ASPAs 152/153: Western Bransfield Strait and Dallmann Bay: Highlights of Scientific Research Results

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Summary

The U.S. National Science Foundation has supported several decades of research on the unique fish populations in ASPA 152 (Western Bransfield Strait) and ASPA 153 (Dallmann Bay). Recognized as important habitat and probable spawning grounds for several fish species, including the notothen (rockcod) *Notothenia coriiceps* and the icefish *Chaenocephalus aceratus*, these ASPAs were established in 1991 as important sites for scientific research and protection of the dynamic fish and benthic communities there. The research summarized below has resulted in dozens of scientific publications on the marine communities of ASPAs 152 and 153 that span the disciplines of ecology, physiology, climate change impact, evolution, and genomics. Research highlights from these disciplines are described.

***Ecology***

* On the High Antarctic shelf, Notothenioids (which includes icefishes) today dominate the fish fauna and are recognized as one of the few examples of a species flock of marine fishes.
* Studies of these fishes advance the understanding of the ectothermic mode of life, especially in extreme cold.
* Antarctic fish, especially in their early larval stages, are an important component of the food web that sustains life in the cold Southern Ocean surrounding Antarctica. Larvae feed on smaller organisms (phytoplankton and zooplankton) and in turn are eaten by larger animals. Some adult notothenioid species are important prey for seals and killer whales.
* Western Bransfield Strait supports a rich seasonal bloom of microorganisms at the base of the food web, and *Thysanoessa macrura* is the most common euphausiid.

*Relevant papers: Nordhausen 1992; Kuhn et al. 2011*

***Physiology***

* Icefishes are physiologically unique as they are the only vertebrates that are white-blooded, meaning they lack hemoglobin, the protein of red blood cells that binds oxygen in the blood, and have lost the red blood cells that carry hemoglobin. It has been hypothesized that these mutations were selectively advantageous in the icefish lineage because they might decrease oxidative damage within the body, thereby conferring an evolutionary advantage in the extremely cold and oxygen-rich waters of the Southern Ocean. However, this hypothesis is not universally accepted, and the white blood of icefishes may simply be a result of neutral mutations. Nonetheless, icefishes have co-evolved a suite of physiological changes that maintain cardiac and circulatory function in the absence of hemoglobin.
* Neutral buoyancy is unusual in notothenioid fishes; however, many species of the flock have evolved toward neutral buoyancy, a trait that facilitates feeding in the water column.

*Relevant papers: Beers et al. 2010; Biederman et al. 2019a,b; Cheng & Detrich 2007; Detrich et al. 2000; Eastman & Sidell 2002; Eggington et al. 2019; Hunter-Manseau et al. 2019; Joyce et al. 2018a; Joyce et al. 2019; Kuhn et al. 2016; O’Brien et al. 2013, 2014, 2016, 2018, 2020; Pucciarelli 2006*

***Climate Change***

* Antarctic fishes live near the limits of their physiological tolerance and are threatened by warming temperatures, ocean acidification, and commercial fishing pressures.
* White-blooded icefishes are particularly sensitive to increasing temperatures due to their lack of hemoglobin, and studies on these “sentinel species” investigate their responses to current and projected warming of the waters surrounding the Antarctic Peninsula.
* The cellular proteome of Antarctic fishes will likely be resilient to current rates of warming, at least for several centuries.
* However, embryos of *Notothenia coriiceps* developed twice as quickly under projected warming scenarios for the next two centuries. Accelerated embryonic development would result in a decoupling of the phenology of hatching and light-driven food availability (phytoplankton), with hatchling starvation a likely outcome. Moreover, a significant proportion of embryos develop abnormally at warmer temperatures, which also would negatively affect food web dynamics and hatchling recruitment.
* In 2018 researchers discovered that specimens of the crowned notothen *Trematomus scotti* near the ASPA 152/153 area exhibited highly concerning large pink tumors that covered 10-30% of their bodies. One specimen of a diseased painted notothen *Nototheniops larseni* was found in ASPA 153. The researchers determined that rare single-celled parasites called “X-Cells” are causing the tumors. The disease is causing weight loss and other detrimental health impacts in affected fishes. Studies are under way to learn more about this phenomenon, but it may be a result of warming waters and melting ice in the habitat.

*Relevant papers: Beers and Sidell 2011; Desvignes et al. 2022; O’Brien & Crockett 2013; Eggington et al. 2019; Joyce et al. 2018b; Le Francois et al. 2017; Postlethwait et al. 2016; Berthelot et al. 2018;*

***Evolution and Genomics***

* Multiple studies have been performed to investigate the evolutionary loss of Hemoglobin (Hb) and Myoglobin (Mb) in icefishes. Results suggest that deletion of genomic regions containing hemoglobin genes may have been facilitated by mobile genetic elements.
* Understanding of genome evolution in Antarctic notothenioid fishes is rapidly advancing based on specimens collected in ASPAs 152 and 153 and the Western Antarctic Peninsula. These genome sequences have shown that expansion of mobile genetic elements and evolution of novel microRNAs have contributed to notothenioid adaptation. The public availability of these genomes is stimulating worldwide research on the notothenioid species flock.

*Relevant papers: Amores et al. 2017; Auvinet et al. 2018; Auvinet et al. 2020; Berthelot et al. 2019; Cocca et al. 1995, Cuellar et al. 2014; Daane & Detrich, 2022; Daane et al. 2019a,b, 2020; Damsgaard et al. 2019; Desvignes et al. 2016; ; Desvignes et al. 2019; Detrich and Amemiya 2010; Detrich et al., 2010; Hu et al. 2016; Kim et al. 2019; Near et al. 2007; Near et al. 2006; Peck et al. 2005; Rix et al. 2017; Sidell & O’Brien 2006; Shin et al. 2014; Yergeau et al. 2005; Zhao et al. 1998*

***Applications to Human Health***

* Results of icefish studies have led to a greater understanding of the mechanisms responsible for oxidative stress, which is a phenomenon associated with multiple human diseases (cancer, Alzheimer’s, Huntington’s and Parkinson’s) and aging.
* Comparison of the expression of blood genes by white-blooded icefishes and closely related, but red-blooded, notothenioids revealed the role of hemogen as an important transcription factor that is required for the terminal maturation of red blood cells.
* Comparative studies (see previous bullet) also revealed that the *bloodthirsty* gene encodes an RBCC/TRIM gene required for erythropoiesis.
* Research on the unique, cold-adapted microtubule proteins of Antarctic fishes may lead to new therapies for treatment of cancers, dementias, injuries, and other diseases.

*Relevant: papers: O’Brien et al. 2013; O’Brien et. al. 2014; O’Brien et al. 2016; Mueller et al. 2014; Lewis et al 2015; Kuhn et al. 2016; Peters et al. 2018; Detrich et al. 1987, 1989, 1990, 1992, 2000; Parker and Detrich, 1998; Redeker et al. 2004; Cuellar et al. 2014; Yergeau et al. 2005*