengths (Rigby et al. 2019).

In a different study, Bayesian negative binomial mixed effects models indicated substantial declines in hammerhead shark CPUE over the past five decades. In 1962, an average of 9.5 hammerhead sharks were recorded per net per year, which declined by 92% to 0.8 hammerhead sharks in 2016 (Roff et al. 2018). However, the magnitude of declines reported in these studies are not well supported by the stock assessment models (Table 6).

Various factors complicate the use of standardised catch rates in the QSCP as a proxy for relative abundance of Scalloped Hammerheads over time (Simpfendorfer et al. 2011):

- Catches in the QSCP are largely representative of the male segment of the population.
- Changes in mean body size are variable between studies (Simpfendorfer et al. 2011; Noriega et al. 2011; Roff et al. 2018), potentially due to the confounding effect of species composition. For a period when species-specific data were available (1997–2017), the average size of Scalloped Hammerheads captured in the QSCP declined by 16% (Roff et al. 2018).
- Commercial gillnet fishing in the same waters maintained significant catches of hammerhead sharks during a period of zero catches in the QSCP (Simpfendorfer et al. 2011; Harry et al. 2011b).
- Declines in the QSCP catches commenced in the 1960s, i.e., prior to the largest reconstructed catches of Scalloped Hammerhead across north-eastern Australia, Indonesia, and PNG (Saunders et al. 2021).
- The QSCP data may represent only localised depletions within inshore waters along Australia's east coast or contraction near the edge of the species' range (Roff et al. 2018; Saunders et al. 2021).
- A variety of gear and operational changes in the QSCP (reviewed by Leigh 2015) likely influenced hammerhead shark catches, although the most significant of these (removal of nets in the early 1990s) was accounted for in the various analyses (Simpfendorfer et al. 2011; Roff et al. 2018; Rigby et al. 2019).

Taken together, the causes of declining catch rates of hammerhead sharks in the QSCP remain unclear and catch rates alone do not provide sufficient information to make accurate conclusions about exact population levels (Simpfendorfer et al. 2011). However, the drastic reductions in relative abundance indicated by the QSCP, even if localised or representing a contraction at the edge of the species' range, are in contrast with the increasing biomass trajectories in recent years shown by most of the models presented in Saunders et al. (2021) (Thomson 2021).

Other assessments

The Action Plan for Australian Sharks and Rays (Kyne et al. 2021) balanced (1) declines reported for the QSCP and globally (Rigby et al. 2019), (2) existing management measures, and (3) areas that may provide refuge from fishing, to infer that the Australian population of Scalloped Hammerhead has undergone a reduction of more than 50% over the last three generations (72

years). As such, Kyne et al. (2021) reports that the Australian population of the Scalloped Hammerhead meets the IUCN Red List of Threatened Species Criteria for Endangered A2bd. Based on the same information, the Australian population of the Scalloped Hammerhead is also categorised as 'Depleted' in the Report Card for Australia's Sharks and Rays (Simpfendorfer et al. 2019).

The global population of the Scalloped Hammerhead is listed as Critically Endangered A2bd by the IUCN Red List of Threatened Species (Rigby et al. 2019). This listing was informed by a global trend analysis that estimated a population reduction for Scalloped Hammerhead of more than 80% over the last three generations (Rigby et al. 2019). The analyses used a custom-built Bayesian state-space tool for trend analysis of abundance indices for IUCN Red List assessments. The results of the global assessment have not been projected to the regional scale (i.e., the Australian extent of the species). Rather, the global assessment provides broader context for this national assessment, i.e., evidence of the potential for fishing pressure to drive population size reductions and eligibility for listing under Criterion 1.

Conclusion

Notwithstanding the caveats and limitations associated with the stock assessment models (listed above), the Committee considers that the models in Saunders et al. (2021) use more comprehensive datasets compared to other studies (including those in Table 5). In particular, they include estimates of mortality for all the activities that are likely to interact significantly with the species in northern Australian waters and neighbouring regions. Accordingly, the present listing assessment evaluates all available sources of information, including the stock assessments and their associated caveats and limitations, to make inference about population size reduction under Criterion 1.

