Thesis summary

Learning enables animals to develop adaptive responses to novel situations and changing environmental conditions based on individual experience. Although the cognitive abilities of birds, mammals, and bony fishes have been intensely studied, little research has focused on the learning capacity of Chondrichthyans (sharks, rays, chimaeras). The early divergence of sharks and rays from other vertebrates makes sharks an ideal model system to explore the evolution of cognition in vertebrates. The need for an understanding of the cognitive ability of chondrichthyans has also recently been highlighted in relation to the effects of wildlife tourism. Recent studies have documented changes in behaviour, feeding ecology, and body condition in response to tourism related feeding activities. Therefore, the overall objective of my thesis is to improve our understanding of the cognitive abilities of sharks in relation to shark tourism.

Habituation acts as a fundamental filtering mechanism that can free up neuronal resources. Understanding its limitations in sharks will help to better understand its evolutionary origin. Following the daily exposure to the smell of squid, the response of Port Jackson sharks rapidly decreased. This suggests that the use of smell as a daily attractant for tourism operators could result in sharks becoming less likely to respond over time. Building on findings from this study on a fundamental cognitive capacity of sharks, I tested the effects of reward frequency and magnitude on learning rates. Sharks were trained in a simple spatial cognitive task consisting of the choice between two potential foraging pathways. Findings from this study suggest that the frequency at which sharks were trained had greater influence on learning performance than the amount of food they received as a reward.

Tracking food resources through time and space is vital for maximising fitness. Learning about novel food patches often requires animals to make an association between temporal and spatial information. To assess whether juvenile lemon sharks are able to learn

such time-place associations I used semi-captive experiments, where sharks were fed daily over 41 days at two distinct times and locations inside a 45 m^2 enclosure. I found no evidence of time-place learning in this species; rather, juvenile lemon shark movement was more affected by tidal fluctuations than daily feedings. To determine if juvenile lemon sharks are able to anticipate feedings under natural conditions, I initiated a daily feeding regime over 27 days at a novel location. Sharks started to anticipate feeding events within ~11 days, as shown by a change in their fine-scale movement patterns and activity. While activity was affected by feeding, it was not sufficient to affect the sharks' field metabolic rates or energy requirements.

Overall, my PhD thesis advances our understanding of the cognitive capacities and limitations of elasmobranchs, which helps to fill a knowledge gap in the fields of biology, neurophysiology, ethology, and ecology. My thesis further provides experimental evidence that supports the view that cognitive capacities of elasmobranchs are similar to those found in other vertebrate groups. Results from my thesis also provide empirical information for decisions and policies of wildlife tourism management that involve feeding sharks. Based on my findings, I emphasise the importance of managing the frequency of shark feeding operations as a more sustainable approach compared to the amount of food used per feeding event. While these data are applicable to wildlife tourism and conservation planning for these and other benthic and epipelagic shark species, future studies should aim to determine species-specific implications and investigate ontogenetic changes in cognitive abilities.