



Short communication

The first description of oarfish (*Regalecus russellii* Cuvier 1816) (Regalecidae) ageing structures

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Introduction

Despite being a large, conspicuous teleost with a worldwide tropical and temperate distribution, the giant oarfish *Regalecus* spp. remain very rare fish species in terms of scientific sampling. Subsequently, very little biological information is known about *Regalecus* spp. and almost nothing has been concluded in the field of age and growth (Roberts, 2012). No studies of otoliths or temporal (annual) markings on any hard structures have been reported, and to our knowledge otoliths have never been recovered from any specimens (Tyson Roberts, personal communication), although a few texts do provide illustrations of *Regalecus* sp. otoliths (Lin and Chang, 2012; Nolf, 2013). Further inferential difficulty comes from the fact that age and growth studies of any Lampridiforme species are rare. *Lampris guttatus* is perhaps the only Lampridiforme species for which any biological information has been reported (Francis et al., 2004), which stems from the species commercial value. In order to begin understanding any species (for later purposes of management, conservation, etc.), basic biological information is needed. In the present study, we examine not only the first *Regalecus russellii* otolith, but provide suggestions toward future work that should direct data collection that can be used to generate basic biological information for this species.

Materials and methods

On 13 October 2013 a recently deceased *Regalecus russellii* (Cuvier 1816) specimen was discovered at a depth of approximately 6 m off the coast of Catalina Island, California, USA. The fish was approximately 5.5 m in length and appeared to be largely intact, but the loss of some anterior tissue prevented reporting this length as standard length or total length. The specimen was sampled by personnel from local universities for biological information, including on 7 November 2013 when the author (SRM) examined and sampled hard structures for their potential to estimate age. In the weeks prior to the author's investigation, the specimen had been preserved by freezing and although some external

degradation and tissue removal had taken place, the specimen was largely intact.

To collect the sagittal otoliths, an incision was made along the cranial-caudal plane of the head, similar to how many other teleosts are sampled for otoliths. Approximately 3–5 incisions were made along this plane to remove cartilaginous head and skull material, eventually opening to the brain cavity and the membranous labyrinth. Two sacculi were observed (Fig. 1), and one (presumably) sagittal otolith was recovered. No second sagittal otolith nor any lapilli or asterisci otoliths were observed or confirmed. Other hard parts were collected for aging potential, including a dorsal fin spine from the second crest, a pelvic fin ray, and an anterior vertebra. The dorsal fin spine was one of the most anterior spines (within the first 5), although the exact order of the spine was unknown due to previous dissection. Prior to



Fig. 1. Cranial cavities in which a sagittal otolith from *R. russellii* was collected

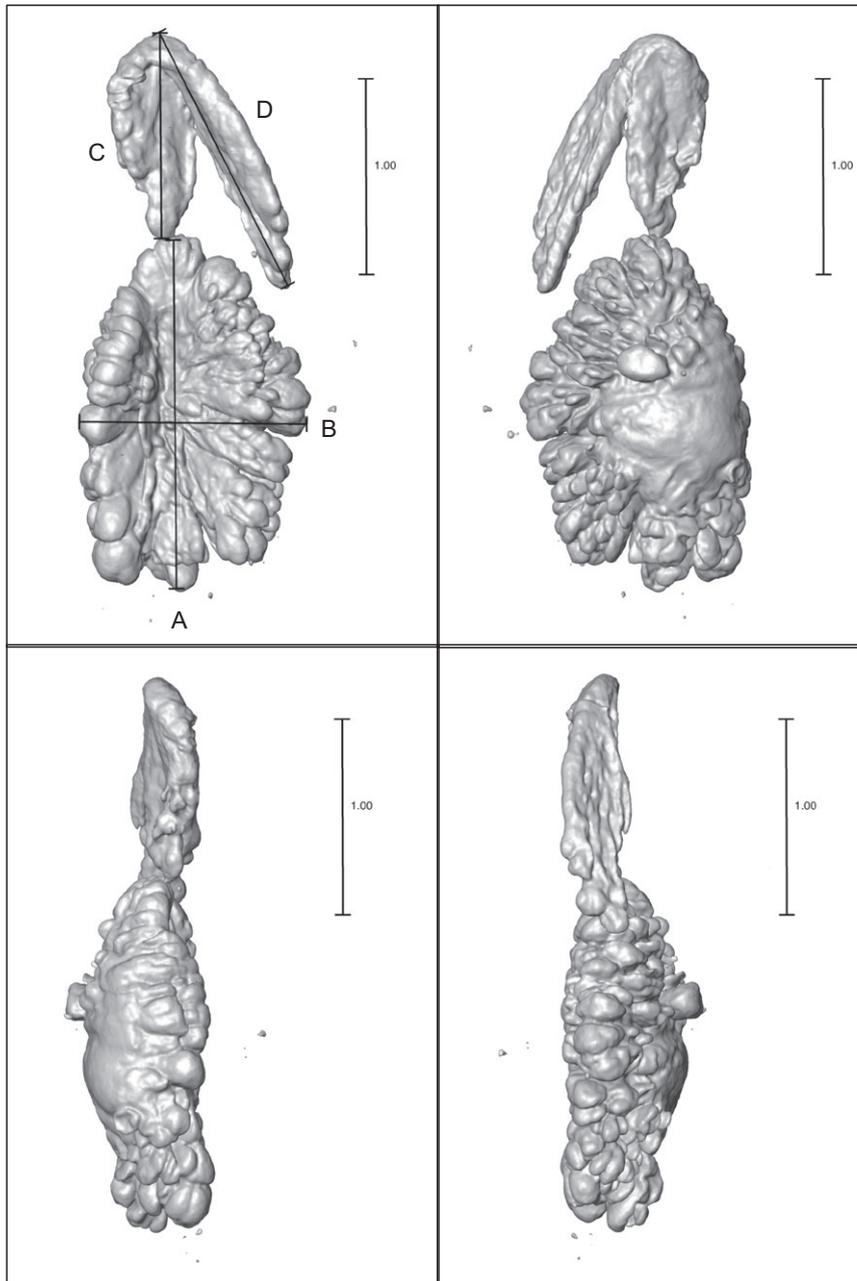


Fig. 2. Four views of CT image of putative sagittal otolith from *R. russellii*. Scale bar = 1 mm; measurements include A = 1.77 mm; B = 1.14 mm; C = 1.04 mm; D = 1.44 mm