The present listing assessment outlines a broad range of information that includes different types of evidence regarding population size reductions for the Scalloped Hammerhead. In formulating its advice, the Committee considered the following key points:

1. The Committee's 2018 advice (TSSC2018) evaluated multiple published indicators of decline on both the east and west coasts (Table 5) and inferred that the Australian population size reduction was most plausibly between 50 and 80%. Among these, declines of 66.6–99.8% in standardised catch rates have been reported for the QSCP. Although they have not been used quantitatively to inform the conclusion under Criterion 1, these studies provide additional context to help evaluate the uncertainty within the stock assessment results in Saunders et al. (2021).
2. For the Indo-Pacific stock, the biomass range of 0.50–0.21 (the EPBC Act thresholds corresponding to a decline of 50–79%, i.e., thresholds for the Endangered category) contained the largest percentage (42.6%) of biomass trajectories in 2019 (Table 6).
3. Depletion estimates for the most supported and most precautionary stock-structure scenario (continental shelf movements but with stock divide around the WA/NT border) range from 0.10 to 0.89 (mid-point 0.50, i.e., within the Endangered category).
4. For the Western, Northern and Eastern components, the biomass range of 0.70–0.51 (corresponding to the Vulnerable category) contained the largest percentage (49.5–81.7%) of biomass trajectories in 2019 (Table 5). However, the Committee considers that delineation of the Northern and Eastern components at the Torres Strait land bridge

is not as plausible as the ‘continental shelf movements but with stock divide around the WA/NT border’ based on analyses of current genetics information (Heupel et al. 2020).

5. There is strong evidence for substantial global declines of the Scalloped Hammerhead caused by fishing (Rigby et al. 2019). The total shark catches, and hence Scalloped Hammerhead catches, reported in Indonesia and PNG are likely to be underestimates of the total catch, and the reported figures do not include the substantial amount of illegal fishing that occurs in those jurisdictions (Table 2) (Saunders et al. 2021) (although the stock assessment models included reconstructed illegal catches).
6. The species is likely to experience cumulative impacts of multiple threats including various sources of fishing mortality, habitat degradation and climate change.

When all the aforementioned information is considered, the Committee judges that the Scalloped Hammerhead is inferred to have undergone a severe reduction in numbers over the last three generations (72 years for this assessment), from 1950 to 2021, whereby decline is most plausibly between 50 and 80%, and the cause of reduction (i.e., mortality caused by fisheries) has not ceased. The various sources of evidence outlined above are based on catch data, which is treated as an index of abundance appropriate to the taxon. Therefore, the species has met the relevant elements of Criterion 1 to make it eligible for listing as Endangered.

When considering thresholds for assessing commercially targeted marine fish, the Committee refers to the Commonwealth Government Harvest Strategy Policy. This policy allows that declines of up to 60% (from pre-fishing biomass levels) are acceptable for commercially harvested fish species where depletion is a managed outcome. It is important to note that the Scalloped Hammerhead is largely a byproduct and bycatch species in Australia, with a history of scarce, unreliable and unvalidated catch and discard information, both within Australia and for shared stocks in Indonesia and PNG. Because of the absence of reliable indices of abundance, reliable and precise estimates of current depletion and MSY cannot be calculated (Thomson 2021).

The purpose of this consultation document is to elicit additional information to better understand the species’ status. The conclusion outlined above should therefore be considered to be tentative at this stage, as it may be changed as a result of responses to this consultation process.

Criterion 2 Geographic distribution as indicators for either extent of occurrence AND/OR area of occupancy

	Critically Endangered Very restricted	Endangered Restricted	Vulnerable Limited
B1. Extent of occurrence (EOO)	< 100 km ²	< 5,000 km ²	< 20,000 km ²
B2. Area of occupancy (AOO)	< 10 km ²	< 500 km ²	< 2,000 km ²
AND at least 2 of the following 3 conditions:			
(a) Severely fragmented OR Number of locations	= 1	≤ 5	≤ 10
(b) Continuing decline observed, estimated, inferred or projected in any of: (i) extent of occurrence; (ii) area of occupancy; (iii) area, extent and/or quality of habitat; (iv) number of locations or subpopulations; (v) number of mature individuals			
(c) Extreme fluctuations in any of: (i) extent of occurrence; (ii) area of occupancy; (iii) number of locations or subpopulations; (iv) number of mature individuals			

