Bomb radiocarbon dating of the Indian Ocean blue shark *Prionace glauca*: a preliminary test of ageing accuracy

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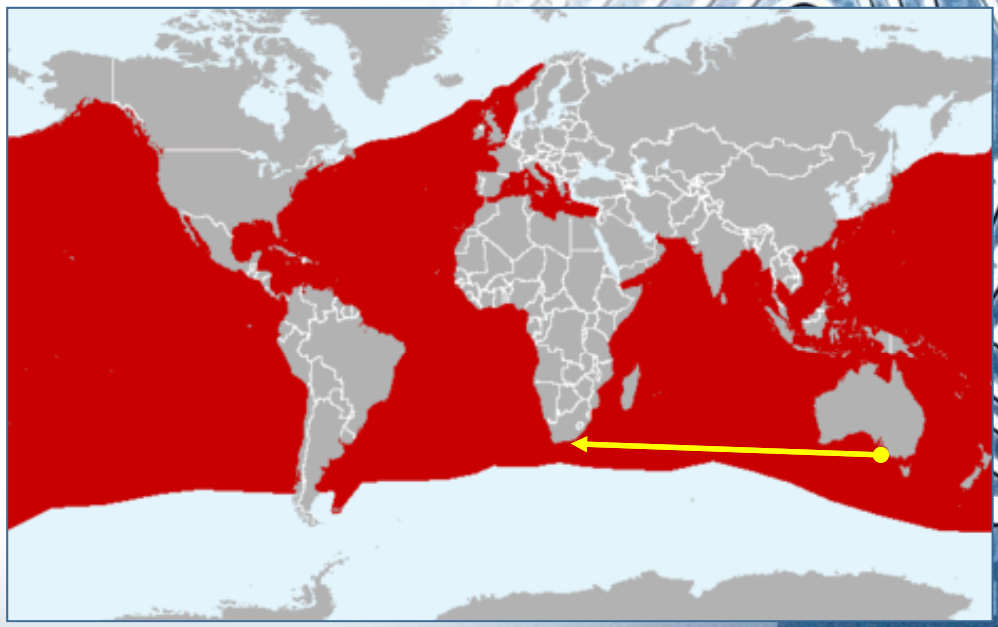
Blue shark *Prionace glauca*

- Principal shark bycatch species in the Indian Ocean LL fisheries
- Distributed circumglobally from temperate to tropical waters
- Highly migratory species exhibiting transoceanic migrations

