GROWTH DYNAMICS OF ARCTIC AND SAFFRON COD IN THE NORTHERN BERING AND CHUKCHI SEAS

Thomas E. Helser, Delsa M. Anderl and Craig R. Kastelle

Age & Growth Program, Resource Ecology and Fisheries Management Division, Alaska Fisheries Science Center, National Marine Fisheries Service, National Oceanic and Atmospheric Administration, 7600 Sand Point Way N.E., Seattle, Washington 98115. Thomas.helser@noaa.gov

BOEM Bureau of Ocean Energy Management

NOAA FISHERIES

Abstract

We analyzed the growth dynamics of Arctic cod (*Boreogadus saida*) and saffron cod (*Eleginus gracilis*) from the northern Bering Sea, Bering Strait, and Chukchi Sea from data collected during the 2012 Arctic Ecosystem Integrated Survey (Arctic EIS). Specifically, our objectives were to: 1) develop an age determination procedure for estimating the age of fish from otoliths, 2) characterize the growth dynamics both in terms of population age compositions and estimating growth curves, and 3) examine spatial variation in growth among regions of the Chukchi and Northern Bering Seas. Otoliths (and length data) collected during previous 1976-1979 baseline National Marine Fisheries Service surveys were analyzed to provide a comparison to fish growth in 2012. Otolith growth increments were evaluated for saffron cod using otolith stable oxygen isotope (δ^{18}O) signatures as a proxy for annual seasonal temperature cycles. Relationships between δ^{18}O and temperature were verified in laboratory studies.

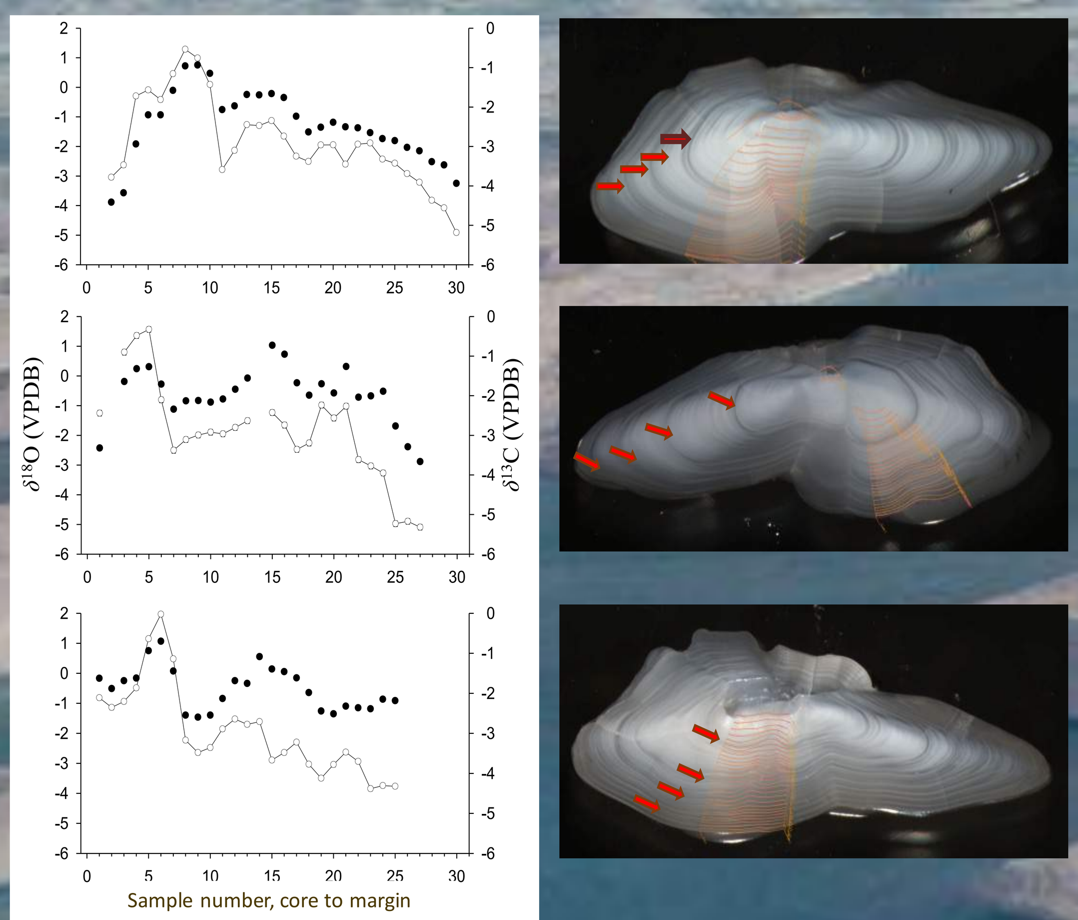

Figure 1a. Sequences of sub-annual oxygen (δ^{18}O; open dots) and carbon (δ^{13}C; black dots) isotopes from 3 saffron cod otoliths, plotted by successive sample number from the otolith core to margin (left). Saffron cod otolith cross sections (right), which were microsampled from the core to the margin, correspond to the δ^{18}O sequences. The δ^{18}O signatures from these otoliths show that translucent growth zones (annuli) coincide with δ^{18}O maxima, and indicate annuli form during winter months when water is cold.

