ABUNDANCE, DEMOGRAPHY AND POPULATION STRUCTURE OF THE GREY REEF SHARK (*CARCHARHINUS AMBLYRHYNCHOS*) AND THE WHITETIP REEF SHARK (*TRIAENODON OBESUS*) (FAM. CARCHARHINIDAE)

Thesis submitted by
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April 2006

For the degree of Doctor of Philosophy in Marine Biology
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CONTRIBUTION OF OTHERS TO THIS THESIS

Corey Green (Primary Industries, Victoria):

- Photography of sectioned oxytetracyclined vertebrae (Chapter 3)

Ashley Williams (James Cook Uni):

- Excel growth model fit macro (Chapter 3)

Mizue Hisano & Sean Connolly (James Cook Uni):

- "R" code for maximum likehood tests of reef/zone abundance data (Chapter 2)
- "R" code for fitting logistic bootstraps to maturity data (Chapter 4)
- "R" code for fitting saturation curves to *Carcharhinus amblyrhynchos* litter size (Chapter 4)

Sue Reilly (James Cook Uni):

- Histological expertise in preparing and sectioning shark gonads (Chapter 4)

Jenny Giles (CSIRO):

- *T. obesus* tissue samples from Bali (Chapter 7)

Richard Fitzpatrick and Andy Dunstan (MV *Undersea explorer*):

- *T. obesus* tissue samples from Osprey reef (Chapter 7)

I would also like the following granting bodies for their financial support of this project:

- Australian Academy of Science
- Australian Coral Reef Society (x3)
- Cooperative Research Centre (CRC) Reef (x5)
- Great Barrier Reef Marine Park Authority (x3)
- PADI Aware Asia Pacific (x2)
- School of Marine Biology and Aquaculture (James Cook University) (x3)
- Kate & Noel Monkman stipend support (James Cook University)

PUBLICATIONS ARISING FROM THIS THESIS

Published.

Robbins WD. 2006. Evaluation of two underwater biopsy probes for *in situ* collection of shark tissue samples. *Marine Ecology Progress Series* 310: 213-217.

Robbins WD and Choat JH. 2002. Age-based dynamics of tropical reef fishes. *Technical Manual. James Cook University.* Townsville. 39pp.

In review.

Robbins WD, Hisano M, Connolly S and Choat JH. *In review*. Ongoing collapse of coral reef shark populations. *Current Biology.*

In prep.

Robbins WD and Choat JH. *In prep*. Abundance of reef shark populations: Implications for conservation and management. *P. Roy. Soc. Lond. B. Bio.*

Robbins WD. *In prep*. Age and growth of two species of coral reef carcharhinids on the Great Barrier Reef (Australia). *J. Fish. Biol.*

Robbins WD. *In prep*. Reproductive biology of the grey reef shark *Carcharhinus amblyrhynchos,* and the whitetip reef shark *Triaenodon obesus* in tropical waters. *Mar. Biol.*

Robbins WD. *In prep*. Mortality and demography of two species of coral reef carcharhinids: evidence of populations in decline. *Coral Reefs.*

Robbins WD, Choat JH and Bowen B. *In prep*. Genetic stock structure of the whitetip reef shark *Triaenodon obesus* on the Great Barrier Reef (Australia) and across the Indo-Pacific. *Mar. Biol.*

ACKNOWLEDGEMENTS

I would like to thank my supervisor, Prof. J. Howard Choat for his input and faith in this project over the last 5 years. His knowledge of coral reef ecosystems has been a constant source of valuable information, and an inspiration to succeed. Thank you also to Assoc. Prof. Garry Russ for your assistance and co-supervision of this project.

To the many people who have helped me in the laboratory and the field. Thank you for your time, effort, and for many late nights covered in bait and shark bits. Especial thanks to Rachel Green, whose help was invaluable, and always given freely with a smile. Thanks also to Tony Ayling, Eddie Game, Tom Lisney, Chadd Chustz, Kendall Clements, David Raubenheimer, Stirling Peverell and Jess Burton. Also a big thank-you to Kurt Hammond, Brian Bartlam, Auslink commercial fisheries, Jenny Giles, Richard Fitzpatrick, Andy Dunstan and the crew of *Undersea explorer*, as well as the directors and staff of Lizard Island, One-Tree Island, Coconut Island and Criobe field stations.

Thank you to Terry Walker and Corey Green of Primary Industries Research, Victoria. Your assistance in the interpretation of growth rings and reproductive biology of elasmobranches has improved both my knowledge and this thesis enormously. Thanks also to Jennifer Schultz, Lynne van Herwerden, Sean Connolly, Mizue Hisano, Selma Klanten, Sue Reilly, Alex Anderson, John Ackerman, Ashley Williams and Brian Bowen who have assisted me with the analysis and interpretation of results.