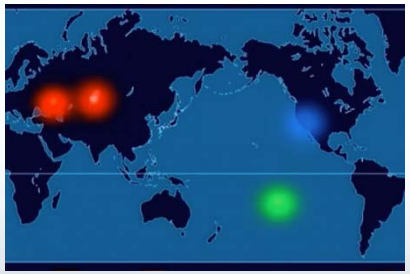


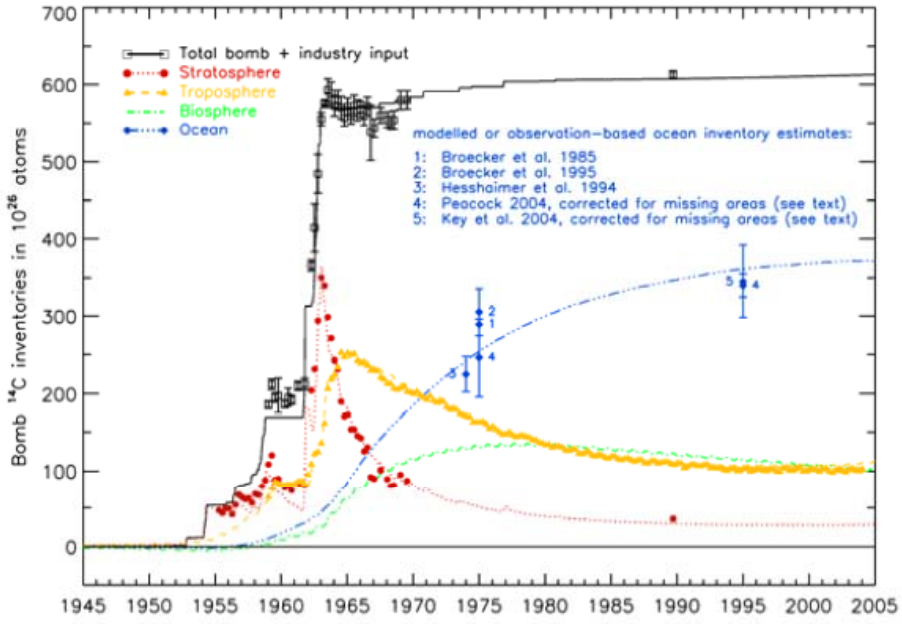
Blue shark *Prionace glauca*

- Long-living fish: estimated age is up to 16-20 years old in Atlantic (MacNeil, Campana, 2002, Skomal, Natanson, 2003)
- In the Atlantic Ocean age validation was done with OTC tagging (Skomal, Natanson, 2003)
- Preliminary max. age estimates for the Indian Ocean: 24 years (vertebrae) (Rabehagasoa et al., 2009)
- No age validations are available to date for the Indian Ocean blue sharks
- Validation is essential for age and growth studies and further potential use in stock assessment
- We used bomb radiocarbon chronology to validate annual deposition of growth rings at blue shark vertebrae

Bomb radiocarbon dating

- Bomb derived radiocarbon from nuclear testing in the atmosphere provides one of the best age validation approaches available for long-lived fishes
- The onset of nuclear testing in the late 1950s resulted in an abrupt increase in atmospheric ^{14}C, which was soon incorporated into corals, bivalves, fish and other organisms
- All vertebrae cores of fish hatched before 1958 contain relatively little ^{14}C and all those hatched after 1968 contains elevated levels





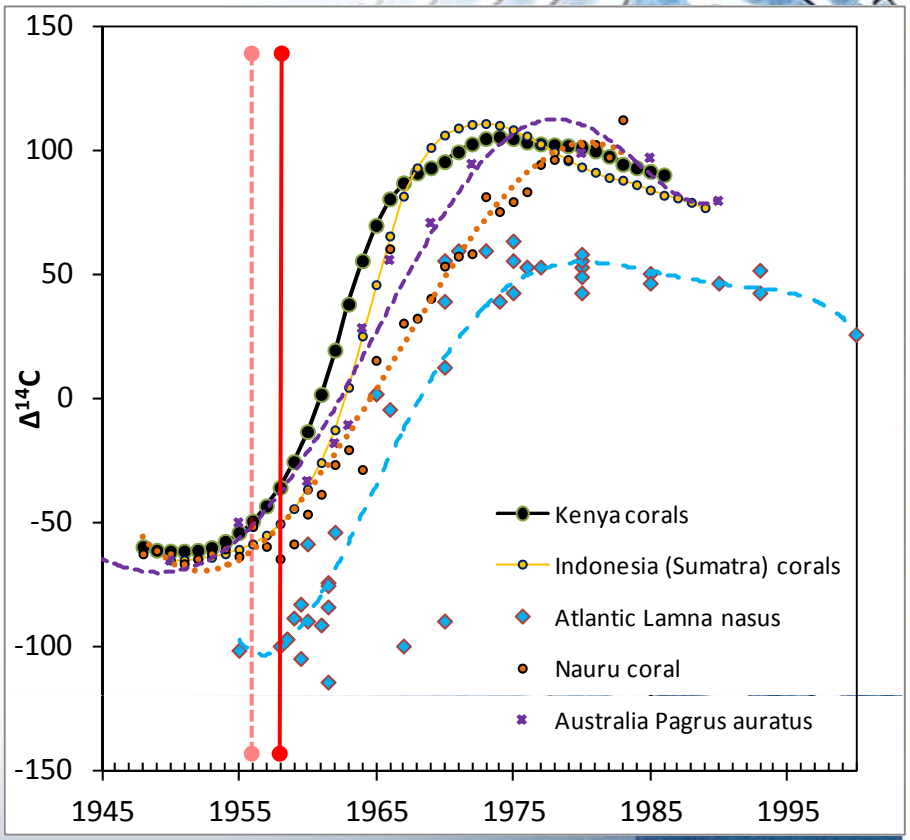
Graph source: Naegler et al., 2005

Bomb radiocarbon dating

- Since the ^{14}C signal recorded in deepsea environments is different from that of surface marine waters (deepsea=delayed), reference (known age) ^{14}C chronologies **appropriate** to the **environment** are necessary;
- Interpretation is simple: under-ageing would phase shift the bones ^{14}C chronology towards more recent years, while over-ageing would phase shift it towards earlier years
- The pre-bomb and post-bomb ^{14}C **levels** are affected by water mixing times, and thus are **irrelevant** for dating. What is important is the **year of initial increase**.