Criterion 2 evidence

Not eligible

The Scalloped Hammerhead has a circumglobal distribution in tropical and subtropical waters. Within Australian waters its EOO and AOO (Table 4) are too large to meet this criterion and thus the Committee finds the scalloped hammerhead ineligible for listing in any category under this criterion. However, the purpose of this conservation advice is to elicit additional information to better understand the species' status. This conclusion should therefore be considered to be tentative at this stage, as it may be changed as a result of responses to this consultation process.

Criterion 3 Population size and decline

	Critically Endangered Very low	Endangered Low	Vulnerable Limited
Estimated number of mature individuals	< 250	< 2,500	< 10,000
AND either (C1) or (C2) is true			
C1. An observed, estimated or projected continuing decline of at least (up to a max. of 100 years in future)	Very high rate 25% in 3 years or 1 generation (whichever is longer)	High rate 20% in 5 years or 2 generations (whichever is longer)	Substantial rate 10% in 10 years or 3 generations (whichever is longer)
C2. An observed, estimated, projected or inferred continuing decline AND its geographic distribution is precarious for its survival based on at least 1 of the following 3 conditions:			
(i) Number of mature individuals in each subpopulation	≤ 50	≤ 250	≤ 1,000
(a) (ii) % of mature individuals in one subpopulation =	90 – 100%	95 – 100%	100%
(b) Extreme fluctuations in the number of mature individuals			

Criterion 3 evidence

Not eligible

The estimated total number of mature individuals within Australian waters is likely to be much larger than 10 000 individuals (Table 4), which is too large to meet this criterion and thus the Committee finds the Scalloped Hammerhead ineligible for listing in any category under this criterion. However, the purpose of this conservation advice is to elicit additional information to better understand the species' status. This conclusion should therefore be considered to be tentative at this stage, as it may be changed as a result of responses to this consultation process.

Criterion 4 Number of mature individuals

	Critically Endangered Extremely low	Endangered Very Low	Vulnerable Low
D. Number of mature individuals	< 50	< 250	< 1,000
D2.¹ Only applies to the Vulnerable category Restricted area of occupancy or number of locations with a plausible future threat that could drive the species to critically endangered or Extinct in a very short time			D2. Typically: area of occupancy < 20 km ² or number of locations ≤ 5

¹ The IUCN Red List Criterion D allows for species to be listed as Vulnerable under Criterion D2. The corresponding Criterion 4 in the EPBC Regulations does not currently include the provision for listing a species under D2. As such, a species cannot currently be listed under the EPBC Act under Criterion D2 only. However, assessments may include information relevant to D2. This information will not be considered by the Committee in making its recommendation of the species' eligibility for listing under the EPBC Act, but may assist other jurisdictions to adopt the assessment outcome under the [common assessment method](#).

Criterion 4 evidence

Not eligible

The total number of mature individuals within Australian waters is likely to be more than 10 000, which is not considered extremely low, very low or low. Therefore, the species has not been demonstrated to have met this required element of this criterion. However, the purpose of this conservation advice is to elicit additional information to better understand the species' status. This conclusion should therefore be considered to be tentative at this stage, as it may be changed as a result of responses to this consultation process.

Criterion 5 Quantitative analysis

	Critically Endangered Immediate future	Endangered Near future	Vulnerable Medium-term future
Indicating the probability of extinction in the wild to be:	≥ 50% in 10 years or 3 generations, whichever is longer (100 years max.)	≥ 20% in 20 years or 5 generations, whichever is longer (100 years max.)	≥ 10% in 100 years

Criterion 5 evidence

Not eligible

Population viability analysis has not been undertaken. Therefore, there is insufficient information to determine the eligibility of the species for listing in any category under this criterion. However, the purpose of this conservation advice is to elicit additional information to better understand the species' status. This conclusion should therefore be considered to be tentative at this stage, as it may be changed as a result of responses to this consultation process.

