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## Advancing Ancient Mollusk Shells as Multi-Proxy Archives of the Past

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# Advancing Ancient Mollusk Shells as Multi-Proxy Archives of the Past



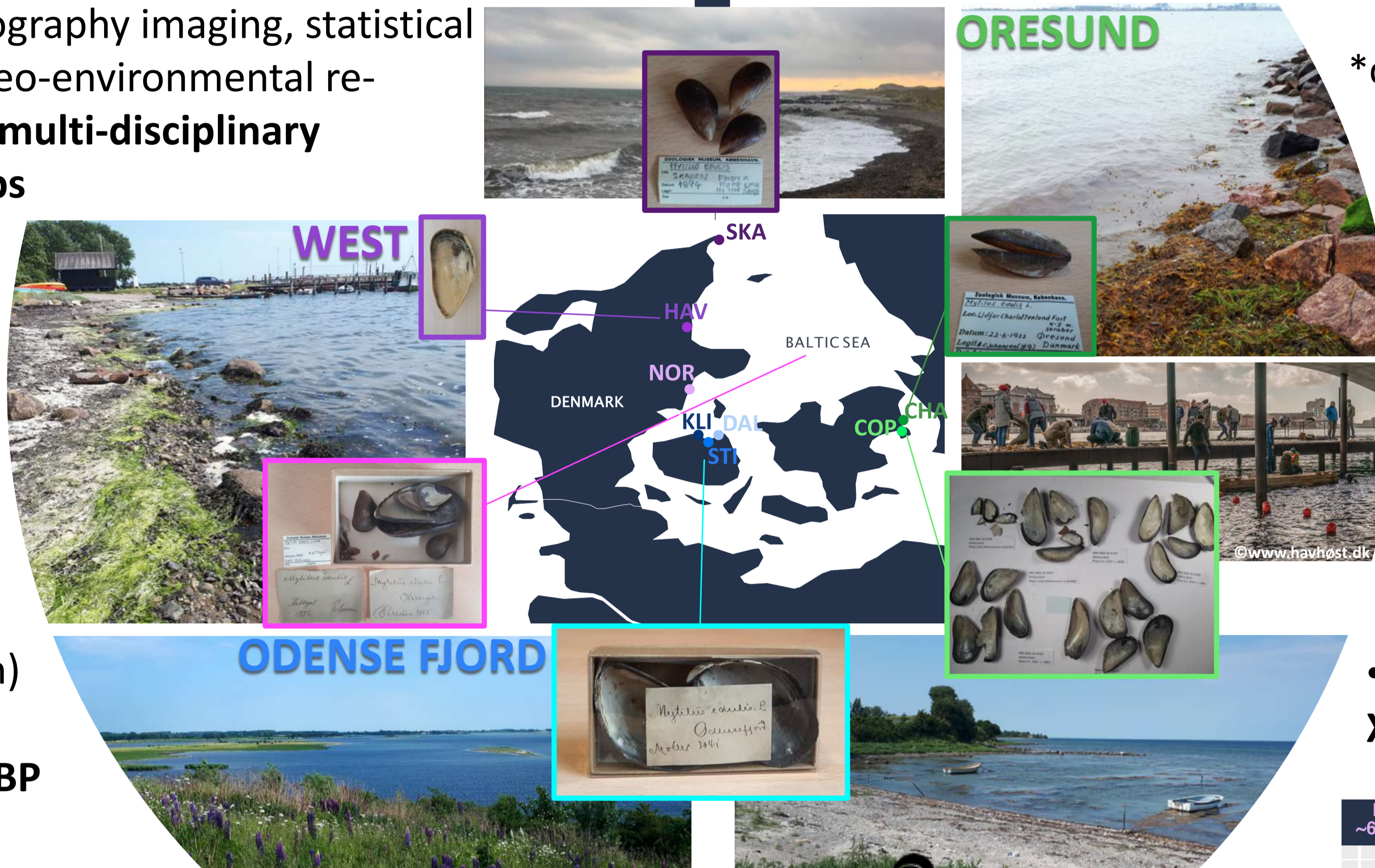
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## BACKGROUND

