Whale Sharks Open Research Doors

By Alistair Dove, PhD

When the Georgia Aquarium opened its doors in November 2005, whale sharks instantly became a flagship species for a new institution. Now after four years, the care of this species in an aquarium setting is beginning to present extraordinary research opportunities. These opportunities will allow scientists to explore for the first time the internal biology of the world's largest fish species, and to integrate these findings with field-based research currently underway at many institutions around the world.

Whale sharks (Rhincodon typus) are an extraordinary circum-tropical and circum-subtropical elasmobranch. They are the only pelagic member of their order, the Orectolobiformes, which includes typically demersal species such as the zebra shark (Stegastoma fasciatum), wobbegongs (Orectolobus spp.), and bamboo sharks (Hemiscyllium and Chiloscyllium spp.). But the two things that really set whale sharks apart from all others are their exceptionally large size and their filter-feeding habit, both of which doubtless contribute to their common name. Adult whale sharks may reach lengths of 45 feet (14 meters) or more, and weights in excess of 25,000lbs (12 tonnes), which makes them the largest fish of any kind, cartilaginous or bony. Their observed diet consists of krill (a type of small shrimp-like crustacean), as well as fish eggs, larval fish and other members of the macrozooplankton. To feed successfully on such items, whale sharks have evolved intricate filter pads, probably derived from gill rakers, which line a capacious mouth that may be 4 feet (1.3m) wide and equally as long.

Georgia Aquarium currently houses four whale sharks in its Ocean Voyager exhibit, which is presently the largest single fish aquarium in the world, containing 6.4 million gallons (24.2 million liters) of synthetic seawater and a diverse collection of teleosts and elasmobranchs. On a diet of Euphausia superba and E. pacifica krill, lance fish, silversides and vitaminsed gel diet, all four animals have grown significantly since they were added to the collection (approximately 3ft/1m per year). They have proven amenable to a limited amount of training, which has greatly aided the husbandry staff in their management of the collection. For instance, each animal is fed with a different colored ladel and from a specific feeding station, to which they return with good fidelity; they are evidently much more food motivated than many sharks that have more sporadic predatory habits.

Since adding whale sharks to the collection, Georgia Aquarium has sponsored field research on whale sharks in Quintana Roo, Mexico, where whale sharks aggregate annually in the summertime off the coast of the Yucatan peninsula. This work, carried out in collaboration with the shark research group led by Dr. Robert Hueter at the Mote Marine Laboratory, has explored population size and composition as well as field diet studies and migratory behavior. These studies compliment a number of other groups that are beginning to examine the biology of this species in the field, which was largely unknown until recent years.

More recently, the management of a collection of whale sharks in an aquarium setting has also presented truly unique and exciting in-house research opportunities of a quite different nature to those underway in field populations. Studies of captive animals have so far focused on behavior, functional anatomy, basic biology and internal physiology and homeostasis.

In a collaboration led by Dr. Matt Grober at Georgia State University, we have begun to explore the behavior of whale sharks in the Ocean Voyager exhibit. Far from being sub-reptilian automatons, whale sharks have a surprisingly diverse behavioral repertoire, and there is even some preliminary evidence of social interactions in the group, such as predictable outcomes of physical contact between given pairs of individuals. Observing whale shark behavior certainly differs from ethological studies in, say, marine mammals. The biggest difference is that the observer needs to "slow down" their mindset; whale sharks move slowly, and their behaviors tend to present quietly and subtly. Nonetheless, this is an exciting area of study, and one that will hopefully pave the way for more behavioral studies of this and other elasmobranchs.

Dr. Phil Motta at the University of South Florida has been using data from both the Mote Marine Laboratory field studies and the animals held at Georgia Aquarium to explore the feeding biology and functional anatomy of whale sharks. These studies involve collaboration with Georgia Aquarium nutritionists Mike Maslanka (presently at the Smithsonian National Zoo) and Leslie Zeigler and are beginning to reveal the diet of whale sharks off the Yucatan, which may involve larger proportions of sergestid shrimps, copepods and fish eggs than krill. The precise filter-feeding mechanism of whale sharks also appears to be unique among animals. Dr. Motta's vision is to build a quantitative model of exactly how the filtration pads work. We can then address questions of how whale sharks manage the bioenergetic balancing act in which they are engaged, feeding as they do on a relatively dilute prey in warm waters that drive a higher metabolic rate than, say, basking sharks experience in the rich waters of the cold temperate north.

Many opportunities have arisen from the efforts of Georgia Aquarium husbandry and veterinary services staff to carry out routine medical exams on whale sharks in the Ocean Voyager exhibit, although there is nothing routine about it. These medical procedures require the collaboration of dozens of staff from dive operations to husbandry, plant engineering, life support and veterinary services. The result is that veterinary staff have been able to obtain regular blood and other biological samples, as well as apply several imaging modalities (e.g. ultrasound, endoscopy) and it has also allowed the husbandry staff to obtain accurate morphometrics in ways that have not heretofore been possible in field studies. The clinical veterinary group led by Dr. Tonya Clauss is actively involved in clinical research arising from these efforts. There has also been a synergism of curatorial activities of this sort with research; Drs Hueter and Motta have been able to come to the aquarium and during these medical procedures take direct measurements, collect samples and "lab" test methodologies destined for the field work relevant to their respective research interests.

My own research has focused on the internal biology of whale sharks, particularly on blood. Their blood cell morphology is consistent with other orectolobiforms, which means that they have large red and white cells, which may have important implications for their functional capacity. More recently I have been collaborating with Dr. Julia Kubanek, Dr. Johannes Leisen, Dr. Les Gelbaum and Dr. Facundo Fernandez at the Georgia Institute of Technology to explore the chemistry of whale shark serum using a discovery-based approach called metabolomics, which applies nuclear magnetic resonance spectroscopy (proton NMR) and various mass spectrometry techniques to determine the composition of fluid samples. These methods provide tremendous amounts of data about the specific components of whale shark serum and their relative abundances. From all these data we hope to build a conceptual model of the physiology of whale sharks and to optimize methods for metabolomic studies of other marine species.

The future directions for research on whale sharks at Georgia Aquarium will be to maximize the extraordinary opportunities presented by housing this unique species in an aquarium setting, and then to take methods and approaches we develop and apply them to the field. A new direction will add immunological studies that take advantage of

the expertise of Dr. Greg Bossart, who joined the Georgia Aquarium earlier this year as chief veterinary officer and senior vice president, veterinary services. While we can learn a tremendous amount from captive animals, it will always require extrapolation to apply these findings to wild populations, so there remains no substitute for field work when it comes to collecting the most biologically-relevant data about this remarkable species. Tremendous logistic challenges lie in the future of these efforts, but through collaboration with a number of talented specialists, we have come a long way in just a few years in the aquarium setting and the potential research returns are great. By stimulating research activities, we can fill gaping holes in our understanding of one of the world's largest and most unusual species and thereby enhance efforts to preserve and protect the amazing whale shark.

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