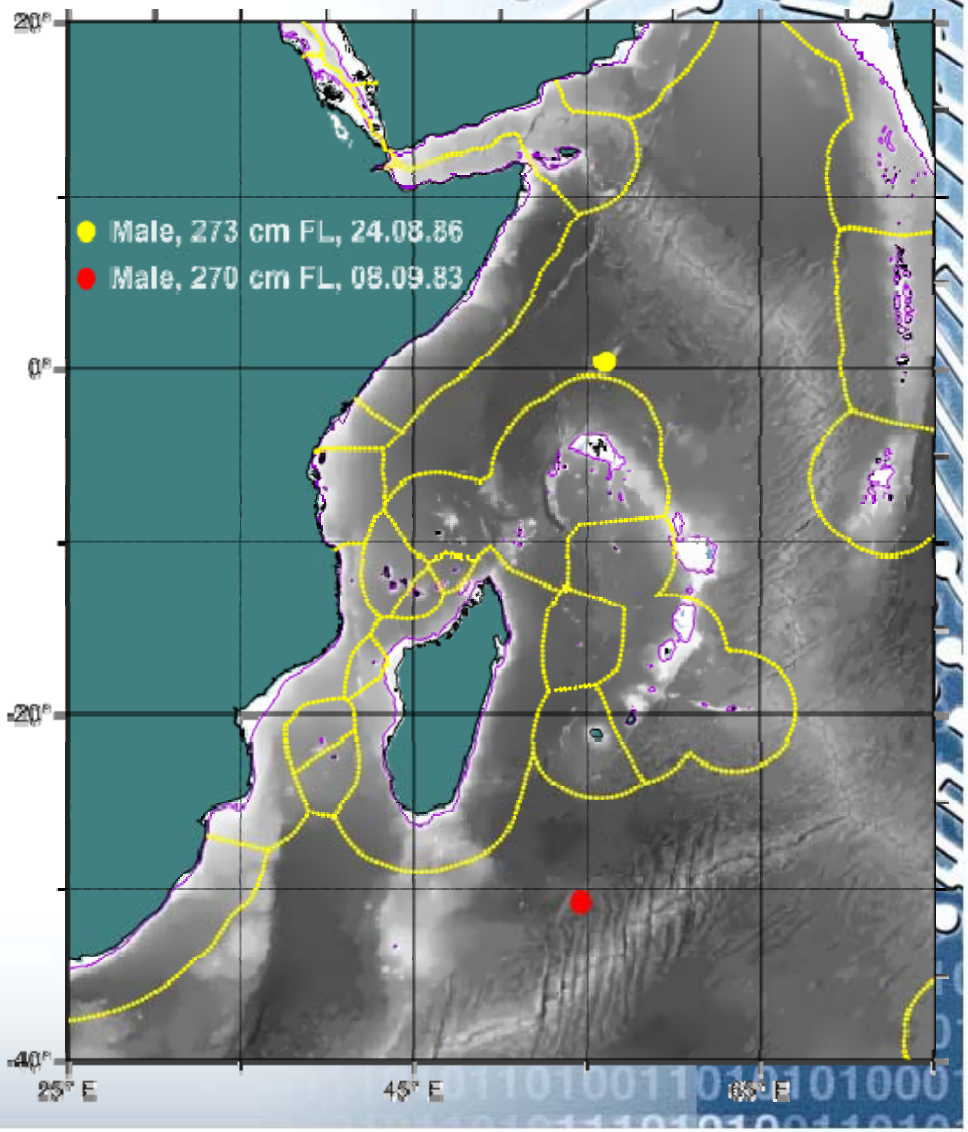
Bomb radiocarbon dating

- Reference chronology from the Indian Ocean is available for Kenyan and Indonesian corals.
- Shown are the most relevant bomb radiocarbon reference chronologies:
  - Corals: Kenya, Indonesia, and Nauru;
  - Pagrus auratus otolith chronology from southern Australia;
  - The most complete shark chronology (porbeagle) from the NW Atlantic.
- All chronologies begin to increase between 1956 and 1958 (vertical lines)



