

**Workshop on the Development and Implementation of a
Population Estimate to provide an Estimate of East Coast
Population Numbers for Grey Nurse Sharks (*Carcharias taurus*)
Sydney Institute of Marine Science, Chowder Bay, Sydney**

Friday 11 July 2008, 09:00 – 16:00

FINAL AGENDA

09:00 – 09:15. Arrival and Tea/Coffee

Session 1 – Background, Anticipated Outcomes & Previous Investigations

09:15 – 09:20 Welcome (Alistair Gilmour)

09:20 – 09:30 Project aims, study team & timing (Marcus Lincoln Smith)

09:30 – 10:10 Introduction of participants, points-of-view & expected outcomes (AG)

10:10 – 10:30 Overviews of Previous Investigations (MLS & Julian Pepperell)

10:30 – 10:45 Discussion (AG to lead)

10:45 – 11:00 Tea/Coffee Break

Session 2 – Development of the Preferred Protocol

11:00 – 11:30 Methods of Population Estimation, including visual counts (MLS)

11:30 – 11:50 Baited Video Units (Chris Roberts & Bill Gladstone)

11:50 – 12:40 Marking and recognition techniques for sharks

- Physical tagging (Vic Peddemors)
- Spot recognition and analysis (VP, Carley Bansemer, Sean Barker)

12:40 – 13:00 Discussion (AG to lead)

13:00 – 13:45 Lunch

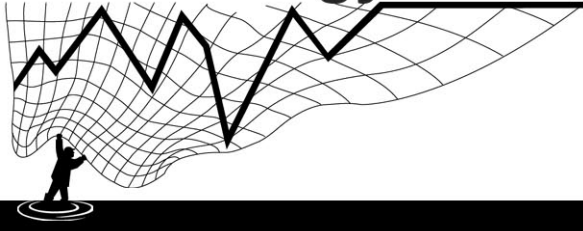
Session 3 – Implementation of the Preferred Protocol

13:45 – 14:45 Objectives, Locations, Methods (MLS)

14:40 – 15:00 Tea/Coffee Break

15:00 – 16:00 General Discussion, Wrap-up & Close (AG to lead)

<i>Grey Nurse Sharks - East Coast Population Estimate (52/0708)</i>	
Grey Nurse Shark Population Estimate - list of participants at Sydney Workshop, 11/7/08	
Name	Affiliation
Professor Alistair Gilmour	Chairman - Macquarie University
Kate Reeds	Rapporteur - TEL
Peggy O'Donnell	Rapporteur - TEL
Marcus Lincoln Smith	Study Team - The Ecology Lab P/L
Chris Roberts	Study Team - The Ecology Lab P/L
Rob Harcourt	Study Team - Macquarie University
Charlie Huveneers	Study Team - Macquarie University
Vic Peddemors	Study Team - Macquarie University/NSW DPI
Bill Gladstone	Study Team - Newcastle University
Carley Bansemer	Study Team - University of Queensland
Julian Pepperell	Study Team - Pepperell Consulting
Emma Lumb	Cwlth DEWHA
Narelle Montgomery	Cwlth DEWHA
Paul Anderson	Cwlth DEWHA
Cassandra Herbert	Cwlth DEWHA
Bill Talbot	Threatened Species - NSW DPI
Dave Harasti	Threatened Species - NSW DPI
Peter Gallagher	Threatened Species - NSW DPI
Bob Creese	Ecological Research - NSW DPI (available half day)
Nick Otway	Shark Research, NSW DPI
Brendan Kelaher	Manager Batemans Bay Marine Park
Joe Neilson	NSW DECC
Miles Yeates	Queensland EPA
Sean Barker	Shark Researcher - Macquarie University
Adam Stow	Genetics - Macquarie University
Megan Kessler	NSW NCC
David Pollard	Conservation Researcher
Claudette Reichtorick	Syd Aquarium CF
Ben Birt	NSW NCC
Dave Thomas	EcoDivers
Lori Scinto	National Parks Association - Marine
John Schulter	AUF
Simon Tripp	AUF
Adrian Wayne	AUF
Mel Brown	AUF
Malcolm Poole	Recreational Fishing Alliance of NSW
Jacinda Poole	Recreational Fishing Alliance of NSW
John Burgess	ANSA
Phil Ingram	Anglers Action Group
Anissa Lawrence	Oceanwatch - commercial fishers
Peter Hitchens	Southwest Rocks Dive
David Booth	University of Technology, Sydney