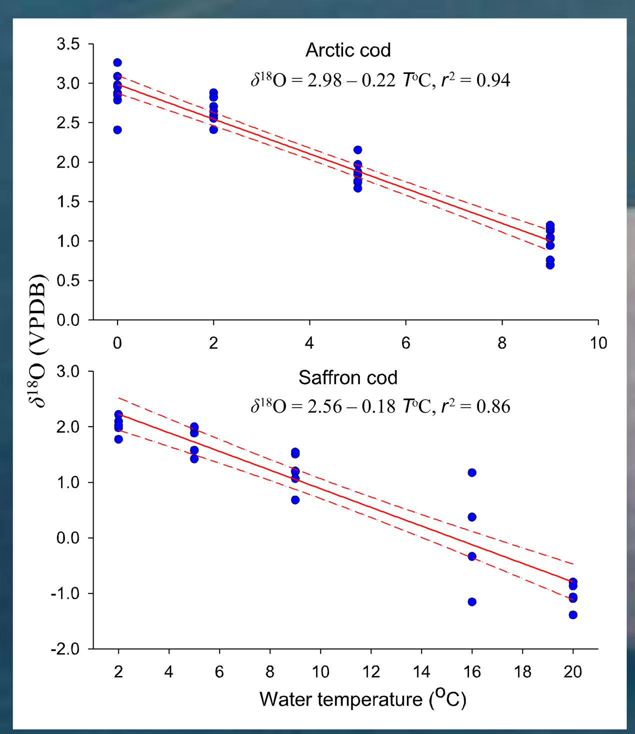

Figure 1b. Laboratory studies confirm that water temperature controls the oxygen isotope (δ^{18}O) in Arctic cod and saffron cod otoliths.

Methods

- Over 2,000 Arctic cod and saffron cod otoliths from the 2012 Arctic EIS survey, and 1,100 from a National Marine Fisheries Service 1976-79 baseline survey were analyzed.
- An age determination criteria was developed and evaluated for between reader precision. Saffron cod were aged from 0.4 mm transverse thin sections, while Arctic cod were aged using the transverse cuts and burned to enhance patterns.
- Body size and otolith growth metrics were analyzed for species-specific functional forms.
- Otolith oxygen isotopes (δ^{18}O) were used to verify the annual winter and summer growth, which was confirmed by laboratory temperature studies.
- Growth curves using the von Bertalanffy function were fit to the age data and statistically analyzed for spatial and temporal patterns.