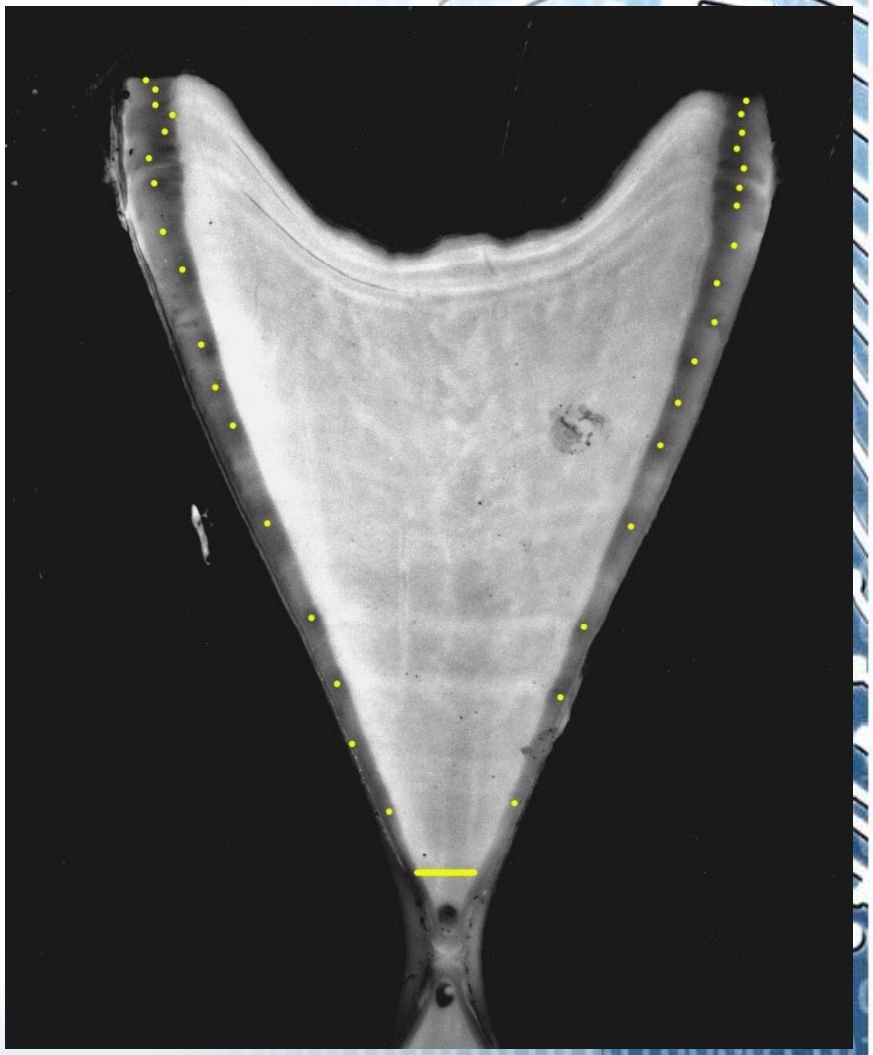
Indian Ocean blue sharks samples

- Vertebrae from two biggest blue sharks caught during SIOTLLRP in 1980s were selected:
  - Male, 330 cm TL, 273 cm FL, 134 kg TW, caught 24.08.1986 in the equatorial Indian Ocean, and
  - Male, 330 cm TL, 270 cm FL, 150 kg TW, caught 08.09.1983 in the southwestern Indian Ocean
- Vertebrae were sectioned and aged
- Individual annuli (or pairs of annuli) were micromilled and assayed for bomb radiocarbon

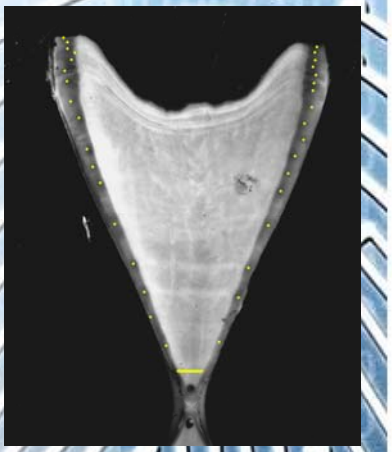


BSH No 1: Equatorial waters, 273 cm FL, 1986

- Based on our interpretation of the growth bands, the shark was between 18-19 years old;
- The first 2 annuli from the section, which would have corresponded to a date of formation of 1968-1969 were extracted;
- This period is at the end of the period of increasing bomb radiocarbon (not a good candidate for assay).
- We decided to assay the sample in case we had underestimated the age



