Summary

Within the species-rich genus *Sebastes*, four species are found in the North Atlantic, Acadian redfish (*S. fascicatus*), small redfish (or Norway haddock, *S. viviparus*), golden redfish (*S. marinus*) and deep-sea redfish (*S. mentella*). The latter two are of highest interest to commercial fisheries, especially the pelagic occurrences of *S. mentella* in the Irminger Sea that were explored in their full dimensions only recently. Despite the high fishing pressure on redfish resources, only patchy knowledge on their distribution, stock structure, reproductive cycles and growth exists, preventing optimum harvesting strategies. The vague nature of the scientific basis for redfish assessment, particularly the controversial concepts on the amount and delimitation of stocks in the Irminger Sea and adjacent waters, has motivated an EU-funded multidisciplinary research project on redfish. As part of this project, the work presented in this thesis was focusing on stock separation and growth of the two predominantly exploited species, *S. marinus* and *S. mentella*, utilising a suite of advanced techniques applied to their ear bones (otoliths) collected across the distributional range. Otolith shape analysis was used to examine species-specific differences and geographic variation, together with the analysis of the elemental composition of the otoliths. The bias and precision of age determinations and inferred growth of redfish was tested by comparisons between age reading experts and reading methods. Utilising the ratio of two naturally incorporated radioisotopes in otolith cores, radiometric age validation of redfish was achieved.

The first paper employing otolith shape analysis was studying interspecific variation within the genus *Sebastes* by univariate and multivariate techniques. Otolith samples from all four North Atlantic redfish species, six rockfish species from the North Pacific and *S. capensis* from the South Atlantic were compared for differences in linear otolith measurements and elliptical Fourier shape descriptors derived from digitised otolith outlines. A distinction between the North Atlantic and North Pacific/South Atlantic species was achieved by univariate and multivariate analyses of the shape variables. Discriminant analysis revealed correct classification of 88% between the four redfish species. High similarity of the North Pacific rockfish to the South Atlantic *S. capensis* and clear discrimination from North Atlantic species coincides with current zoogeographic theories and recently reported genetic results.

The complex stock structure of North Atlantic redfish species has raised several problems preventing a stock-adaptive fisheries assessment and management. Geographic variation of otolith shapes of *S. marinus* and *S. mentella* across the North Atlantic was analysed to evaluate this technique for stock separation. Multivariate analysis of Fourier descriptors revealed relatively small differences between sampling sites and high within-area variation. The overall classification success of the discriminant analysis was poor for both species (< 50%) but increased to 72-74% by combining sampling areas to

regions (west, central, east). The observed similarities within the central North Atlantic areas (Greenland, Iceland, Faroe Islands) and weak separation of western and eastern areas are in accordance with current fisheries management units. Employing the same methodology, considerably clearer small-scale geographic patterns were found for otolith shapes of horse mackerel (*Trachurus trachurus*) in the Northeast Atlantic and Mediterranean, providing new information on stock boundaries that will have immediate impact for fisheries management.

Complementary to otolith morphometrics, otolith microchemistry was tested as a stock separation tool for redfish by means of determining minor and trace elements in different otolith zones of *S. marinus* and *S. mentella*. Relatively high temporal stability in otolith elemental composition was found for juvenile redfish from a major nursery area off East Greenland, collected during five consecutive years. Elemental concentrations, measured in the nucleus, juvenile and marginal otolith zones, were found to differ significantly between sampling areas and showed consistent longitudinal trends for several elements. Multivariate analysis of element constituents by area, however, revealed poor geographic separation (< 50% cross-validated classification success) for both species, comparable to recent studies on deep-sea fish in the Northeast Atlantic. Elevated Sr and Ba levels were observed in the otolith edge regions, as compared to the inner growth zones, whereas Li and Mn exhibited opposite patterns. Ontogenetic effects or changes in growth rate are most likely responsible for these phenomena. The effect of water chemistry or dietary uptake could not be tested directly due to insufficient resolution of available trace element and stomach content data. The recently found evidence for migration of juvenile *S. mentella* from the East Greenland shelf into the pelagic habitat of the Irminger Sea could be confirmed by similarity in nucleus chemistry, indicating a common natal origin. The connectivity within the central North Atlantic, inferred from otolith elemental signatures, and the observed weak separation from the Northwest and Northeast Atlantic are in accordance with the results of concurrently undertaken body and otolith morphometrics, as well as recent genetic studies, and support current fisheries management units.

Age determination of Atlantic redfish has proven to be difficult and led to inconsistent age and growth estimates in the past. Even with consensus on the use of otoliths as preferred structure for ageing, the error observed in redfish age readings has prevented reliable age-based stock assessment. Using otoliths of *S. marinus* and *S. mentella*, a series of exchange schemes was carried out to assess bias and precision of age readings between four readers and between two preparation methods, the break-and-burn and the thin-sectioning technique. Considerable bias between readers and moderate precision was observed in the *S. marinus* readings, especially for ages above 20 years. The percent agreement between readers increased from 17-28% to 45-61% when allowing deviations of ± 1 year and to 80-92% with ± 3 years tolerance. *S. marinus* aged from broken and burnt otoliths were estimated slightly younger than the same individuals scored from thin-sectioned otoliths. The bias and precision

estimates obtained from the *S. mentella* material were generally poorer than for *S. marinus* but similar to reported values for other long-lived fish species. Above 50% agreement were only achieved with ± 3 years tolerance. Growth functions for both species revealed only minor differences between readers and confirmed slower growth for *S. mentella*. Since some of the presented error in age determinations could be attributed to interpretational differences between readers, further intercalibration of redfish ageing is urgently needed in order to provide consistent input data for stock assessment.

Considering the observed error in age determinations of redfish, age validation is essential for a reliable age-based stock assessment. Validation studies for *Sebastes* species were predominantly focused on Pacific rockfish, whereas only few verification attempts have been undertaken for North Atlantic redfish. Using a radiometric ageing technique based on $^{210}Pb/^{226}Ra$ isotope ratios in otolith core samples (pooled by length groups), ages of *S. marinus* around Iceland as well as *S. mentella* off East Greenland and in the Irminger Sea were determined. In general, the isotope ratios corresponded well with expected radioactive ingrowth curves and with traditional age estimates for the same length group. A slight tendency of relative underestimation of ages by traditional annulus counts was indicated, with considerable discrepancies found for *S. marinus* over 40 cm length and *S. mentella* from deeper layers of the Irminger Sea. Irminger Sea redfish of the biggest investigated length group (41-45 cm) exhibited the maximum radiometric age recorded (41.3 years), in contrast to 34.8 years found by reading the annuli. This study confirms slow growth and high longevity of North Atlantic redfish.