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Chapter 1 : Reading : Morphological bases of the systematics and phylogeny of the nototheniid fishes PDF

Morphological bases of the systematics and phylogeny of the Nototheniid fishes A. V. Balushkin (Translator Indira Kohli). A. A. Balkema/Rotterdam (Russian Translation Series 73) () pages. Â£

This article has been cited by other articles in PMC. Abstract Background Pedomorphism is the retention of ancestrally juvenile traits by adults in a descendant taxon. Despite its importance for evolutionary change, there are few examples of a molecular basis for this phenomenon. Notothenioids represent one of the best described species flocks among marine fishes, but their diversity is currently threatened by the rapidly changing Antarctic climate. Notothenioid evolutionary history is characterized by parallel radiations from a benthic ancestor to pelagic predators, which was accompanied by the appearance of several pedomorphic traits, including the reduction of skeletal mineralization that resulted in increased buoyancy. Results We compared craniofacial skeletal development in two pelagic notothenioids, Chaenocephalus aceratus and Pleuragramma antarcticum, to that in a benthic species, Notothenia coriiceps, and two outgroups, the threespine stickleback and the zebrafish. Relative to these other species, pelagic notothenioids exhibited a delay in pharyngeal bone development, which was associated with discrete heterochronic shifts in skeletal gene expression that were consistent with persistence of the chondrogenic program and a delay in the osteogenic program during larval development. Morphological analysis also revealed a bias toward the development of anterior and ventral elements of the notothenioid pharyngeal skeleton relative to dorsal and posterior elements. Conclusions Our data support the hypothesis that early shifts in the relative timing of craniofacial skeletal gene expression may have had a significant impact on the adaptive radiation of Antarctic notothenioids into pelagic habitats. Background Antarctic notothenioids are endemic to the Southern Ocean and probably evolved in situ from a sluggish, benthic perciform species beginning Mya in the then temperate waters of the Antarctic continental shelf [1]. The rich, shallow-water, temperate fish fauna characteristic of the late Eocene 38 Mya became largely extinct due to habitat destruction and changes in trophic structure, thus freeing ecological niches into which the notothenioids radiated [4]. The hallmark of the Antarctic notothenioid radiation is the evolution of secondary pelagicism, which is prominent in the family Nototheniidae [1] and common in the family Channichthyidae [9 , 10]. A significant obstacle facing notothenioids as they radiated into pelagic habitats was the ancestral absence of a swim bladder, the gas-filled chamber that most teleosts use to maintain buoyancy. In pelagic notothenioids, natural selection favored compensatory changes in the musculoskeletal system to achieve neutral buoyancy, including the replacement of densely mineralized bone with cartilage and connective tissue, decreased bone mineralization, and the accumulation of lipid deposits in muscle and connective tissues. Changes in habitat were also accompanied by the evolution of distinct oral jaw morphologies and body shapes that accommodate shifts in diet and foraging behavior [12 , 13]. Trophic evolution among notothenioids resulted in two distinct pelagic ecotypes: True pelagics spend most of their time in the water column where they feed on microinvertebrates. They possess relatively short, protractile jaws for suction feeding and have few, large oral teeth arranged along a single tooth row e. In contrast, benthopelagics spend much of their time on or close to the ocean floor but venture into the pelagic zone to forage on schools of small fish and macroinvertebrates. Most benthopelagic notothenioids have non-protractile, elongate jaws, a wide gape, and many, small oral teeth e. This morphology enables benthopelagics to feed efficiently on krill and schools of small fishes by expanding their buccal cavity, and overtaking and sifting large mouthfuls of prey e. Extant benthic notothenioids preserve the ancestral condition, exhibiting robust skeletons and heavily fortified jaws bearing several rows of large teeth e. Notothenioids achieved secondary pelagicism by pedomorphism, the retention of ancestrally juvenile traits by adults in a descendant taxon [11]. Pedomorphism arises from heterochronic processes that alter the schedule of developmental events [14]. Striking examples of pedomorphic characters in pelagic and benthopelagic notothenioids include delayed and reduced skeletal ossification, retention of the notochord, reduced numbers

of teeth and tooth rows, and reduction of the pterygoid process of the palatoquadrate [13 , 15 - 17]. As a first step toward understanding the molecular mechanisms that underlie skeletal reduction and morphological change in this group, we characterized early craniofacial development in a true pelagic species, P. We describe shared derived aspects of craniofacial development in pelagic notothenioids that differ significantly from those observed in a benthic notothenioid species, N. We found that pelagic notothenioid larvae exhibit a delay in osteogenic development, and that this heterochronic shift is associated with altered gene expression, including delayed expression of the osteogenic markers, col1a1 and col10a1, and prolonged expression of the cartilage differentiation gene, col2a1. These data provide a discrete molecular inroad into the mechanisms that underlie the evolution of this pedomorphic character. We also show that other changes in the patterning of the notothenioid trophic apparatus are due to apparent shifts in the relative timing of development of particular skeletal elements. These data are consistent with the hypothesis that heterochronic shifts in early craniofacial skeletal development have played significant roles in the adaptive diversification of Antarctic notothenioids. Results and Discussion Development of skeletal mineralization is delayed in Antarctic fish Skeletal preparations were made of pelagic notothenioid larvae beginning at developmental stages just before hatching and continuing until just before yolk absorption and the onset of exogenous feeding see Additional file 1 , and compared to those of the benthic notothenioid and outgroup species. The results showed that pelagic notothenioid pharyngeal skeletons lack any mineralized tissues at developmental stages during which other species have begun to differentiate a well-formed bony skeleton Fig. Formation of mineralized tissue was not detected using Alizarin red staining, although developing cartilages had accumulated Alcian-staining cartilaginous material. We conclude that bone mineralization is delayed in developing pelagic, osteopenic Antarctic notothenioid embryos relative to outgroup fishes. To investigate the molecular genetic basis for this delayed ossification, we cloned and examined the developmental expression of genes involved in skeletal matrix formation.

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