Spatial ecology of mobile predators in a nearshore tropical environment and its implication for marine protected areas

Thesis submitted by
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BSc Honours (*Dalhousie University*)

For the degree of
Doctor of Philosophy
Fishing and Fisheries Research Centre
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Townsville, Queensland
November 2011

Nearshore tropical environments provide important habitat for a range of shark species of different life stages including juvenile pigeye *Carcharhinus amboinensis* (top) and adult spottail *Carcharhinus sorrah* (bottom) sharks. *Photo credits: Fishing and Fisheries Research Centre and M. R. Heupel.*

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STATEMENT ON THE CONTRIBUTION OF OTHERS

Research Funding:
- Australian Research Council
- Great Barrier Reef Marine Park Authority
- School of Earth and Environmental Sciences, James Cook University
- James Cook University International Postgraduate Research Scholarship co-funded with the School of Earth and Environmental Sciences

In-Kind Support:
- Fishing and Fisheries Research Centre, School of Earth and Environmental Sciences, James Cook University

Supervision:
- Dr. Michelle Heupel, Australian Institute of Marine Science and James Cook University
- Dr. Colin Simpfendorfer, Fishing and Fisheries Research Centre, School of Earth and Environmental Sciences, James Cook University
- Dr. Andrew Tobin, Fishing and Fisheries Research Centre, School of Earth and Environmental Sciences, James Cook University
- Dr. James Moloney, School of Earth and Environmental Sciences, James Cook University

Statistical and Analytical Support:
- Dr. Colin Simpfendorfer
- Dr. Michelle Heupel
- Dr. James Moloney
- Elodie Lédée, School of Earth and Environmental Sciences, James Cook University

Editorial Support:
- Dr. Michelle Heupel
- Dr. Colin Simpfendorfer

ACKNOWLEDGEMENTS

I extend the utmost gratitude to my supervisory committee, Michelle Heupel, Colin Simpfendorfer, Andrew Tobin and James Moloney. I could not have asked for a better team of people to guide me through this project. Michelle, I have come a long way in three years and I owe that to you. Thank you for your endless patience, guidance and for all the time you invested in me. You taught me a lot and I will forever be grateful. To Colin, your statistical expertise and understanding of elasmobranchs were an invaluable resource. Thank you for imparting knowledge, helping me with R and always having an open door. To Andy, I am grateful for your vast fishing knowledge and for the fresh perspective you gave to this project. Thank you for always taking time for me and for answering my questions. James, thank you for teaching me GIS skills and helping me improve my analytical abilities.

To the Fishing and Fisheries Research Centre, thank you for including me in your group and providing a solid foundation for this project. To Amos Mapleston, Al Harry, Andrew Chin, Owen Li, Natasha Szczecinski, Cynthia Awruch, Jimmy White, Fernanda de Faria, Daniela Waltrick, Audrey Schlaff and Ron Schroeder, your help in the field was invaluable. Without you I would have accomplished a lot less. Ann Penny and Leanne Curry, thank you for having all the answers and helping me with even the little things. To all the volunteers, thank you for the long hours you in put in for me and your enthusiasm for this project.

I am very grateful to the agencies that provided funding for this project including the Australian Research Council, Great Barrier Reef Marine Park Authority and School of Earth and Environmental Science at James Cook University. In addition, a James Cook University International Postgraduate Research Scholarship co-funded with the School of Earth of Environmental Sciences gave me the opportunity to pursue this PhD.

Thank you to the James Cook University staff that assisted with all things administrative, boat, vehicle, equipment, computer and electronic related. Clive Grant, Rob Scott, Ralph Botting, Glen Connolly, Paul Giveny, Phil Osmond, Jane Webb, Julie Fedorniak, Blake Hudson and Beth Moore, thank you for your patience and help. You made my life easier.

To my Townsville friends, thank you for your companionship. Nikki and Katie, I could not have asked for better friends or office mates. Thank you for being my sounding board, my shoulder to lean on and for always being there. You made my time here special. To Cameron and Tom, thank you for your friendship and support. Natasha, I am grateful that you added something North American to my life. Thank you for all the coffee breaks.