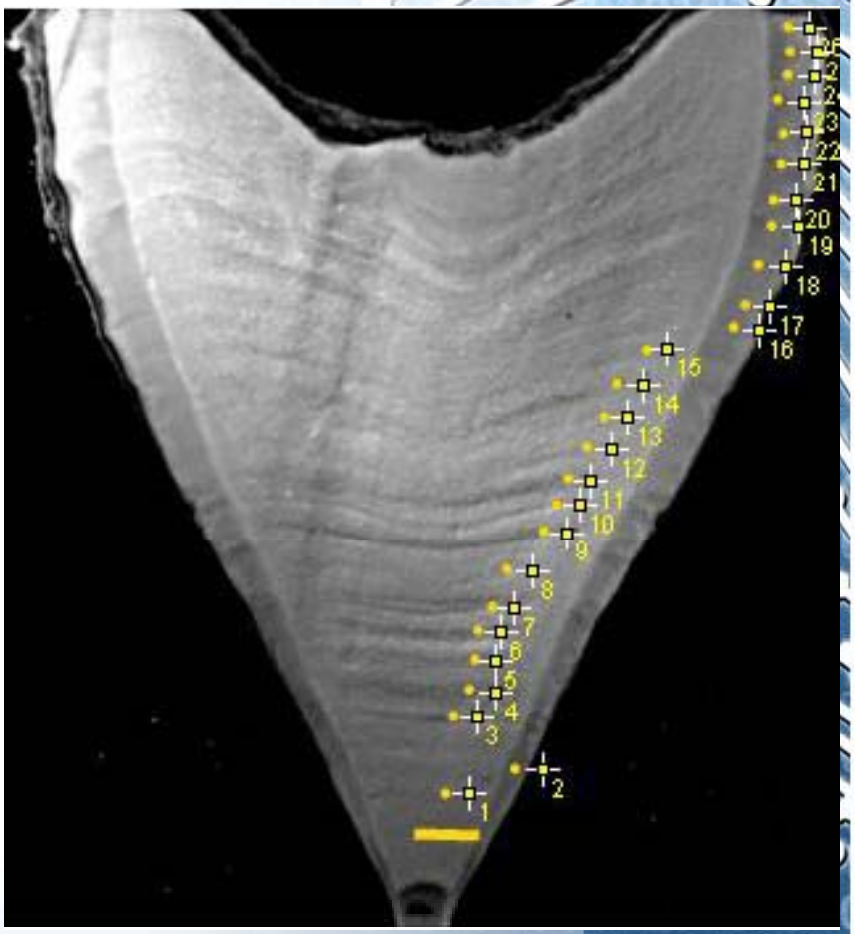
BSH No 1: Equatorial waters, 273 cm FL, 1986



- The $d^{14}C$ value was 64.9, which is indicative of post-bomb radiocarbon.
- Post-bomb values are difficult to link to specific years. We was able to can say that the annuli formed after 1962 or so.
- Assay of the 1st vertebrae is consistent with our age interpretation based on growth bands:
  - It was formed after 1962, the shark was no more than 24 years old. However we cannot say exactly what year it is formed in.
  - This is a useful result in that it shows that we have not seriously over-estimated the age of the shark.

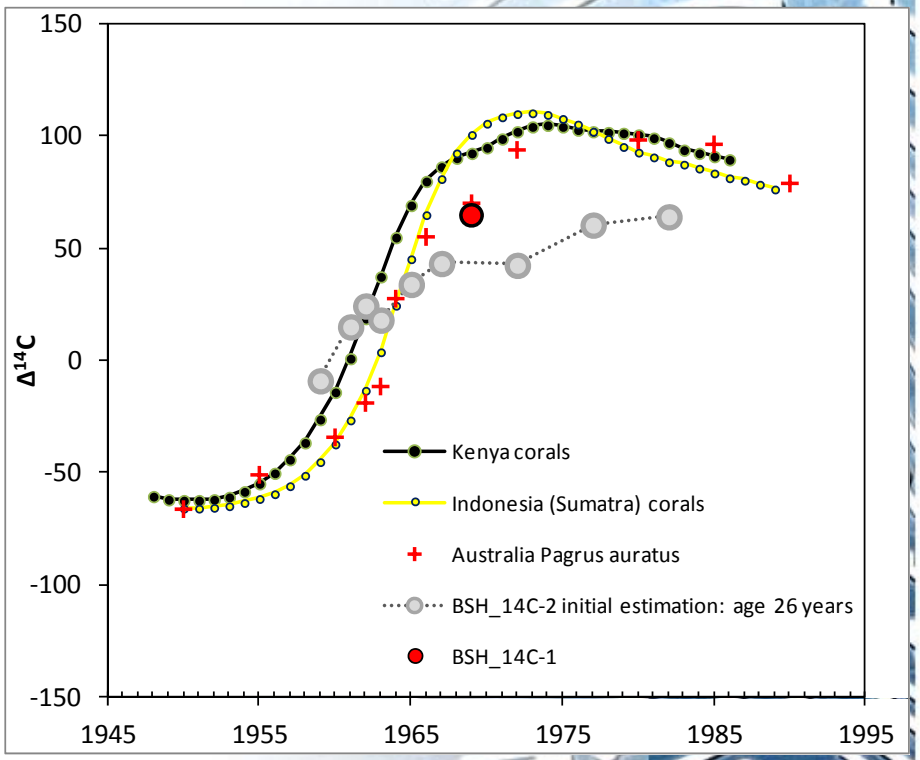
BSH No 2: Southwest Indian Ocean, 270 cm FL, 1983

