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Editorial: Studying the Biology of Aquatic Animals Through Calcified Structures

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Editorial on the Research Topic

Studying the Biology of Aquatic Animals Through Calcified Structures

Calcified structures of aquatic animals can be classified according to their biological function (equilibrium, hearing, structure, etc.), composition (hydroxyapatite, calcium carbonate), and crystallography (aragonite, vaterite, calcite) (Tzadik et al., 2017; Thomas and Swearer, 2019). The chemistry and morphometry of structures such as otoliths, statoliths, spines, scales, bones, cuttlebone, and shells among others, have been widely used to reconstruct organism movement and water properties in many different environments (Walther et al., 2014; Tzadik et al., 2017; Thomas and Swearer, 2019; Avigliano et al., 2020a). Trace and majority elements (e.g., strontium, barium, manganese, magnesium, zinc, lithium, copper, etc.) deposited into the calcified structures can provide insights about habitats experienced during the life histories of fish and other organisms, as well as endogenous processes including growth and metabolism (Hüssy et al., 2020). A robust knowledge about drivers that have an impact on chemistry and shape, and the potential interaction between them, is required to accurately interpret chemical and morphometric patterns. Many studies have implicitly assumed that the water chemical composition is the main driver about composition of these structures. However, in the last decade, field and experimental studies have revealed a complex network of endogenous and exogenous factors that can interact with each other and control uptake and incorporation of elements into (Hüssy et al., 2020). Among the known important endogenous factors are genetics, physiological processes (e.g., reproduction, metamorphosis), growth rate, ontogeny, and biomineralization (Campana, 1999; Loewen et al., 2016; Thomas and Swearer, 2019; Hüssy et al., 2020). The environment to which organisms are exposed throughout their lives is one of the main exogenous drivers, where variables such as temperature, pH, salinity, depth, and dissolved oxygen, can modify the chemical composition of the water directly as well as alter organisms physiology and uptake and incorporation dynamics (Limburg et al., 2015; Loewen et al., 2016; Crichton, 2018; Thomas and Swearer, 2019; Hüssy et al., 2020). Secondarily, diet and even differential fishing pressure (which directly impacts growth parameters) can also play an important role in chemical composition (Ranaldi and Gagnon, 2009; Catalán et al., 2018). Likewise, the factors that affect the shape of these structures are complex (Lombarte and Lleonart, 1993; Vignon and Morat, 2010).

The objective of this Research Topic was to encourage the use of calcified structures (lethal and non-lethal) to study the biology of aquatic animals, not only otoliths of bony fishes, but also structures of cartilaginous fishes and mollusks, among others. The aim was also to highlight

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multiple analytical approaches including chemistry, morphology and morphometry that were synthesized with biological or environmental data, field observations or experimental tests, that paid special attention to the potential variables that affect the incorporation of trace elements. Several articles of this Research Topic were presented at "II Latin American Workshop on otoliths and other calcified structures" (Buenos Aires-Argentina on August 28–30, 2019). In total, 20 manuscripts compose this Research Topic, covering a variety of themes, revised below.

CHEMICALLY UNALTERABLE STRUCTURES

Structures that are chemically unalterable are primarily composed of calcium carbonate, continually accrete, and are not subsequently resorbed or otherwise metabolically active (Thomas and Swearer, 2019). Depending on both endogenous and exogenous factors, calcium carbonate is accreted in the form of vaterite, calcite, or aragonite, the latter being the most abundant in most inert calcified structures (Oliveira et al., 1996; Crichton, 2018). Among these structures are the otoliths (teleost fishes), statoliths (mollusks like cephalopods), statocysts (cnidarians), and the calcified portion of the mollusk shells. These structures are acellular and while primarily composed of calcium carbonate, they are formed on a proteinaceous matrix (Thomas and Swearer, 2019).