4 Green Street Brookvale NSW 2100 Australia
Phone (02) 9907 4440 Fax (02) 9907 4446
Email: mls@theecologylab.com.au

GREY NURSE SHARK WORKSHOP, 11/7/08 – BACKGROUND INFORMATION

Background and Aims

The Department of the Environment, Water, Heritage and the Arts (DEWHA) has commissioned The Ecology Lab Pty Ltd to develop a population estimation protocol and undertake a study to provide an estimate of the east coast population of grey nurse sharks (*Carcharias taurus*). The Ecology Lab is doing the study collaboratively with researchers from Macquarie University, Queensland University, Newcastle University, Sea Predator Research Unit Pty Ltd and Pepperell Consulting Pty Ltd ("The Study Team"). As part of the project, The Study Team is also consulting closely with key stakeholders, including government departments of New South Wales and Queensland, fishing and diving groups, conservation groups and other researchers.

The Objective of the study is:

To identify appropriate population and assessment and monitoring methodologies to standardise protocol and assist in the implementation of priority recovery actions identified in the National Recovery Plan for the grey nurse shark, *Carcharias taurus*.

The terms of reference that underpin this study are appended.

Overview of Population Methods Used to study Grey Nurse Sharks

Grey nurse sharks are a coastal species occurring along the east and west coast of Australia, in parts of Asia and the Middle East, the Mediterranean, Atlantic coast of North America and east coast of South Africa. They generally remain close to the seabed in water depths ranging from a few metres to over 100 m. For much of the time grey nurse sharks reside in aggregations at predictable sites, which generally comprise rocky reefs with prominent topographical features such as large caves, overhangs or gutters with sand or rock floors. Their ecology and reproductive ecology makes them vulnerable to over-fishing and declines have been reported in numerous localities. In NSW and Qld they have suffered mortality due to protective beach meshing programmes, fishing and spearfishing. They have been fully protected in NSW since 1984 and in Qld since 1991. Catch returns from protective beach meshing and anecdotal reports from fishers and divers indicate declines along the east coast of Australia, although there is no understanding of what the pre-human population size of this species was, or should have been.

Previous surveys of grey nurse sharks on the east coast have utilised two broad methods. First, indices of relative abundance have been used as a surrogate for total population size. This includes change in catches of grey nurse sharks (and other species) from beach nets over time and variation in counts of grey nurse sharks by scuba divers compared among recognised aggregation sites and/or through time.

Second, mark-recapture methods have been used to derive an estimate of total (absolute) abundance. This method has been used along the east coast of Australia and South Africa. NSW DPI marked by tagging 24 sharks at sites between Fish Rock (Qld) and the Tollgate Islands (southern NSW). Sharks were tagged by being captured, brought to the surface, placed in a cradle beside the research vessel and then double-tagged with a disk tag, one in each dorsal fin. Sharks were released and assumed to distribute themselves throughout the population over approximately one year. The subsequent count of sharks was done by Underwater Visual Census (UVC), although some tagged sharks were also reported by fishers who had captured tagged grey nurse sharks inadvertently.

In South Africa, some 3,500 to 4,000 grey nurse sharks were tagged along the east coast over several years, using recreational fishers, researchers (both by shark capture and underwater tagging) and personnel clearing live sharks from protective beach nets. Several different types of tags were used, including the disc type (as also utilised by NSW DPI) and streamer tags inserted via plastic or stainless barb. The Natal Sharks Board developed a method for tagging grey nurse sharks with streamer tags underwater, which was considered to be highly efficient and cause minimal harm to the sharks. Notwithstanding this, damage to sharks can occur and has been reported from all types of tags, with streamer tags considered to cause the least damage.

Considerable effort has been expended to develop methods to identify individual sharks using natural markings, such as spot patterns. For example, natural distinctive markings on the nurse shark, *Ginglymostoma cirratum*, were used in a mark-recapture experiment at a marine reserve in Brazil. Natural marks included body marks and scars, commonly found on the dorsal, pectoral and caudal fins. All work was done by UVC, including counts and compilation of photographs of sharks. Photo-identification was used to estimate population size using mark-recapture formulae and population structure of whale sharks, *Rhincodon typus*, at Ningaloo Reef, Western Australia. Analysis was based on photographs taken over 12 years and identification was facilitated using a combination of spot and stripe patterns behind the last gill slit and forward of the dorsal fin. In total, 581 photographs were taken from which 159 individuals were identified.