Adequacy of survey

The survey effort has been considered adequate and there is sufficient scientific evidence to support the assessment.

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Version history table

Document type	Title	Date [dd mm yyyy]
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Appendix 1. Stock assessment (Saunders et al. 2021) sensitivity testing

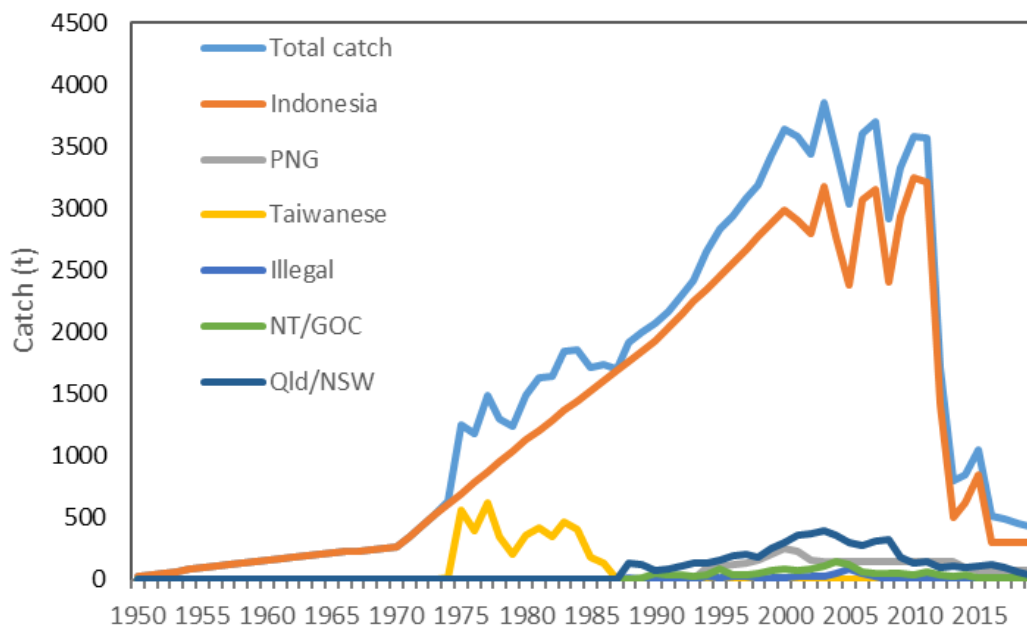


Figure A1.1 Reconstructed annual catch for the Indo-Pacific component between 1950 and 2019 (from Saunders et al. 2021).

