Introduction to proceedings of the 4th International Otolith Symposium

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Introduction

Otolith science continues to make substantial contributions to traditional fisheries management and stock assessment efforts while expanding its role in ecological research and conservation applications. Certain intrinsic properties of otoliths, including continual growth, deposition of distinct daily and seasonal increments, ability to permanently record chemical aspects of the environment, and species-specific shape, combine to create one of the most versatile vertebrate structures used in science and management. Although historically used to study age and growth and for stock assessment applications, otoliths are

currently used to address a wide variety of research questions. Otolith research has made major contributions to our understanding of population structure, demography, foraging ecology, early life history of fishes, and migratory patterns (for reviews, see Campana 1999, 2005; Campana and Thorrold 2001; Elsdon et al. 2008). Researchers worldwide continue to seek novel methodologies for extracting diverse information from otoliths, and the depth and breadth of recent otolith research was evident at the 4th International Otolith Symposium, held on the 24–28 August 2009 in Monterey, California USA.

The Symposium was hosted by the National Oceanic Atmospheric Administration's Southwest Fisheries Science Center, Moss Landing Marine Laboratories, and University of California Santa Cruz. Participants included 268 scientists from 36 countries with 272 presentations on a diverse array of otolith-related topics. The Symposium is the most recent in a series of international symposia conducted over the last two decades. The first symposium, which was held in 1993 at Hilton Head, South Carolina USA, was organized to: (1) review and synthesize otolith research with emphasis on both fundamental research and applications; (2) highlight current research and identify data gaps; and (3) stimulate new work and new investigators (Secor et al. 1995). In 1998, the second symposium was held in Bergen, Norway and built upon the ideas that: (1) otoliths had become the primary structure for age estimation in fishes and

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accuracy and precision were of paramount importance; and (2) otoliths were valuable beyond studies of age and growth (Fossum et al. 2000). The third symposium provided a ‘forum to establish the current level of understanding in extracting otolith-derived ecological information for natural resource assessment and management’ for participants who travelled to Townsville, Australia in 2004 (Begg et al. 2005). This, most recent, symposium focused on presenting state-of-the-art research and highlighting future directions for this increasingly important area of science and management.

The 2009 Symposium featured 178 oral and 94 poster presentations organized into five thematic areas: (1) age and growth; (2) chemistry; (3) life history and management; (4) physiology and morphology; and (5) sclerochronology and the environment (Fig. 1). Each of these themes, with the exception of the rapidly expanding field of sclerochronology, is represented in this Special Issue. Additionally, there are two synthesis contributions. The first examines how otolith-derived information has provided new insights on fish migration (Secor 2010). The second focuses on how otolith structural analyses have contributed to our understanding of ecological and oceanographic processes relevant to ecosystem-based management (Sponaugle 2010).

Fig. 1 Number of presentations given at the 4th International Otolith Symposium. The 272 presentations (178 oral and 94 poster) were organized into five thematic areas: age and growth; chemistry; life history and management; physiology and morphology; and sclerochronology and the environment. *Filled bars* represent oral presentations and *open bars* represent poster presentations

Age and growth

The need for accurate ageing remains an important component of otolith studies around the world (Campana 2001). A total of 65 oral and poster presentations were included in this theme section. Representative examples within this issue include efforts to further refine methodologies, such as bomb radiocarbon analyses to validate ages of both long-lived (Armsworthy and Campana 2010) and short-lived (Melvin and Campana 2010) species, as well as to use shape analysis in ageing applications (Beyer and Szedlmayer 2010). The expanding application of otolith studies to conservation science is highlighted by the use of traditional age and growth analyses to examine temporal changes in the demography of species of concern (Fowler and King 2010; Terwilliger et al. 2010).