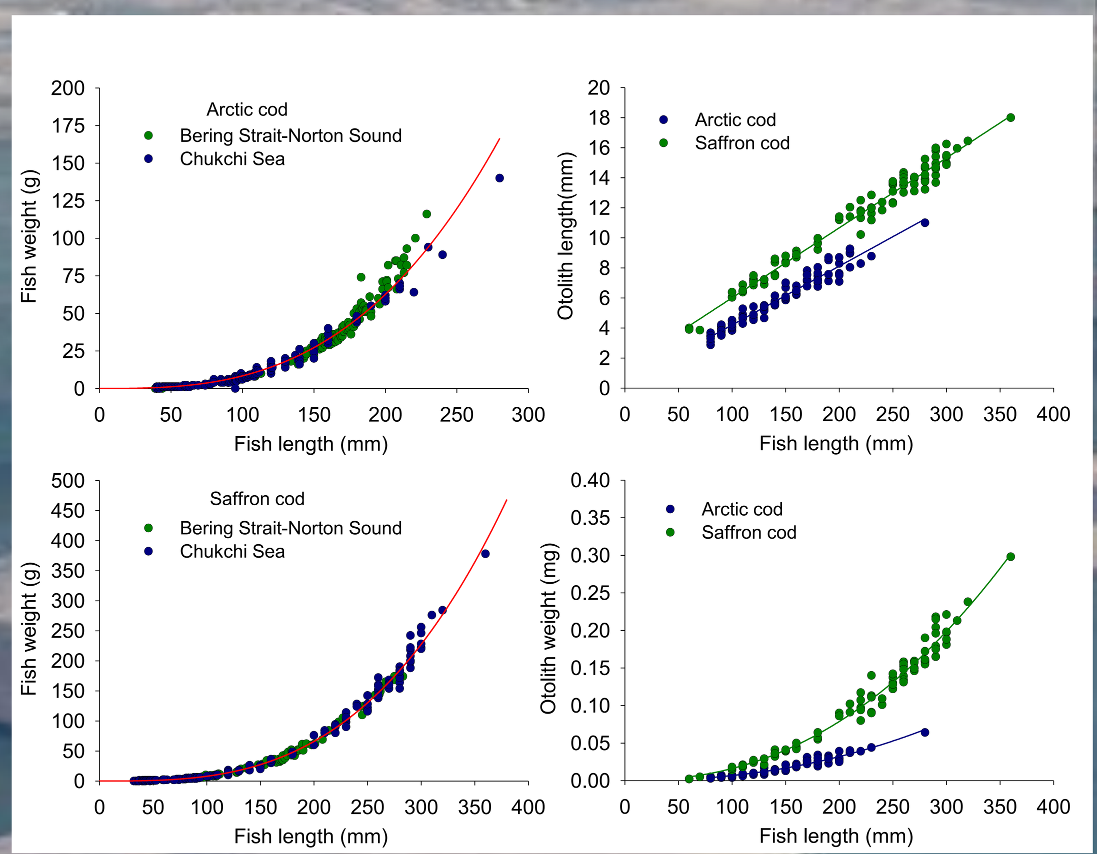

Figure 2. Saffron cod and Arctic cod body weight-body length, otolith length-body length, and otolith weight-body length relationships from specimens collected during the 2012 Arctic Ecosystem Integrated Survey in the Chukchi Sea.

Results

- Based on between reader comparisons (>600 samples) of two independent age readers, agreement (+/- 0 years) was 70% and 90% for Arctic cod and saffron cod, respectively, with low relative bias (functional regression).
- For saffron cod, peaks in δ^{18}O signature corresponded to the visual interpretation of winter (translucent) growth zones verifying the annual growth patterns (Fig. 1a & 1b).
- Growth relating body weight to body length differed between species but not regions (Fig. 2):

  $W_{AC} = 1.30E^{-5} \cdot L^{2.9}$; $W_{SC} = 6.075E^{-6} \cdot L^{3.1}$

  Otoliths size grew proportional to body size:

  $OL_{AC} = 0.28 + 0.04$ FL; $OL_{SC} = 1.39 + 0.05$ FL.
- In 2012 Saffron cod (L_∞ = 363 mm, K = 0.378) attained larger asymptotic sizes at faster growth rates than Arctic cod (L_∞ = 209 mm, K = 0.312) (Fig. 3).
- Arctic cod growth rates were higher with more northerly latitudes suggesting a possible cline (C. Chukchi K=0.324 > S. Chukchi K=0.297 > N. Bering K=0.171) (Fig. 3).
- Both species exhibited reduced asymptotic sizes and higher growth rates in 2012 compared to the same regions 33 years earlier, in the late 1970s. Saffron cod in 1970s: L_∞ = 560 mm, K = 0.121 compared to saffron cod in 2012: L_∞ = 363 mm, K = 0.378, and Arctic cod in 1970s: L_∞ = 244 mm, K = 0.276 compared to Arctic cod in 2012: L_∞ = 209 mm, K = 0.312 (Fig. 3).