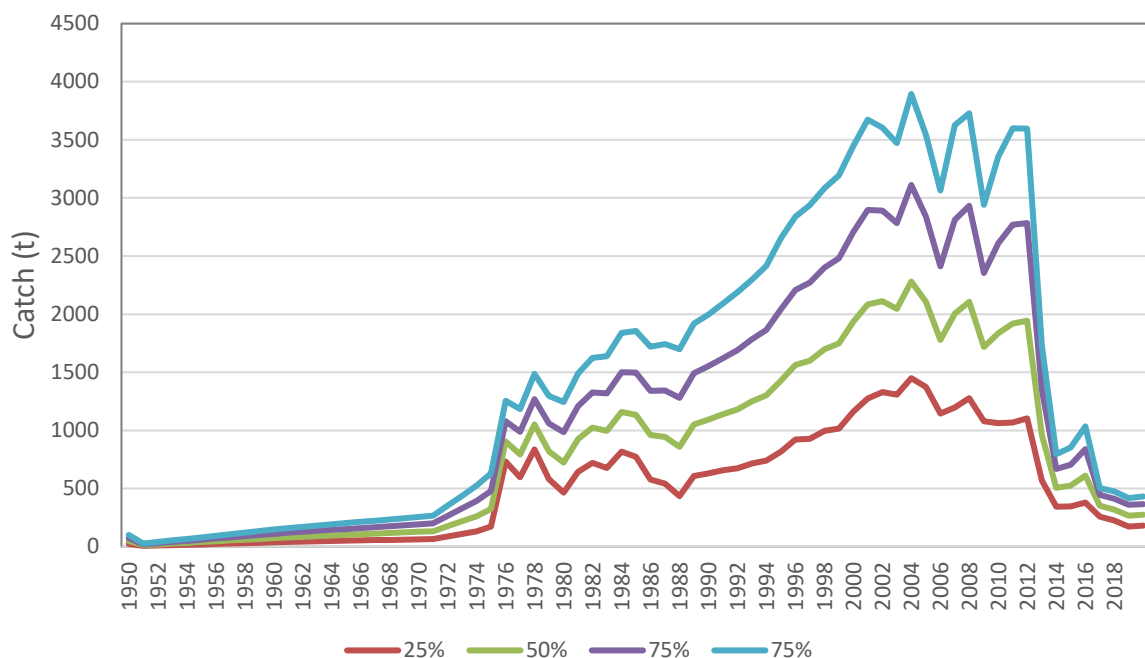


Figure A1.2 Reconstructed annual catch for the Indo-Pacific component between 1950 and 2019. Catch data includes Indonesia, PNG, the Taiwanese fishery, IUU catch, NT, Qld and NSW. Different lines represent different catch histories under the tested scenarios (25, 50, 75, 100% of Indonesian and PNG catch) (Courtesy Northern Territory Department of Industry, Tourism and Trade; July 2021).

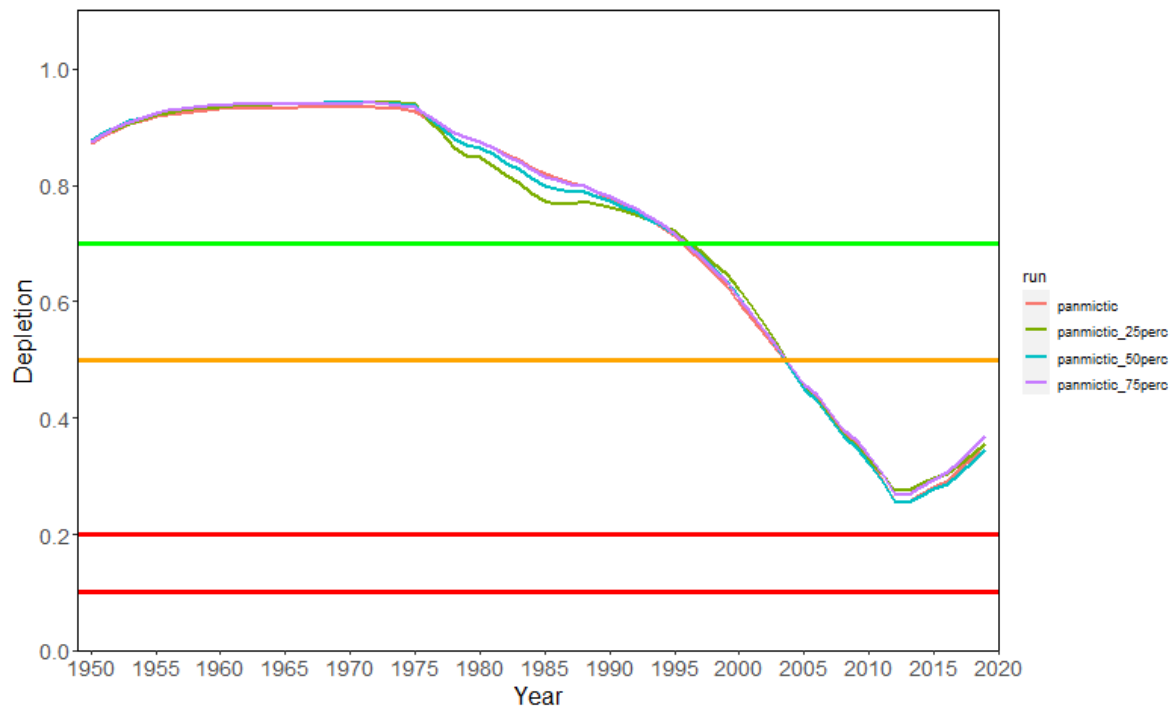


Figure A1.3 CMSY-derived relative biomass trajectories for the Indo-Pacific stock catch sensitivity test. Biomass trajectories are very similar when plotted as decline in biomass relative to the unexploited biomass (Courtesy Northern Territory Department of Industry, Tourism and Trade; July 2021).