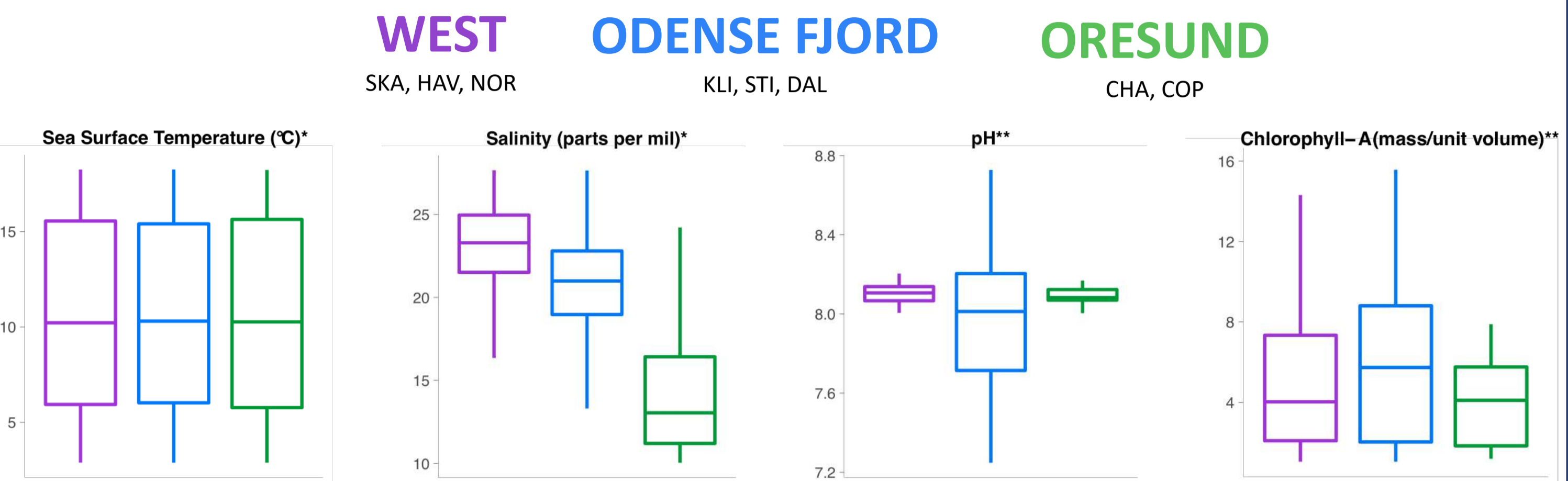
Mollusk shells were recently revealed as **metagenomic archives of the past**, potentially covering the last 100,000 years. This has not only opened new avenues for ancient DNA research but also added DNA to the list of morphological, structural and biogeochemical shell proxies that inform about the evolution, life history, stress responses and past environments of mollusks. Multi-proxy studies thus offer the unique opportunity to characterize, at high resolution, the dynamics of their different **biological responses to environmental changes**.

Here, we focus on **marine mussels** as model organisms for eco-evolutionary studies. We combine 3D computed tomography imaging, statistical shape analyses, diffeomorphometry, paleo-environmental reconstruction and ancient genomics. In a **multi-disciplinary approach**, to investigate the **relationships between the shell morphology and genomic composition of wild *Mytilus edulis* x *M. trossulus* hybrid zone** at both the **spatial and temporal scales**.