To my family and friends back home, thank you for your understanding, encouragement and for believing in me. Kim, thank you for being such an unconditional friend. To my parents, sisters and brothers, thank you for always cheering me on and encouraging me to follow my dream. To my Nova bear, your furry face always made me smile and for that I am grateful. For Darryl there is no thank you big enough. Darryl, I thank you for everything. Thank you for all the early mornings and late nights, keeping me sane, and for your patience, understanding, support and unwavering confidence in me. Thank you for sharing this experience with me, I could not have done it without you.

LIST OF PUBLICATIONS RESULTING FROM THIS RESEARCH

Original Articles:

Knip, D. M., Heupel, M. R., and Simpfendorfer, C. A. (2010). Sharks in nearshore environments: models, importance, and consequences. *Marine Ecology Progress Series* **402**, 1-11. ***Journal Feature Article***.

Knip, D. M., Heupel, M. R., Simpfendorfer, C. A., Tobin, A. J., and Moloney, J. (2011). Ontogenetic shifts in movement and habitat use of juvenile pigeye sharks *Carcharhinus amboinensis* in a tropical nearshore region. *Marine Ecology Progress Series* **425**, 233-246.

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Knip, D. M., Heupel, M. R., and Simpfendorfer, C. A. (in review). Habitat use and spatial segregation of adult spottail sharks *Carcharhinus sorrah* in tropical nearshore waters. *Journal of Fish Biology*.

Knip, D. M., Heupel, M. R., and Simpfendorfer, C. A. (in review). Evaluating marine protected areas for the conservation of tropical coastal sharks. *Biological Conservation*.

Conference, Workshop and Meeting Presentations:

Knip, D. M., Heupel, M. R., Simpfendorfer, C. A., Tobin, A. J., and Moloney, J. (2008). Spatial ecology of mobile predators in a nearshore tropical environment. Poster presentation. *James Cook University School of Earth and Environmental Sciences Conference*. Townsville, Queensland. November 12, 2008.

Knip, D. M., Heupel, M. R., Simpfendorfer, C. A., Tobin, A. J., and Moloney, J. (2009). Spatial ecology of mobile predators in a nearshore tropical environment: preliminary results. Poster presentation. *8th Indo-Pacific Fish Conference*. Fremantle, Western Australia. June 4, 2009.

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Knip, D. M., Heupel, M. R., Simpfendorfer, C. A., Tobin, A. J., and Moloney, J. (2010). Seasonal patterns in movement and distribution of juvenile pigeye sharks (*Carcharhinus amboinensis*) in Cleveland Bay, north Queensland. Oral presentation. *Sharks International*. Cairns, Queensland. June 7, 2010.

Knip, D. M., Heupel, M. R., Simpfendorfer, C. A., Moloney, J., and Tobin, A. J. (2010). Site fidelity and habitat use of the spottail shark (*Carcharhinus sorrah*) in a tropical nearshore environment. Oral presentation. *Joint Meeting of Ichthyologists and Herpetologists*. Providence, Rhode Island. July 9, 2010. ***American Elasmobranch Society Best Student Presentation Award***.

Heupel, M. R., Simpfendorfer, C. A., Knip, D. M., Chin, A., and White, J. (2010). Spatial ecology of nearshore elasmobranchs. Oral presentation. *Joint Meeting of Ichthyologists and Herpetologists*. Providence, Rhode Island. July 10, 2010.

LIST OF OTHER PUBLICATIONS COMPLETED DURING THIS RESEARCH

Original Articles:

Heupel, M. R., Knip, D. M., de Lestang, P., Allsop, Q. A., and Grace, B. S. (2011). Short-term movement of barramundi in a seasonally closed freshwater habitat. *Aquatic Biology* **12**, 147-155.

Knip, D. M., Heupel, M. R., and Simpfendorfer, C. A. (in review). To roam or to home: site fidelity in a tropical coastal shark. *Marine Biology*.

ABSTRACT

Nearshore environments are of high value and provide important habitat for a diverse assemblage of shark species. However, these regions are also highly dynamic, creating challenging conditions for inhabitants due to their shallow nature and close proximity to shore. This dissertation research defines the spatial ecology of sharks within a nearshore tropical environment to (1) provide a better understanding of the factors influencing species distribution, habitat use and movement patterns and (2) evaluate the effectiveness of marine protected areas (MPAs) for sheltering these mobile species from exploitation (e.g. fishing pressure).