Studies in both Australia and South Africa indicate that grey nurse sharks have individually unique patterns of spots and hold promise for population estimates based on spot recognition (“photo-tagging”) in a mark-recapture context. This approach avoids significant interaction with grey nurse sharks and removes potential injury to sharks from tagging.

Mark recapture techniques are the principle way in which the absolute abundance of a population can be estimated (other than counting every individual in a population). The basic technique of a mark-recapture study is to apply or utilise some mark(s) for a sample of animals from a population at one point in time; the population is then sampled at a later time to identify the number of marked animals as part of the total number counted. Fundamentally, the proportion of marked individuals in the second sample should be the same as the number of marked individuals in the whole population. Key assumptions that should be met include the following:

1. Over the time period being studied the population should be essentially static with essentially no immigration, emigration, births or deaths.
2. All individuals have the same probability of being marked in the first instance.
3. The process of marking does not affect re-sighting of individuals.
4. Marked and unmarked individuals must mix throughout the population by the time of the re-sighting survey.
5. There must be an equal probability for resighting marked and unmarked animals.
6. Marks cannot be lost before the second sample or overlooked during re-sampling. If marks are lost, or marked animals unreported, analysis will yield an over-estimate of population size because it will assume a smaller proportion of marked animals.

A second broad category of mark-recapture applies to open populations. These require at least three sampling occasions, from which not only the population size is estimated but also the population parameters such as survival probability. This approach is not available for the current project because provision has been made for only one sampling occasion following marking of grey nurse sharks. It would, however, be appropriate for any follow-up studies after completion of this project.

Stakeholder Consultation

During the initial stage of this study extensive consultation was held with all stakeholder groups, including researchers, managers, fishers, divers and conservation groups. The project was described to

the stakeholders and information was sought on locations of grey nurse sharks and key issues from various stakeholder perspectives.

Pilot Investigations

During this stage a pilot investigation was also undertaken primarily at Seal Rocks and the Solitary Islands to trial several prospective procedures, including:

- UVC by scuba and free divers at recognised and non-recognised aggregation sites, and for varying periods of time and in depths ranging from < 10 m to 30 m. These counts were used to provide estimates of relative abundance as well as information on shark sizes, sex, evidence of hook/lines and general site conditions. UVC was done following methods described by NSW DPI, including a core 15 minute count at recognised aggregation sites. Three supplementary methods were also trialled: 1) Surveys for longer periods, recorded in increments of 5 minutes; 2) expanded searches at recognised sites; 3) surveys by scuba or snorkel at non-recognised sites, as identified by fishers and divers.

Outcome: During the pilot investigations, 226 grey nurse sharks were counted by UVC. The use of the three supplementary procedures approximately doubled the count of sharks that would have been obtained using the core method.

- Photographic techniques used obtain records of spot patterns that could be used to uniquely identify sharks and to assist in measuring shark length. Two parallel lasers of low power a known distance apart and mounted onto cameras provided reference points against which shark length could be measured.

Outcome: During the pilot, reasonable success was achieved in obtaining photographs of sharks of sufficient quality to be used for photo-tagging. Notwithstanding this, care is required to ensure that the sample size is maximised when there are numerous sharks present in an aggregation – this may require more than one dive at a site. Moreover, it is likely that greater success would be achieved by photographing only one flank

- Baited Remote Underwater Video Stations (BRUVS) which are video cameras mounted within a frame and focused on bait arm containing fish bait. Four BRUVS were lowered to the seafloor at sites of known aggregations in order to determine if sharks could be attracted to the units and hence photographed and counted. The intention is to be able to deploy BRUVS in depths too deep for safe scientific diving (e.g. 30 – 100 m).

Outcome: The pilot study found that the BRUVS were successful in attracting and photographing grey nurse sharks. Therefore, they are likely to be useful in establishing the presence of sharks at deeper sites if they occur there. The pilot, however, indicated that BRUVS are likely to underestimate the abundance of grey nurse sharks at a site. Moreover, images obtained by BRUVS are likely to yield fewer photographs suitable for spot-recognition, but they probably would be suitable for identifying physical tags because this would not require the extraction of a still photograph.

Selection of Prospective Sites for Grey Nurse Sharks

In total, 118 survey sites have been identified at which counts of relative abundance, estimates of size and initial “marking” of grey nurse sharks could be done, including:

- All recognised aggregation sites, including designated critical habitats.
- Numerous non-recognised sites that have been identified following review of the literature and stakeholder consultation.