## ENVIRONMENT

• **3 REGIONS** sampled for modern shells and tissues



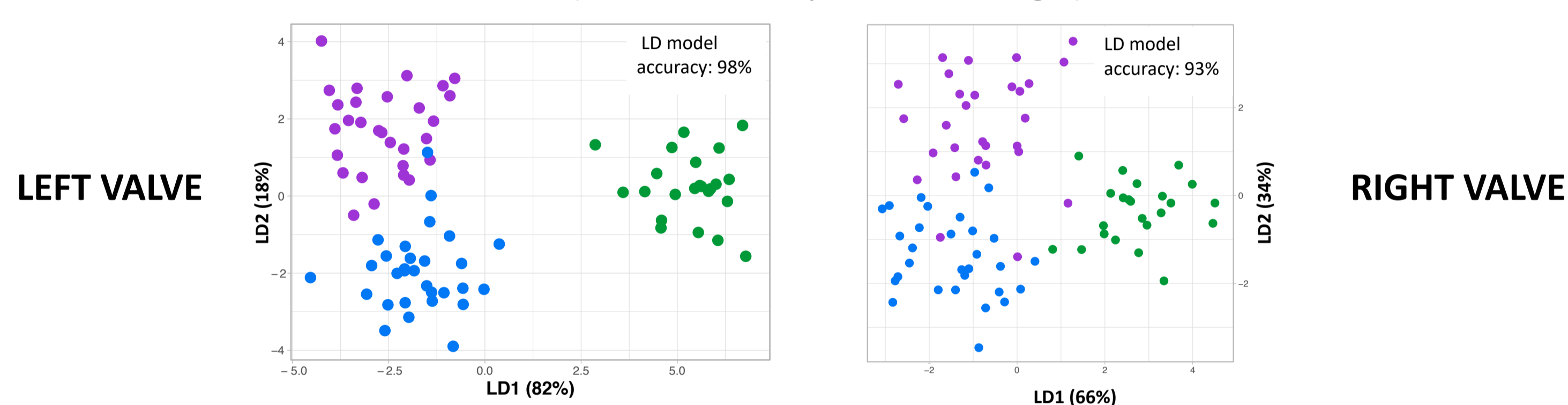
\*daily and \*\*monthly means obtained for 2018 from the Copernicus Marine Environment Monitoring Service (CMEMS)

• Past environmental conditions reconstructed through isotopic analyses of ancient shells (e.g.,  $\delta^{18}\text{O}_{\text{shell}}$ ,  $\delta^{13}\text{C}_{\text{shell}}$ ).