To the friends of mine who have helped me with feedback, assistance and for always being there when I needed it. To these people I say a very heartfelt thank-you. Especial thanks go (in no particular order) to Jo-anne Blinco, Kerrie Gorman, Elisabeth Laman-tripp, Rachel Green and Shane Askew. And to Ailsa Kerswell – thank you for being the best friend, partner and giant freddo provider a guy could have. You were always there with a smile, a coffee, and although usually not taken, more often than not good advice.

And finally to my parents, who have always been there for me, and always encouraged me to follow my goals. Without your support I would never have come this far. Words seem so inadequate, but thank you so much.

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Thesis abstract.

Reef sharks (fam. Carcharhinidae) are high-order predators, found throughout the Indo-Pacific. I examined the abundance, growth, reproduction and demography of two species of reef carcharhinid; the grey reef shark (*Carcharhinus amblyrhynchos)* and the whitetip reef shark (*Triaenodon obesus*), and investigated the genetic stock structure of *T. obesus* across the Indo-Pacific.

Underwater visual census protocols were successfully developed, and provided real-time, fisheries-independent estimates of reef carcharhinid abundances. Visual censusing of a minimally-exploited reef system ascertained that reef crest was the preferred habitat of *T. obesus* and *C. amblyrhynchos*, while the blacktip reef shark (*C. melanopterus*) was more abundant in reef flat and lagoon habitats. Reef carcharhinid densities were low, and even in the most abundant habitat, did not exceed 3.5 sharks hectare^{-1}. Visual censuses across reef systems in the Indian and Pacific Oceans found consistently low numbers of reef sharks, with most regions having less than 0.5 sharks hectare^{-1}. Closer investigation of the Great Barrier Reef (Australia) revealed a significant effect of fishing management on reef shark abundance. All levels of fishing pressure impacted upon reef carcharhinid abundance, with reductions on fished reefs of up to 80% and 97% for *T. obesus* and *C. amblyrhynchos*, respectively. This suggests that reef shark populations are particularly vulnerable to population depletion. The inability of marine protected areas to provide refuge for reef carcharhinids was highlighted and discussed.

Age and growth characteristics of *T. obesus* and *C. amblyrhynchos* populations from the Great Barrier Reef were examined through vertebral thin sections. Both shark species

grew slowly, with longevities of 19 years. Females out-lived males in both species. Both sexes of *C. amblyrhynchos* grew at similar rates, while sexually-dimorphic growth rates were observed in older *T. obesus*. Age estimates were preliminarily validated through oxytetracyclined recaptures of *C. amblyrhynchos*, while characterisation of the vertebral edge provided strong evidence that *T. obesus* also lays annual growth bands.

Females matured 1-2 years later than males, at 8 and 11 years for *T. obesus* and *C. amblyrhynchos*, respectively. Mean litter sizes were comparable with smaller (<1 m) carcharhinids. Litter sizes initially increased with female body size in *C. amblyrhynchos*, reaching 3-4 pups per breeding for most of their reproductive life. Litter sizes ranged between 1-4 pups per breeding in *T. obesus*, with a mean of 2 pups per breeding, irrespective of female somatic size. Breeding occurs biennially in both species, with an offspring sex ratio of 1:1. For the longevities recorded, maximum reproductive output was estimated at 12 pups per female for both species.

Population dynamics of the two species were analysed using age-based (Leslie) matrices. Using two methods of mortality estimation, annual decline rates of 6.3-8.8% $year^{-1}$ and 10.3-15.2% $year^{-1}$ were found for *T. obesus* and *C. amblyrhynchos*, respectively. This suggests that reef carcharhinids are overfished on the Great Barrier Reef. Based on current (albeit exploited) demographic parameters, the natural rates of population growth were estimated at 3.4-5.7% $year^{-1}$ for *T. obesus*, and 0.8–3.5% $year^{-1}$ for *C. amblyrhynchos*. Elasticity analyses and reproductive values showed that juvenile survival is the most important component of each species lifespan. However, catch analyses revealed that a high proportion of juveniles are taken in both species (especially *C. amblyrhynchos*). At the current rates of decline, abundances of *T. obesus*

and *C. amblyrhynchos* are forecast to decline to 16-27% and 4-12% of current levels on fished reefs in the next 20 years, respectively.

Development of an *in-situ* underwater biopsy probe enabled non-lethal, minimally invasive, collection of reef carcharhinid tissues. High levels of genetic differentiation were found in *T. obesus* across the Indo-Pacific, as well as between two contiguous sites on the Great Barrier Reef. Genetic separation did not correlate with geographic separation, suggesting that *T. obesus* has a high degree of site fidelity on coral reefs, even when migrations are possible. On an evolutionary scale, it was found that the Indian Ocean was invaded first by *T. obesus*, with Pacific Ocean invasion occurring simultaneously with a second Indian Ocean invasion.

The unique combination of fisheries-independent abundance counts, population dynamics and investigation of genetic stock structure provides a comprehensive overview of the low abundance and slow population dynamics of coral reef carcharhinids. Findings from this PhD provide further evidence of the variety of age and reproductive strategies employed by the family Carcharhinidae, and a scientific basis for future decisions regarding reef carcharhinid management.