All sites have been classed into three priorities for visitation, comprising 64, 36 and 18 Priority I, II & III sites, respectively. Emphasis would be placed on visiting as many of the Priority I sites as possible, with sites of lesser priority visited on an opportunistic basis. It is aimed to visit a minimum of 50 sites, although this will be subject to weather and sea state.

Recommended Protocol for Estimating the East Coast Population of Grey Nurse Sharks

The protocol that is recommended to achieve the objective of the project involves a mark-recapture experiment with sharks being recorded primarily using UVC, but also with some use of BRUVS at deeper sites. In addition, counts of relative abundance would be obtained to enable comparisons of data with previous surveys. We recommend that the sample sizes be structured to be able to yield a minimum population size of grey nurse sharks ranging from 300 to 5,000 individuals. Based on this range and simulations of various combinations of mark and resighting numbers, our goal is to photo-tag a minimum of 200 individual sharks in each of the two phases of the study (i.e. the mark and re-sighting phases).

As a contingency, we also propose to mark, using streamer tags, a total of 80 grey nurse sharks. Sharks would be tagged by divers underwater and the process would not involve capture or restraint of any sharks. In order to facilitate the estimation of large population size, we would need to inspect approximately 450 individuals by eye for the presence or absence of tags during the re-sighting phase. Given that over 200 sharks were observed at a few sites during the pilot study a goal of 450 sharks is not unrealistic. Ideally all tagged sharks would also be photographed as a form of “double-tagging” to enable cross checking of methods, estimation of tag loss, etc.

The preferred protocol for estimating the size of the east coast population of grey nurse sharks will be subject to approval by DEWHA, consensus at the technical workshop and requirements for permits (including ethics approval) from the Commonwealth, NSW and Qld. At this time, we recommend the following protocol based on the information gathered during this stage of the project.

1. A minimum of 50 sites within safe diving depths (> 30 m) would be visited along the east coast of Australia extending from Bundaberg to Eden. Sharks would be searched for using scuba and snorkel as appropriate for the site and sea conditions, with the aim of maximising access to most or all of the sharks present at each site visited. Additional sites would be sampled opportunistically.
2. At each site up to three tasks would be addressed:
 - a. Photographs would be taken of the left flank of as many sharks present as possible. The photographs would frame each shark from its snout to its caudal pit, with the aim of capturing images capable of being analysed in terms of spot patterns. At least one diver would have photography as a dedicated task at each site. Where large aggregations of grey nurse sharks occur (say, > 25 sharks), two photographers would be used if available. Digital cameras would be used with parallel lasers mounted on them to enable estimates of shark length to be made.
 - b. A separate diver would accompany the photographer(s) and compile a count of abundance, length, sex presence of fish hook(s) or line and local environmental conditions. Counts would be done over an initial 15 minute time period, with data recorded in five minute increments thereafter. This would allow a comparison with earlier methods of sampling relative abundance and potentially increase the number of sharks recorded.
 - c. As a contingency for the photo-tagging, up to 80 sharks would be physically tagged underwater using a streamer (dart) tag. The tag would be inserted near the dorsal surface of the shark just in front of the first dorsal fin using a hand spear with a specially constructed applicator, similar to work done in South Africa. If possible, each shark would be photographed after physical tagging, which would essentially provide two means of recognising some sharks. The tags would be colour-coded for bioregion and between recognised and non-recognised sites.
3. One survey would be undertaken in July/August 2008. This would represent the photo-tagging phase. Several teams of scientists would be involved, but the study would commence in the north and work southwards, to help control (but probably not eliminate) the risk of double-counting sharks that are migrating to the north. Each team would

comprise two or more scientists, with some assistance from local divers where feasible (who could provide local knowledge on sharks sites and safety matters). Quality of data collection will be strictly controlled by the researchers in each field team. The survey would be done over the shortest time span possible, which optimistically will be over two weeks but may extend over four weeks depending on weather conditions.