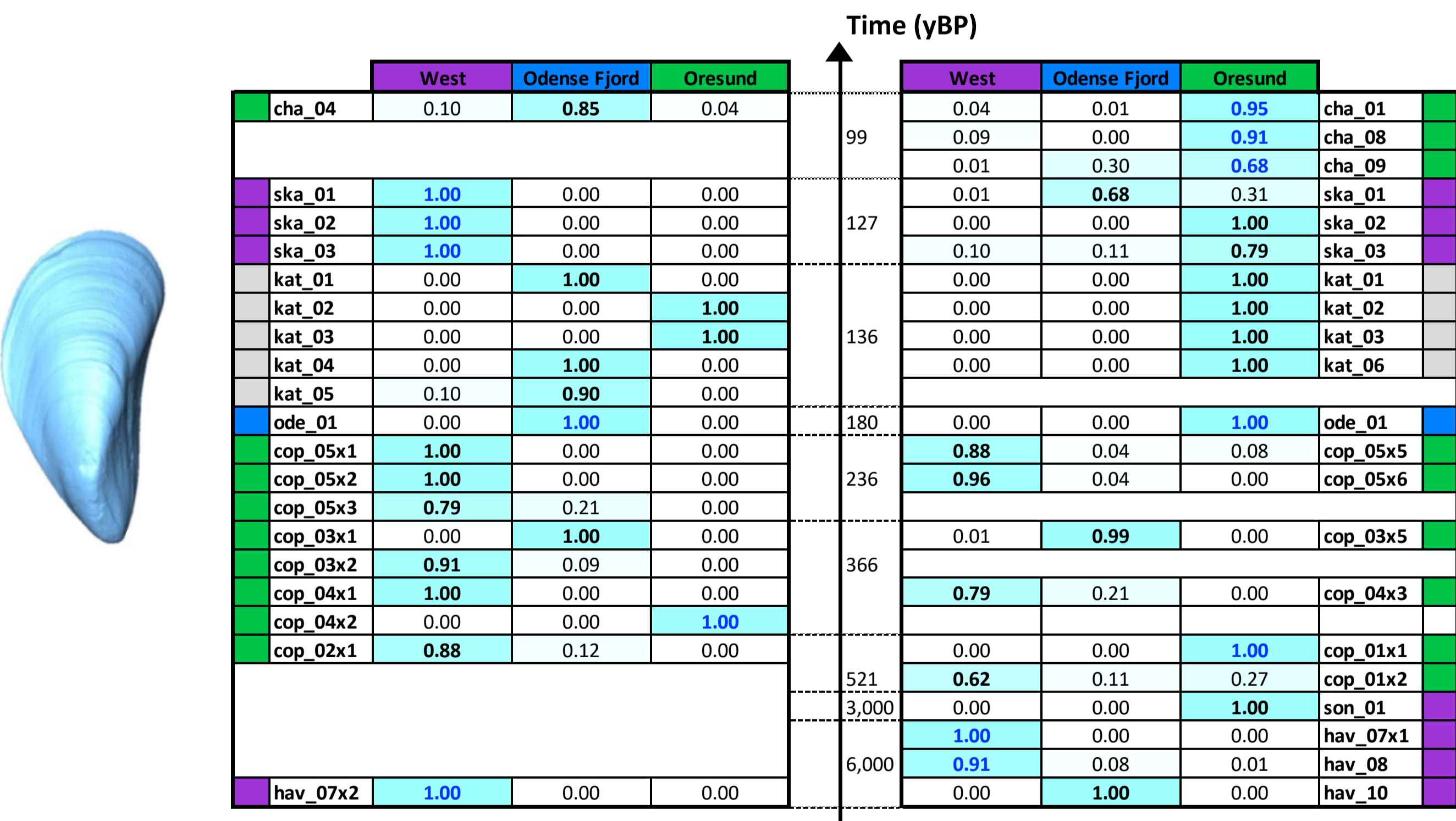
## SHELL MORPHOLOGY

- 206 micro-CT scans (<58  $\mu\text{m}$  resolution)
- 83 modern complete shells
- 40 ancient shells dated to ~99-6,000 yBP

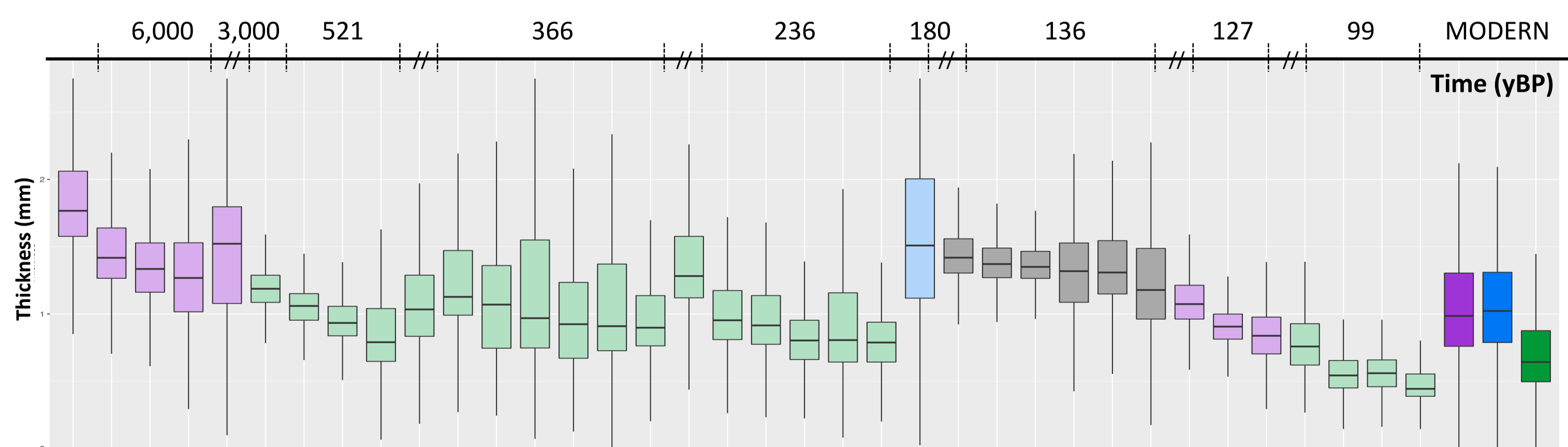
• **DIFFEOMORPHIC DIFFERENTIATION OF MODERN SHELLS BY BALTIC SEA REGION**  
Linear Discriminant (LD) functions for modern shape variation (shells colored by REGION of origin)



• **TEMPORAL CHANGES IN MORPHOLOGICAL POPULATION AFFINITIES**  
LD Posterior probabilities for REGION prediction of ancient shells