A variety of included papers employed unalterable structures. Lilkendey et al. used otoliths to study the somatic growth rates of reef fish, and their relationship with fresh submarine groundwater discharge. Other authors used sclerochronological techniques in Mediterranean fishes to reconstruct environmental changes (Matić-Skoko et al.) and quantify temporal variability in growth of fishes from the Southwest and North Atlantic Ocean (Garcia Alonso et al.; Lattuca et al.,; Tonheim et al.; Wilhelm et al.). Otolith chemistry was used to identify natal sources, delineate stock structure and investigate life histories of marine fishes from many regions including the South and North Pacific (Feyrer et al.; Rogers et al.), and Southwestern Atlantic (Lattuca et al.) and North Atlantic (Tripp et al.) oceans. In addition, Vasconcelos-Filho et al. described a non-destructive micro-computed tomography scan protocol to explore the eco-densitometry of otoliths which could be used in a wide range of species to study age and growth. Matić-Skoko et al. have also done a review on otolith chemistry and sclerochronology research in the Mediterranean.

Studies using controlled laboratory assays were also contributed that develop our understanding of the mechanisms regulating elemental incorporation into otoliths, including growth rate, water composition, salinity, and temperature (Miller and Hurst; Martinho et al.). Moreover, Tonheim et al., identified the influence and importance of environmental and genetic factors for *Clupea harengus* otolith chemistry throughout the life of a fish, along with assessments of genetic contributions to phenotypic variability on the otolith microstructure. Finally, stable oxygen isotopes of statoliths from the squid *Sepioteuthis lessoniana* were used to predict seasonal movement patterns (Chiang et al.), while the cuttlebone chemistry ratio was a promising growth rate proxy for evaluating differences among wild populations of cuttlefish (Chung et al.).

CHEMICALLY ALTERABLE STRUCTURES

Among the most chemically alterable structures used for the biological studies of aquatic organisms are the scales and the skeletal system (spines, fin rays, bones, etc.) (Avigliano et al., 2019). These structures, unlike the inert ones, are formed by living tissue immersed in a hydroxyapatite matrix, which may be subject to resorption (Tzadik et al., 2017). The resorption phenomenon can limit the use of these structures to, for example, trace life history using chemical markers. On the other hand, the resorption of growth *annuli* in scales and bones can lead to underestimation of the age of the organisms studied.

Nevertheless, since the extraction of some structures such as scales or fin rays turns out to be non-lethal, it may offer a viable alternative way to study vulnerable fishes provided comparable chemical signatures to otoliths are found in these structures (Woodcock et al., 2013; Avigliano et al., 2019). In addition, structures like vertebrae provide an opportunity to study cartilaginous fishes that lack otoliths. Non-lethal methods using spines and scales have been employed to study lifetime movement patterns and assess stock structure in many species (Rude et al., 2014; Seeley et al., 2015; Seeley and Walther, 2018; Avigliano et al., 2019). Although scale and fin spine resorption through life is well-documented, chemical stability in the marginal area has been observed, making it a suitable tool for stock identification in some fishes (e.g., Avigliano et al., 2020b).

This collection brings together an interesting diversity of articles on calcified structures such as vertebrae and scales. Researchers applied vertebrae microchemistry to investigate habitat use of an endangered coastal shark (Feitosa et al.), while vertebrae increment patterns were also used as a proxy of somatic growth of a philopatric and demersal shark (Izzo and Gillanders). Vertebrate were also used to provide the first validation of the annual formation of growth bands in the whale shark using bomb radiocarbon assays (Ong et al.). Moreover, intra and interspecific morphometric variation of scapula-coracoids of three skate species were analyzed to assess its utility as a diagnostic characteristic (Mabragaña et al.). Finally, geometric morphometric approaches were used in scales to delimit fish species and assess how fish scale shape varies with genetic structure or with marine ecoregions (Ibáñez et al.; Pacheco-Almanzar et al.).

FINAL REMARKS

In summary, this Research Topic includes 20 papers that gathered 148 authors of several universities and research centers from 20 countries (Argentina, Australia, Brazil, Canada, Croatia, Germany, Iceland, Japan, Mauritius, Mexico, Namibia, New Zealand, Norway, Pakistan, Portugal, Saudi Arabia, South Africa, Sweden, Taiwan, USA). Most of the studies were developed in an interdisciplinary and inter-institutional framework, reflecting the importance of collaborative research development and bringing new knowledge to the study of calcified structures.

AUTHOR CONTRIBUTIONS

EA conceived the Research Topic and wrote the manuscript. AV and BW wrote the manuscript. All authors contributed to the article and approved the submitted version.

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