4. BRUVS would be deployed in deeper water at ≥ 10 sites along the east coast to provide some indication of the occurrence of grey nurse sharks in deeper water and potentially yield some photographs of sufficient quality to use in the estimates of population size. Comparison of BRUVS images obtained at these deeper water aggregations to photographs taken at shallow water aggregations may also provide insight into the degree of mixing between these areas.
5. A second survey is currently scheduled to be done in October/November 2008. Consensus for the timing of this survey would be sought at the Technical Workshop, but our recommendation is to delay this survey until autumn 2009 to allow thorough mixing of marked individuals throughout the east coast population. During the second survey, Tasks 1, 2a and 2b would be repeated, but there would be NO further physical tagging done.
 - a. The photographer(s) would aim to collect a minimum of 200 images of individual grey nurse sharks (in aggregate from all field teams). If possible, photographs would be taken of any sharks that had previously been tagged during the first survey. This would potentially provide extremely valuable information on the rate of tag losses and confirmation of the presence of consistent spot patterns between the surveys.
 - b. A separate diver accompanying the photographer(s) would compile a count of shark abundance, size, sex, presence of hooks, etc at each site. Particular care would be taken to look for and count any sharks with tags previously administered during the first survey. Wherever possible, the colour-coding on the tags would be recorded. The aim would be to inspect a minimum of 450 sharks (in aggregate from all field teams) for the presence/absence and colour-codes of tags. Only those sharks that are close enough to the diver such that s/he is confident that a tag would have been observed if present would be included in the counts of tag presence or absence. Therefore, sharks seen in the distance will be included in counts of relative abundance but not in assessments of tagging.
6. BRUVS would be deployed in deeper water as per the first survey, but subject to review of the findings of the first survey.
7. In the laboratory, images would be analysed by eye and spot-recognition software (I³S program) to compile a database of individually recognisable grey nurse sharks. All images would be archived to allow further analysis in the future, if required. Video images/stills from BRUVS would be inspected for the presence of tags and for spot patterns that could identify individual sharks.
8. The data obtained on numbers of sharks photo-tagged during the first survey; the numbers photo-tagged in the second survey and the numbers of those photo-tagged in the second survey that were recognised from the first would be used to determine population size, variance and confidence using mark-recapture formulae. Parallel analyses would be done using the data from sharks tagged physically. In addition, data on relative abundance, size, sex and evidence of hooking would be summarised and interpreted spatially and temporally.

Appendix: Terms of Reference to develop a population estimation protocol and undertake a study to provide estimated east coast population numbers for grey nurse sharks (*Carcharias taurus*).

The Objective of the study is:

To identify appropriate population and assessment and monitoring methodologies to standardise protocol and assist in the implementation of priority recovery actions identified in the National Recovery Plan for the grey nurse shark, *Carcharias taurus*.

To achieve this objective, The Study Team is to perform the following Services:

1. Develop a standardised protocol, including a review and assessment of the current population abundance estimation techniques, to estimate the numbers of the east coast population of grey nurse sharks.
 - The protocol must be robust, statistically defensible and appropriate to the species.
 - The protocol must also be repeatable and able to develop a time-series of abundance estimates in order to measure population trends.
 - All relevant stakeholders will need to be consulted in the development of the standardised protocol.
2. Apply the agreed, proposed method for estimating the population numbers of the east coast population of grey nurse sharks. The study should be undertaken in such a manner as to estimate population numbers for the whole distribution of the east coast population, including addressing assumptions of immigration and emigration.

To provide the Services listed above, the Study Team will perform the following Activities:

1. Undertake a comprehensive review of all current population estimation methodologies, outlining which aspects would, and would not, be suitable for estimating population size of the east coast population of grey nurse sharks, including a detailed discussion of the preferred population methodology.
2. Consult stakeholders (on project background, proposed methodology, participation, grey nurse shark population site details, subject to appropriate management of information given to The Study Team in confidence).
3. Design and implementation of, and reporting on, a pilot study to:
 - a. Refine diver survey methods
 - b. Review historical survey site information
 - c. Compare estimates using diver and video methods
 - d. Acquire further data to be used to catalogue individual grey nurse sharks.
4. Select prospective sites for study during the implementation phase of the study.
5. Prepare a draft report on findings of the above activities for DEWHA.
6. Convene a technical workshop in Sydney to discuss and agree on the preferred protocol. Attendees to include collaborators, peer reviewers, representatives from DEWHA, key stakeholders, etc.
7. Undertake the field component of the project to gather data to determine a population estimate for the east coast population of grey nurse sharks.
8. Submit a final report to DEWHA, with an assessment of the extent to which the performance of the Activities met the study Objective.

The study is being undertaken in two stages. Stage 1 addresses Activities 1 – 5. Activity 6 will be incorporated into the Final of the Stage 1 Report. Activities 7 and 8 will constitute Stage 2.