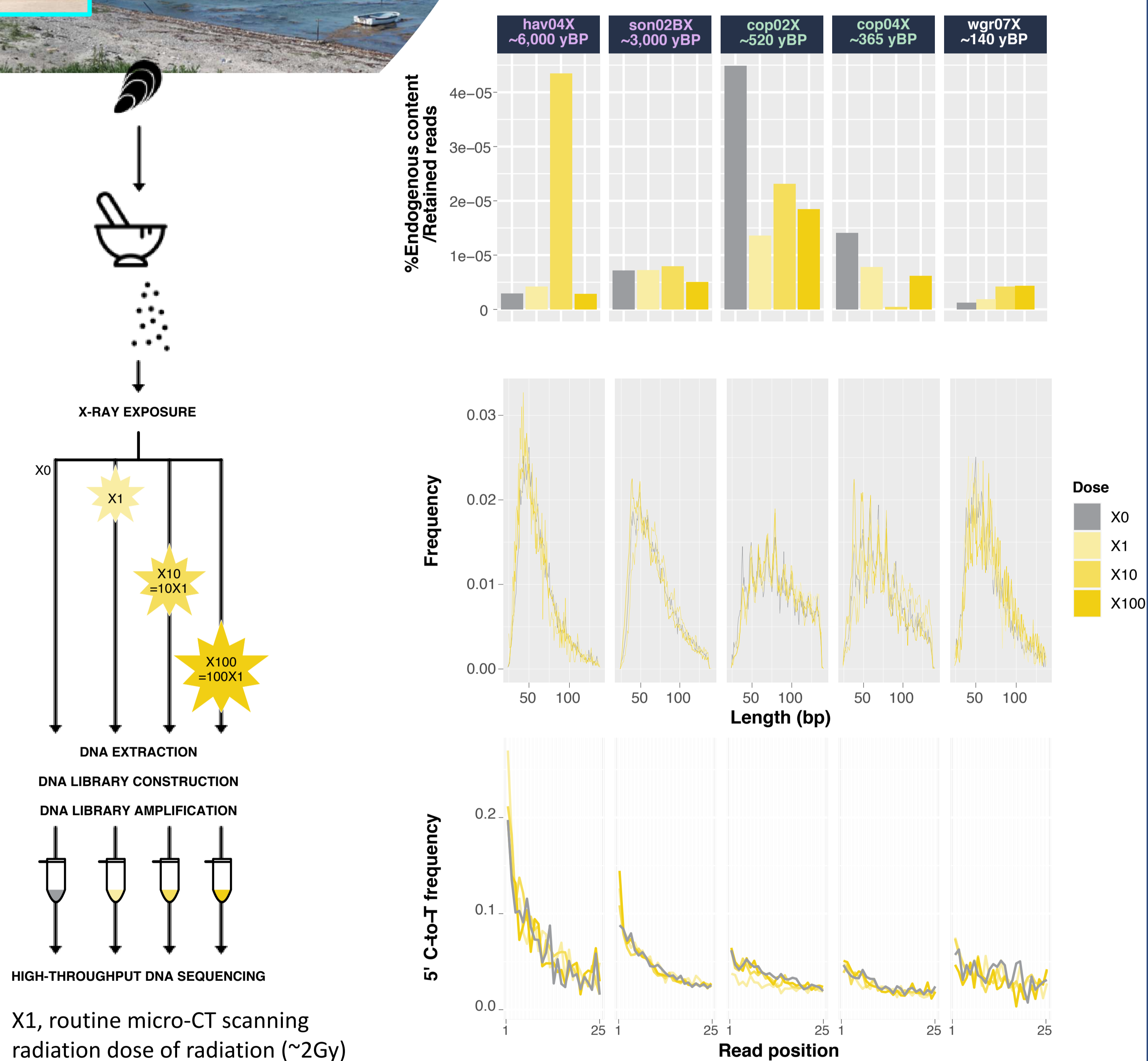
• **LOCAL DECREASE IN SHELL THICKNESS THROUGH TIME**