- Estimated age is 26 years
- The 1st and 2nd annuli (pooled), 3rd and 4th (pooled), 5th, 6th, 8th, 10th, 15th, 20th and 25th were assayed for $d^{14}C$
- If age interpretation 26 years is correct, counting back from the edge (1983), oldest annuli (1st/2nd) should have formed in 1959/1960



BSH No 2: Southwest Indian Ocean, 270 cm FL, 1983

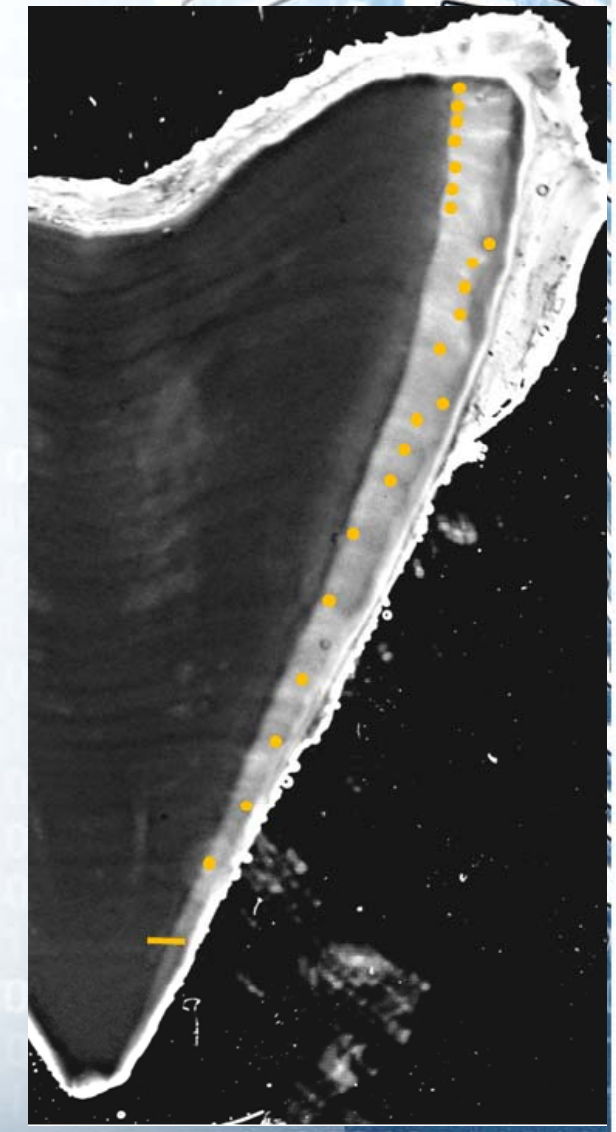
- Two things are evident from overlay of reference chronologies and 2nd blue shark ^{14}C assay:
  - **The earliest annulus is not pre-bomb**: it had formed after the bomb signal had started increasing. **Actual** year of **initial** increase **impossible to determinate**;
  - **The early years of the blue shark chronology are offset from the reference by about 3 years**.



- That suggests that the blue shark is actually ~3 years younger (~23 years)