Although shark species are highly diverse and occur in a wide range of habitats, limited effort has gone into understanding population level use of habitat. Theoretical models describing coastal shark populations have remained largely unchanged since the 1960s despite limitations in applicability to many species, with smaller-bodied species being poorly represented by the current models. Coastal shark populations have typically been described as using nearshore nursery areas as juveniles and then moving further offshore as adults. A new theoretical model is proposed in this dissertation to represent those species that spend most or all of their life within nearshore regions, but do not show use of discrete nursery areas. Description of this new model outlines the importance of nearshore regions to smaller-bodied species in particular.

Field work was conducted using passive acoustic monitoring to examine the presence and movements of two coastal shark species within a nearshore tropical environment. An array of fifty-seven acoustic receivers deployed throughout two MPA regions in Cleveland

Bay, north Queensland, Australia, passively tracked pigeye *Carcharhinus amboinensis* and spottail *Carcharhinus sorrah* sharks from 2008 to 2010. These species were selected to define differences in the use of nearshore habitat between sharks that have different life history and ecological characteristics, putting the results of the theoretical population models into context. *Carcharhinus amboinensis* individuals consisted of juveniles from three age classes (young-of-the-year, one-year-olds and two-year-olds), and *C. sorrah* individuals were adults.

Juvenile *C. amboinensis* were present in Cleveland Bay for long periods, ranging from 3 to 429 days (mean = 88). Individuals associated strongly with shallow turbid habitats, with core home ranges consistently remaining in areas adjacent to creek and river mouths. Significant differences in minimum convex polygon measures of home range revealed that older juveniles used larger areas and undertook movements from core ranges more frequently than younger juveniles. Movements of *C. amboinensis* were related to the tidal cycle, but changes in water depth associated with the tide had the strongest influence on the youngest juveniles. An ontogenetic shift in depth used was also evident, with young-of-the-year individuals restricting their movements to shallower depths (mean = 236 cm) than one- and two-year-old individuals (means = 261 and 269 cm, respectively).

Freshwater influences associated with the wet season played a role in habitat use of juvenile *C. amboinensis* in this nearshore region. Home ranges and distribution of *C. amboinensis* showed distinct changes across two consecutive wet seasons, with individuals moving away from creek mouths during times of high freshwater inflow. Although juvenile *C. amboinensis* moved in response to freshwater inflow, home range sizes remained stable, and the amount of space individuals used did not change in

relation to freshwater inflow. This result suggests that individuals use consistent amounts of space despite changes in location.

Adult *C. sorrah* were also present in Cleveland Bay for long periods, ranging from 8 to 408 days (mean = 190). Unlike *C. amboinensis*, however, this species used areas away from creek and river mouths and generally remained in deeper water habitats (mean = 421 cm). Analyses of home range revealed that individuals consistently used the same areas and similar amounts of space over time. A high level of spatial segregation occurred among *C. sorrah* within this nearshore region, with individuals using different types of habitat and showing high attachment to specific areas. In addition, the range of depths individuals used varied between sexes. Males tended to remain within a narrow depth range, whereas females displayed a seasonal shift in the range of depths used. Mean monthly depths varied by as much as 200 cm for females, with individuals using shallower habitats where water temperature was higher (up to 4º C) during the winter months.

Both species spent a large proportion of time inside the MPAs. The mean proportion of time *C. amboinensis* and *C. sorrah* spent inside MPAs was 0.22 and 0.32, respectively, and MPA use varied seasonally. Both species used large areas inside the MPAs, but individuals generally used only half of the available protected space. All individuals made excursions from the MPAs, however, both species exited and re-entered MPAs within consistent locations along the boundaries.

Long-term use of Cleveland Bay demonstrates that this region contains important habitat for both juvenile *C. amboinensis* and adult *C. sorrah*. However, differences in movement and habitat use suggest that this nearshore environment serves different functions for these species. Use of discrete, shallow areas is likely a refuging strategy for young *C.*

amboinensis, and an ontogenetic shift in depth used may be a mechanism to decrease competition between different juvenile age classes using the same area. For *C*. *sorrah*, the high level of spatial segregation among individuals may be a strategy to improve foraging success by increasing separation and using more areas. Although movement and habitat use patterns varied between species, both used MPA regions for a large proportion of time. Thus, coastal MPAs provide some protection and benefits for mobile species like sharks. By defining the spatial ecology of coastal sharks, this dissertation contributes to improving the conservation and management of their populations, and provides a framework for future research on the effectiveness of MPAs for mobile species within Australia and around the world.

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