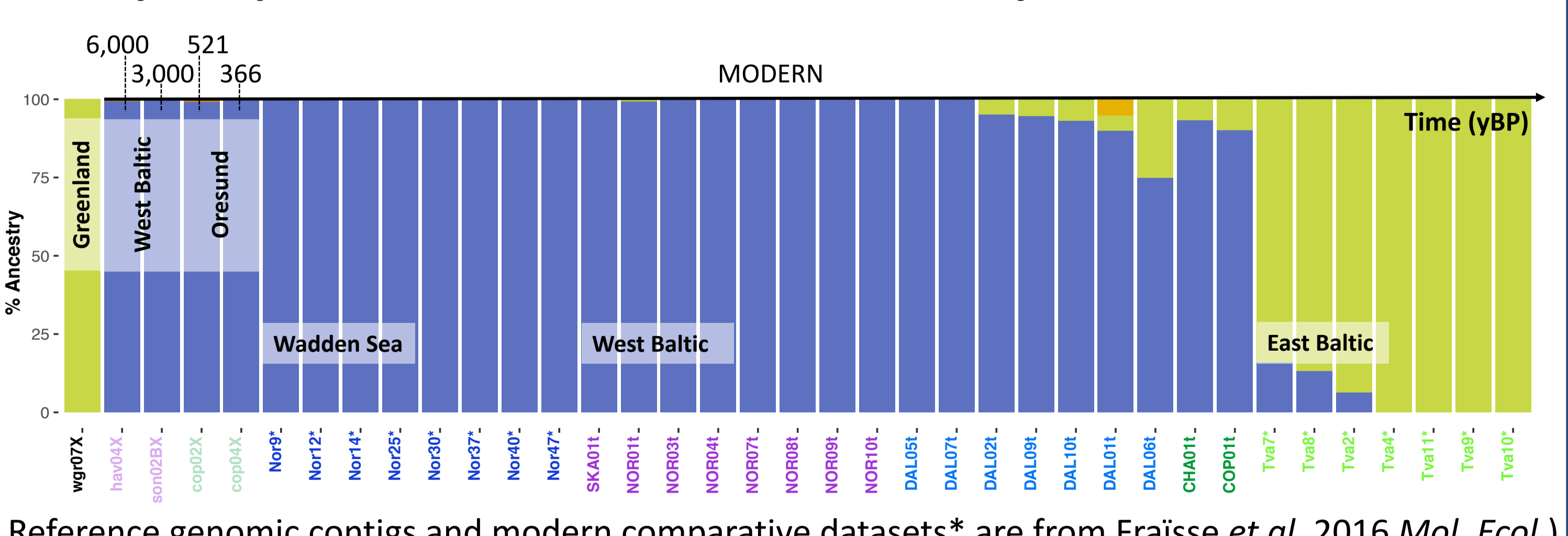
For each shell, thickness was measured at ~50,000 points on the surface.

## GENOMICS

• **NO SIGNIFICANT IMPACT OF ROUTINE X-RAY EXPOSURE ON ANCIENT DNA**



• **ANCIENT AND MODERN POPULATION STRUCTURE: geographical and temporal patterns of *M. edulis* x *M. trossulus* hybridization**



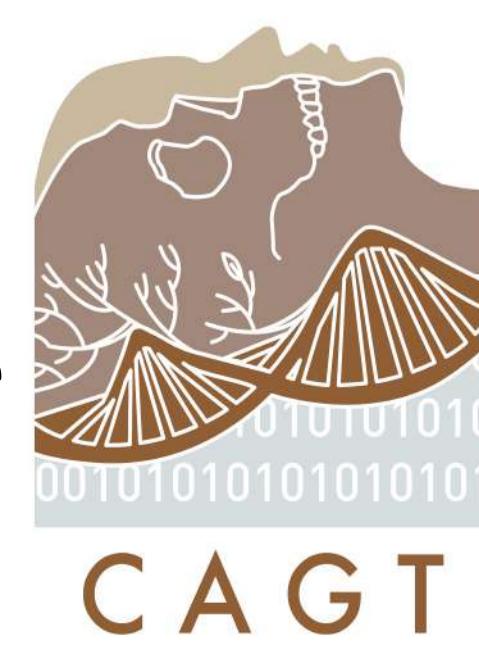
Reference genomic contigs and modern comparative datasets\* are from Fraïsse *et al.* 2016 *Mol. Ecol.*

• **Associated References:**

Der Sarkissian *et al.* 2017 *Mol. Ecol. Res.* 17(5):835-853. doi: 10.1111/1755-0998.12679

Der Sarkissian *et al.* 2020 *Front. Ecol. Evol.* 8:37. doi: 10.3389/fevo.2020.00037

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