sectioning and mounting of the otolith for aging purposes, a CT (computed tomography) scan was completed at the Pennsylvania State University's Center for Quantitative X-Ray Imaging followed standard CT scanning methods (see Ryan and Shaw, 2013 for example). After CT scanning was complete, all four tissue specimens were prepared (sectioned and mounted) with conventional methods (Dr. S. Campana's Otolith Research Lab at the Bedford Institute of Oceanography in Nova Scotia, Canada). Mounted tissues were then aged independently by both authors, along with input from Steve Campana, an experienced reader of hard parts.

Results

The extracted otolith was encased in a cartilage-like envelope or membrane and the CT scan (which shows the otolith and not the encasing envelope) revealed a highly crenulated surface and near break in the otolith into a smaller V-shaped bone, which could be an asteriscus otolith (Fig. 2). Asteriscus is more likely than a lapillus based on the general proximity of the asteriscus to the sagitta and their shared placement in the pars inferior. The four sectioned and mounted tissue specimens (Fig. 3) presented variable markings. Evidence of concentric bands could be fairly easily observed on the pelvic fin ray and dorsal spine, with either 6



Fig. 3. Sectioned images of three potential aging structures from a *R. russellii* specimen. (a) pelvic fin ray section; (b) dorsal spine section; (c) (anterior) vertebra; (d) putative sagittal otolith. Note: A and B are annotated with potential (annual) markings

or 7 bands, respectively. The vertebra also showed bands, yet many were difficult to distinguish and multiple readers arrived at varying estimates all greater than the number of bands observed in the fin tissue. Finally, the otolith was perhaps the least informative tissue sample as an absence of bands prevented any reasonable estimation of markings.

Discussion

Calcified structures in fishes often grow in proportion to somatic growth, and variable rates of accretion can be interpreted as markings, bands, or rings used to estimate time. *R. russellii* may be a difficult species to age for a number of reasons. First, their life history and associated habitats are largely undescribed, thus it is not clear that rates of accretion in calcified structures follow the patterns that result in interpretable markings in many other teleost species. For example, seasonality (water temperature) greatly influences growth and accretion in putative aging structures, and without a better understanding of habitat use of *R. russellii*, we cannot confirm that they expose themselves to the seasonality needed to develop temporal markings in tissue. It is also unclear what the main prey items of *R. russellii* are (Roberts, 2012), and as growth is linked to feeding, prey availability may not occur along a seasonal gradient. For example, lack of clear bands may result from near-continuous year-round

feeding, which is possible in a migratory, epipelagic species. Perhaps more importantly, many epipelagic fishes, including Lampridiformes, have (or are predicted to have) very small otoliths (Paxton, 2000; Lombarte and Cruz, 2007). This trend has been attributed to the lack of utility of otoliths in rough, open seas, along with the generality for large eyes and reliance on visual cues over auditory cues (Paxton, 2000). For these reasons alone the otoliths of *R. russellii* may be so diminutive both in size and function that less investment in otolith tissue has resulted in a species that is difficult to process and observe (or at least using convention methods). This trend has also led to a recent increase in examining non-otolith tissue for aging other epipelagic species. Specifically, vertebrae have shown promise in many elasmobranch species (e.g. Bubley et al., 2011; Cuevas-Zimbrón et al., 2013) and fin spines and rays are particularly useful in aging epipelagic teleosts (e.g. Hill et al., 1989; Rodríguez-Marín et al., 2012; Hobbs et al., 2014).

Reports of aging other Lampridiformes are scarce, though one report (Francis et al., 2004) has discussed age and growth of *Lampris guttatus*. *Lampris guttatus* were best aged with fin rays as otoliths were small and fragile, and not suitable for aging. Inferring a trend from two confamilials is done with caution, but we do note the apparent consistency between the reports on aging Lampridiformes. Francis et al. (2004) also noted the rapid growth early in life for *Lampris*

guttatus, and while we cannot infer any growth rate from our single sample, it would stand to reason that fast rates of growth early in life could explain the large sizes that *Regalecus* spp. attain (as do many other Lampridiformes), assuming our aging is relatively accurate.

This report represents the first successful attempt at removal of otoliths from an *R. russellii* specimen, in addition to the sectioning and interpretation of multiple potential aging structures of the species. Continued attempts at otolith removal and examination in *R. russellii* species should continue to take place; however, we report evidence for utility of other hard tissues – specifically dorsal fin spines and pelvic fin rays – for aging purposes. This preliminary finding is promising for the simple fact that *Regalecus* spp. otoliths have historically been difficult to sample, while dorsal and pelvic fin spines are easily identified and sampled. The possibility to age many more *Regalecus* spp. increases without reliance on the otolith, and for the first time we expect that basic biological information (age and growth) may be attainable with time as future *Regalecus* spp. are examined. We may still be a long way from truly validated ages of *Regalecus* spp. (see Campana, 2001 for discussion of validation methods), although with continued efforts to sample and corroborate tissue evidence, and the promise of a variety of specimen sizes, we should soon be able to develop a much improved understanding of ages and growth rates in these unique and rare species.

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