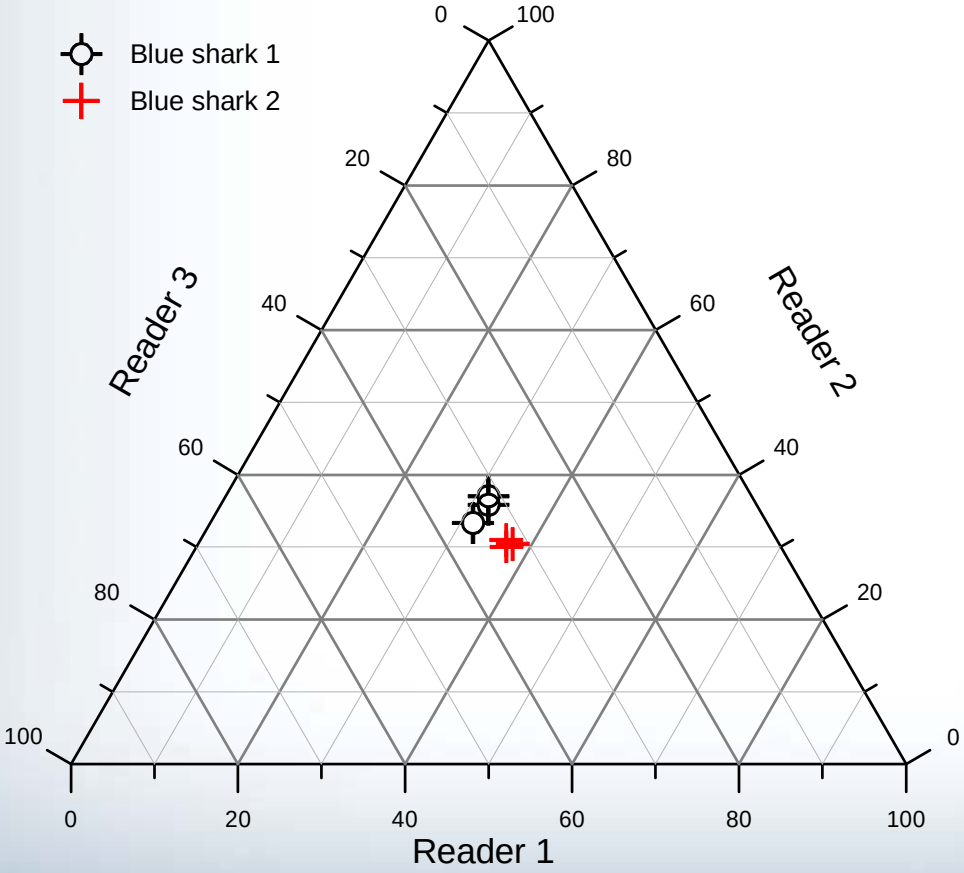
BSH No 2: Southwest Indian Ocean, 270 cm FL, 1983

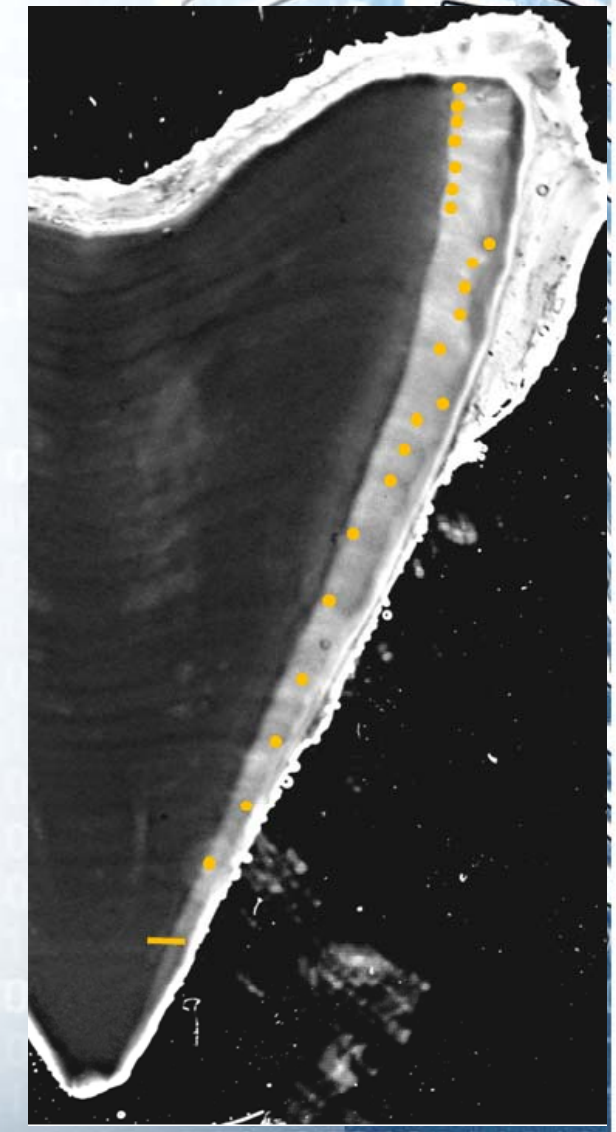
- Second independent blind reading
  (two readers, first reader does not participated):
  Estimated age is **22** years



