Summary of your achievements and how your research is related to the DoD's mission

My main research interest focuses on locomotor behavior, mainly of aquatic vertebrates. I use a functional morphological approach to elucidate the evolution of locomotion mechanics. I am particularly interested in the role of fins and other control surfaces during steady and unsteady locomotion. I employ techniques that enable three-dimensional conformation analyses of fins and fluid dynamics. In addition, I am also interested in the physiology and function of the musculoskeletal system as well as in material properties of fish appendages. Many relevant questions remain unanswered in fin evolution and adaptations to functional requirements of different flows. Since swimming in fishes is essential for foraging, searching for mates, and escaping predators, natural selection is expected to act on locomotor structures, such as fins, to optimize performance according to each species habitat. The outcome of such research yields the potential for applications to improve remotely operated vehicles (ROVs) performance.

I have worked on shark and estuarine fish species in terms of foraging ecology, reproductive biology, age and growth and habitat use. I have also investigated aspects of foraging behavior in soles and predator-prey interactions. As an undergraduate student in Portugal, I sampled the mako sharks from the pelagic longline fisheries to determine seasonal changes in foraging ecology, age at first maturity and population dynamics. I also had the opportunity to intern at the National Marine Fisheries Service, Panama City Lab, FL, where I did field work with the main goal of monitoring the densities of the different shark species in coastal bays. As a researcher at the Oceanographic Institute I worked on connectivity between nurseries and coastal stocks and human impact on estuarine ecosystems.

As a PhD student at the University of Rhode Island (URI) I studied the functional morphology of shark dorsal fins during steady swimming and maneuvering, using techniques such as gross anatomy, morphometrics, 3D kinematics, electromyography and particle image velocimetry. I found that dorsal fins in sharks are controlled independently of the trunk musculature and play a role in thrust or stabilization dependent on the fin, the species and the behavior. While at URI I also collaborated in other projects on escaping responses of cartilaginous fishes and fluid mechanics during feeding behavior in skates and rays.

As a postdoctoral researcher at Ghent University, Belgium, I worked on biomechanical aspects of prehensile tails in seahorses. I also collaborated on morphological analyses of seahorse’s unique myomere and plate arrangement in the tail region. Specifically I analyzed the 3D kinematics of two seahorse species with contrasting tail morphologies, investigated seahorse preferences for different holdfast properties and worked together with engineers creating finite element models representing this unique behavior among fishes. The premise behind this project being that the highly flexible but still structurally sound tail of seahorses could be used for applications in medical instruments, such as catheters. While at Ghent University, I also led the efforts in creating a fluid flow model based on buccopharyngeal morphometrics that predicts the timing and magnitude of flow generated by suction feeding fishes.

Studying fish swimming, especially how fish maneuver in confined spaces yields potential applications to bio inspired robots and ROVs. Sharks in particular are primitive fishes that have a simpler body plan thus more suitable as proxies for man made structures. As a specialist in shark steady and unsteady locomotion I am in a unique position to develop concepts that will enhance ROVs maneuverability without undermining their steady propulsion. Sharks use a combination of passive structures and active control to correct roll destabilization. My knowledge of fluid dynamics and particle image velocimetry technology coupled to my understanding of fish locomotion and of the robotics literature puts me in a unique position to develop bio inspired solutions for stability and maneuvering problems. I would like to study also boundary layer conditions as well as flow entrainment near complex fish surfaces to better understand how we can use simplified versions for improved performance. Coupling particle image velocimetry with respirometry of different body shape fishes we can have a good estimate of the energy requirements and thus create prototypes that can be tested in the same swim tunnels and test arenas for improved performance.

My work on the seahorse tail as a bioinspired model also holds promise for armor solutions. The high flexibility of the tail of the seahorse,which is capable of moving with several degrees of freedom laterally and ventrally is combined with a very high tensile strength of the plates themselves that protect the soft tissues of this delicate creature. Similar to the work done with the bichir plates at MIT our work is well suited for armor covers at areas where bending is very important such as knees and elbows.