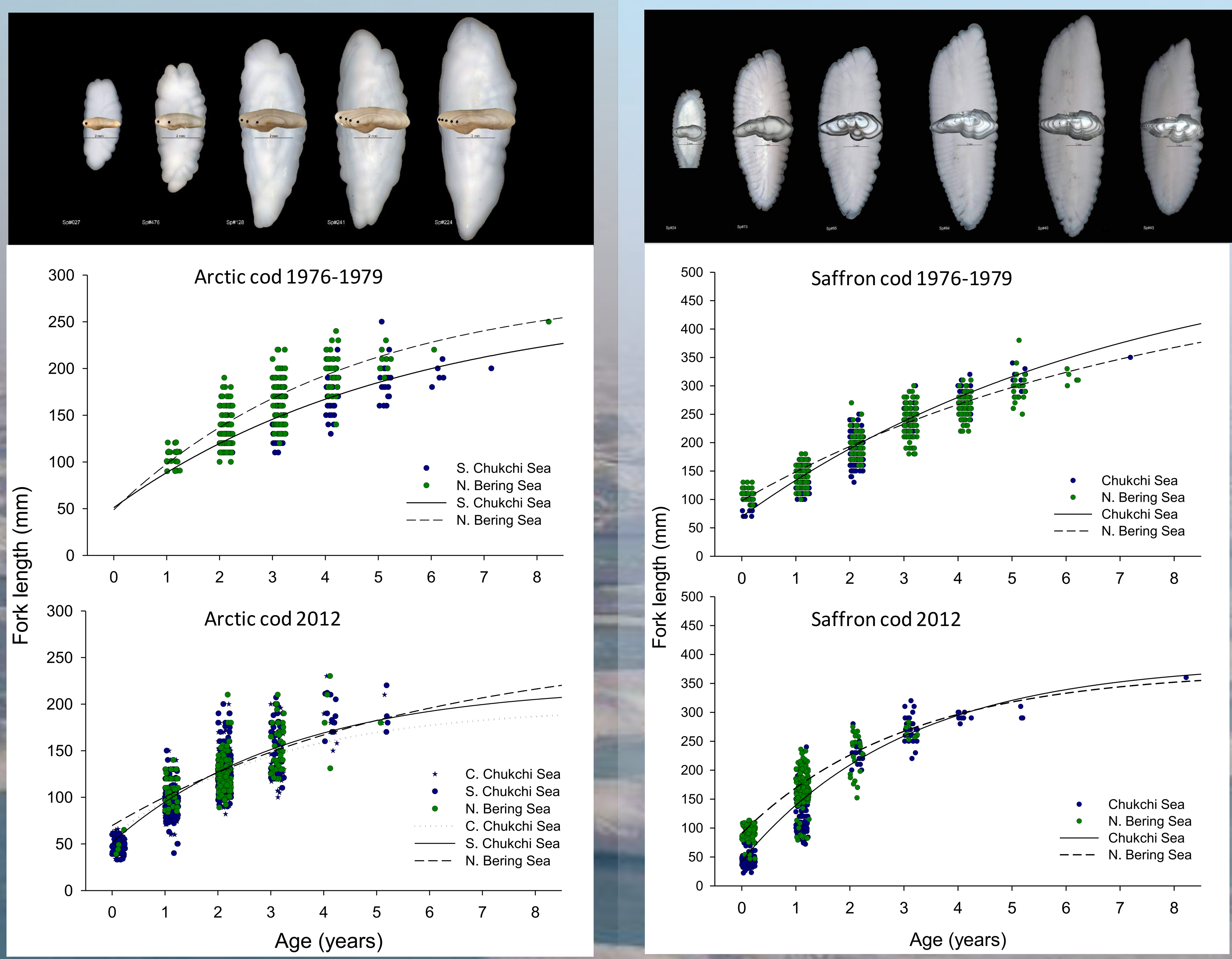

Figure 3. Arctic cod (left panel) and saffron cod (right panel) length (fork length, mm) at age (estimated by otoliths) and fitted von Bertalanffy growth curves by region in the northern Bering and central and southern Chukchi Seas from data collected during the 1976-1979 AFSC base-line and 2012 Arctic Ecosystem Integrated Surveys. Regions correspond to northern Bering Sea (including the Norton Sound; 63.1°N-65.5°N), southern Chukchi Sea (65.5°N-68.3°N), and central Chukchi Sea (68.3°N-72.0°N). Collections were not made in the central Chukchi Sea during the 1976-1979 AFSC baseline survey and data from 2012 was aggregated as Chukchi Sea.

Conclusions

- Based on a large sample of otoliths (>3000) ageing criteria for Arctic cod and saffron cod have been established with good precision (generally better than other gadids in the North Pacific).
- Arctic cod and saffron cod are relatively small bodied fish with short life spans compared to other gadids; oldest encountered was 8 years of age for both species.
- Saffron cod attain a larger asymptotic size with a faster growth rate than Arctic cod.
- Evidence suggests temporal changes in growth for both species with smaller sizes and higher growth rates in the 1970s compared to 2012.
- Higher growth rates of Arctic cod at higher latitudes support the notion that stenothermic, high-latitude fish grow faster at colder temperatures than fish of the same species at lower latitudes.

Acknowledgements

We thank the survey crews for data collection efforts, including Bob Lauth (AFSC) and Franz Mueter (UAF) for overseeing the survey effort. This study was funded [in part] by the U.S. Department of the Interior, Bureau of Ocean Energy Management (BOEM) through Cooperative Agreement M12PG00018 between BOEM, Alaska Outer Continental Shelf Region and University of Alaska Fairbanks / Alaska Fisheries Science Center.

References

Helser,T.E., Colman, J.R., Anderl, D.M., Kastelle, C.R., 2016. Growth dynamics of saffron cod (Eleginus gracilis) and Arctic cod (Boreogadus saida) in the Northern Bering and Chukchi Seas. Deep-SeaRes.II(2016), http://dx.doi.org/10.1016/j.dsr2.2015.12.009i