Table A1.1 CMSY-derived relative biomass trajectories for the Indo-Pacific stock catch sensitivity test. All depletions correspond to years 1950–2019. MSY = maximum sustainable yield (Northern Territory Department of Industry, Tourism and Trade; July 2021).

Sensitivity	Relative biomass (proportion of starting biomass) with 5 th and 95 th quantiles					Percent of depletion trajectories between EPBC & IUCN listing thresholds (expressed as percentage population reduction)					Lowest relative biomass during 1950–2019 with 5 th and 95 th quantiles				MSY (tonnes)
	1950 (starting range)		2019			2019									
	Lower	Upper	5 th	mean	95 th	0–29	30–49	50–79	80–89 ¹	90–99 ¹	Year	5 th	Mean	95 th	
Base (100% Indonesian/PNG catch)	0.8	0.99	0.04	0.36	0.69	5.6	22.5	42.6	15.2	14.1	2013	0.07	0.26	0.52	2185
75% Indonesian/PNG catch			0.04	0.37	0.71	5.4	25.7	42.1	13.6	13.2	2013	0.08	0.27	0.51	1744
50% Indonesian/PNG catch			0.04	0.35	0.68	5.9	25.8	42.8	13.5	12.9	2013	0.08	0.25	0.48	1267
25% Indonesian/PNG catch			0.04	0.36	0.70	13.2	27.1	38.4	11.3	9.9	2013	0.08	0.28	0.52	795

Table A1.2 Scaling of depletion levels and estimation of total depletions for Scalloped Hammerhead. This table contains the results from additional sensitivity tests. Sensitivities were conducted in the Western, Northern and Eastern assessments for the most uncertain catch time series: IUU catches, foreign catches in Australian waters, Australian commercial discards, and Australian recreational catch. MSY = maximum sustainable yield. SRA = stock reduction analysis. Sensitivity types are indicated in parentheses. B = base case. DIF = sensitivity test with double illegal and foreign catches. HF = sensitivity test with double the illegal and foreign catches. DD = sensitivity test with double commercial discards.

Scenario	Model	Type	Depletion (1950-2019)		Area (km ²) ¹	Proportion of total area (km ²)	Scaled depletion		Scenario-wide depletion		
			Min ²	Max ³			Min	Max	Min	Max	Mid
Continental shelf movements but with stock divide around the WA-NT border	Indo-Pacific	Catch-MSY (B)	0.11	0.95	6256591	0.87	0.10	0.83	0.10	0.90	0.50
	Western	Catch-MSY (DIF)	0.06	0.58	902585	0.13	0.01	0.07			
Continental shelf movements but with stock divides at (1) the Torres Strait land bridge and (2) around the WA-NT border	Western	Catch-MSY (DIF)	0.06	0.58	902585	0.13	0.01	0.07	0.30	0.56	0.43
	Northern	Stochastic SRA (HF)	0.37	0.57	5047240	0.71	0.26	0.40			
	Eastern	SRA (DD)	0.17	0.49	1209351	0.17	0.03	0.08			
Limited movement	Western	Catch-MSY (DIF)	0.06	0.58	902585	0.38	0.02	0.22	-0.11	0.63	0.26
	NT/GOC	Catch-MSY (B)	-0.17	0.67	738857	0.31	-0.05	0.21			
	Australian East Coast	Catch-MSY (B)	-0.27	0.64	723990	0.31	-0.08	0.20			

¹ Areas were calculated using the global distribution for the Scalloped Hammerhead in Rigby et al. (2019).

² Minimum depletion was calculated as the biomass 5th-quantile in 1950 minus the biomass 95th-quantile in 2019.

³ Maximum depletion was calculated as biomass 95th-quantile in 1950 minus biomass 5th-quantile in 2019.