Chemistry

Conveners of the 3rd Symposium noted a substantial increase in research focused on extracting information from otoliths based on their chemical composition. Studies on the elemental and isotopic composition of otoliths continue to be a major component of recent research, as indicated by the 79 oral and poster contributions directly related to this theme presented at the 4th Symposium. It is noteworthy that overall >125 presentations incorporated some aspect of otolith chemistry. Given that otolith chemical analyses draw from several sub-disciplines, including ecology, fisheries science, and analytical chemistry, the need for consistent and accurate presentation of relevant analytical procedures continues to be particularly important. Furthermore, in many instances our limited understanding of the mechanisms underlying otolith chemical composition calls for conservative data interpretation. Contributions in this issue include continued efforts to use otolith chemistry to elucidate population structure (Newman et al. 2010; Steer et al. 2010), but studies that incorporate other natural markers, including microsatellite DNA (Svedang et al. 2010) and parasite communities (Niklitschek et al. 2010), are becoming more common. Examples of laboratory experiments aimed at identifying regulating mechanisms and factors that influence otolith chemical composition are also included (DiMaria et

al. 2010; Walther et al. 2010). Additionally, a study that inferred ancient trophic relationships in the Gulf of California based on the isotopic composition of archaeological otolith collections (Rowell et al. 2010) represents an interesting application of otolith chemistry that is likely to expand in the future.

Life history and management

The use of otoliths to address population-level questions continues to be labor intensive and presents challenges in terms of generating adequate sample sizes for robust statistical evaluation. However, the 64 oral and poster presentations in this thematic area highlight the continued efforts of researchers to provide information appropriate for addressing life-history questions. Within this issue, there are several studies that combined field collections with genetic, otolith microstructural and/or chemical analyses to address questions on early life history, migratory pattern, natal origin, and habitat use. For example, Kerr and Secor (2010) combined field collections with otolith microstructural analysis to identify proximate causes of partial migration in an estuarine-dependent species. Highlighting conservation applications of otolith science, other researchers identified key habitats for species of concern based on variation in otolith isotopic composition (Engstedt et al. 2010; Hobbs et al. 2010). Other contributions, which highlight potential management applications, build upon the use of otolith isotopic composition to determine natal origins in Chinook salmon (Barnett-Johnson et al. 2010) and identify anadromous and non-anadromous ecotypes of sockeye salmon (Godbout et al. 2010).

Physiology and morphology

Although there were fewer contributions in this important area, the 40 oral and poster presentations and a dedicated session underscore the continued importance of understanding fundamental aspects of otolith structure and function. Contributions represented in this issue include the development of a novel statistical methodology for shape analysis (Reig-Bolano et al. 2010) along with a direct comparison of otolith chemistry and shape analyses to examine spatial structure in a deep-sea species

(Longmore et al. 2010). There is also an examination of otolith ecomorphological trends in relation to the phylogeny of Nototheniid fishes (Lombarte et al. 2010).

Sclerochronology and the environment

Many aspects of otolith science fall within the field of sclerochronology, which involves the study of physical and chemical variations in the accretionary structures of organisms (Panfili et al. 2002). Twenty-four conference presentations were included in this theme section and several of those incorporated cross-dating, which is a rigorous methodology to align time series from multiple individuals. Cross-dating originated in forest science (Douglass 1941) and has been applied to terrestrial ecosystems and, more recently, aquatic systems (e.g., Black 2009). Several presentations demonstrated how, through the use of methodologies originally applied in dendrochronology, otolith aging error can be minimized and time series can be more confidently aligned to elucidate patterns of growth within and among species and examine climate relationships. The potential to apply aspects of sclerochronology to improve interpretation of otolith structural and chemical data as well as generate environmental proxies is not yet fully realized, but it is evident that contributions will grow as otolith science moves into the future.

Conclusion

The 4th International Otolith Symposium provided a valuable arena for researchers to present current research, exchange ideas with colleagues, and identify future collaborations. Overall, it is evident that otolith science will continue to make significant contributions to fundamental and applied research. Researchers continue to successfully extract highly relevant information from otoliths that is essentially inaccessible through other research approaches. Although it is difficult to predict the future of otolith science, it is interesting to note that nearly 60% of the contributions to this Special Issue deal with some aspect of otolith chemistry while ~20% have direct conservation applications. Otolith science currently encompasses a broad range of research approaches that will

likely continue to expand as new and improved technologies are developed. Although this Special Issue reflects much of the current research presented, it undoubtedly presents an incomplete portrayal of the entire Symposium. We hope that it provides a useful synthesis of the current state of otolith science and will serve as a benchmark for future studies and symposia.

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