BSH No 2: Southwest Indian Ocean, 270 cm FL, 1983

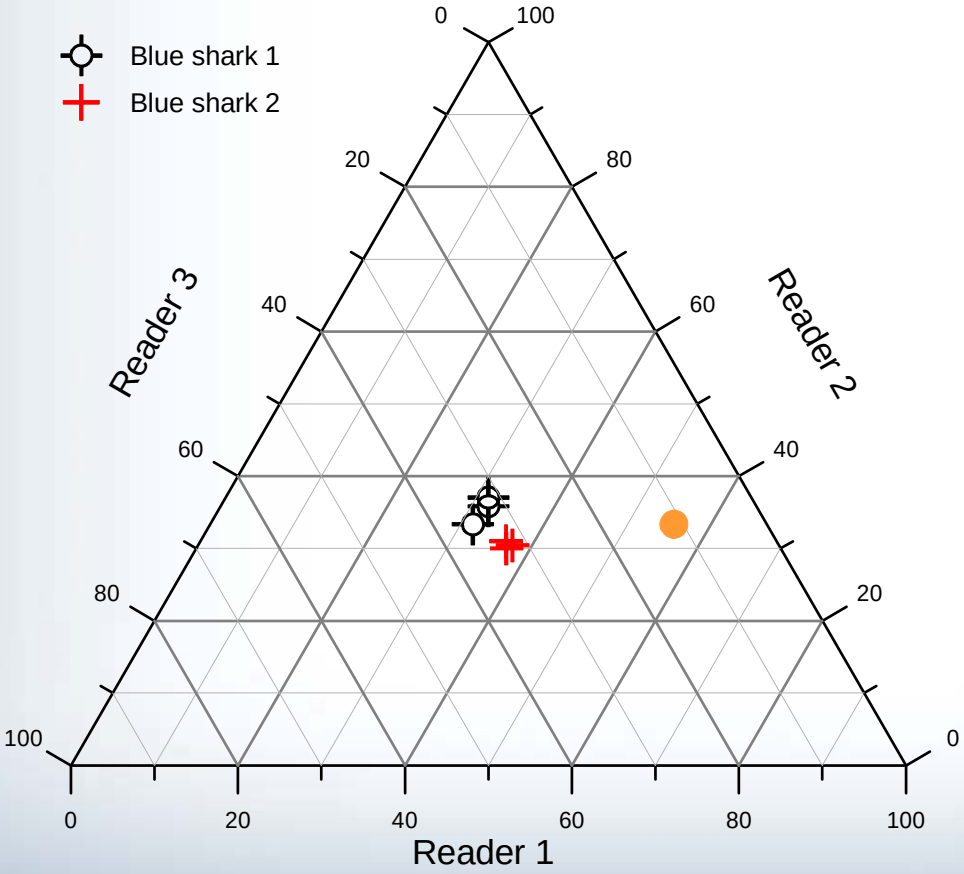
- Good agreement between two readers
- No strong deviation from first reading

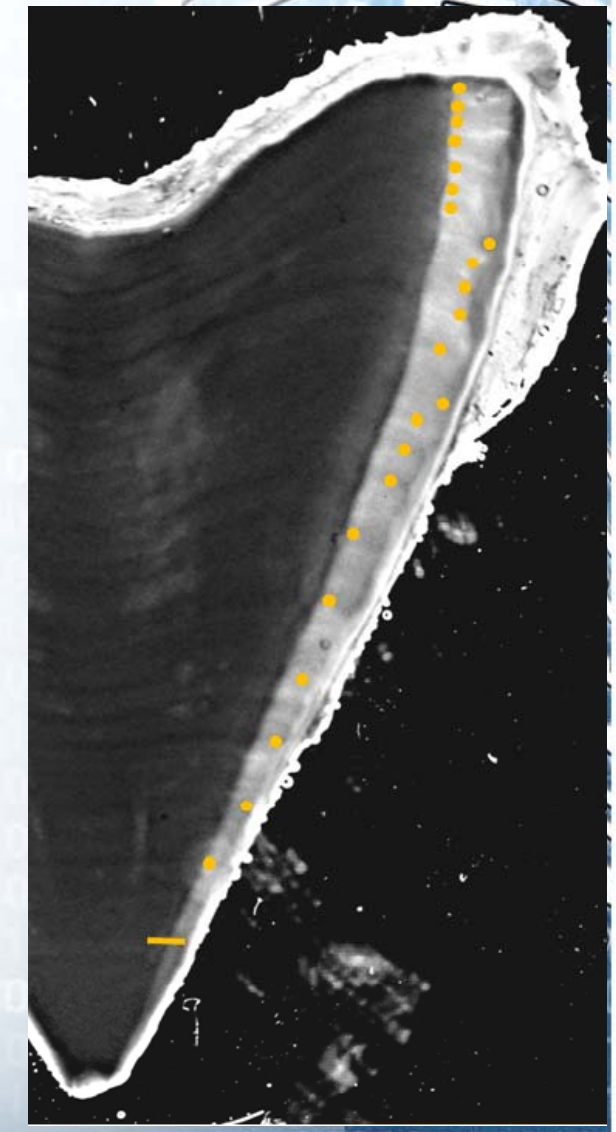




BSH No 2: Southwest Indian Ocean, 270 cm FL, 1983

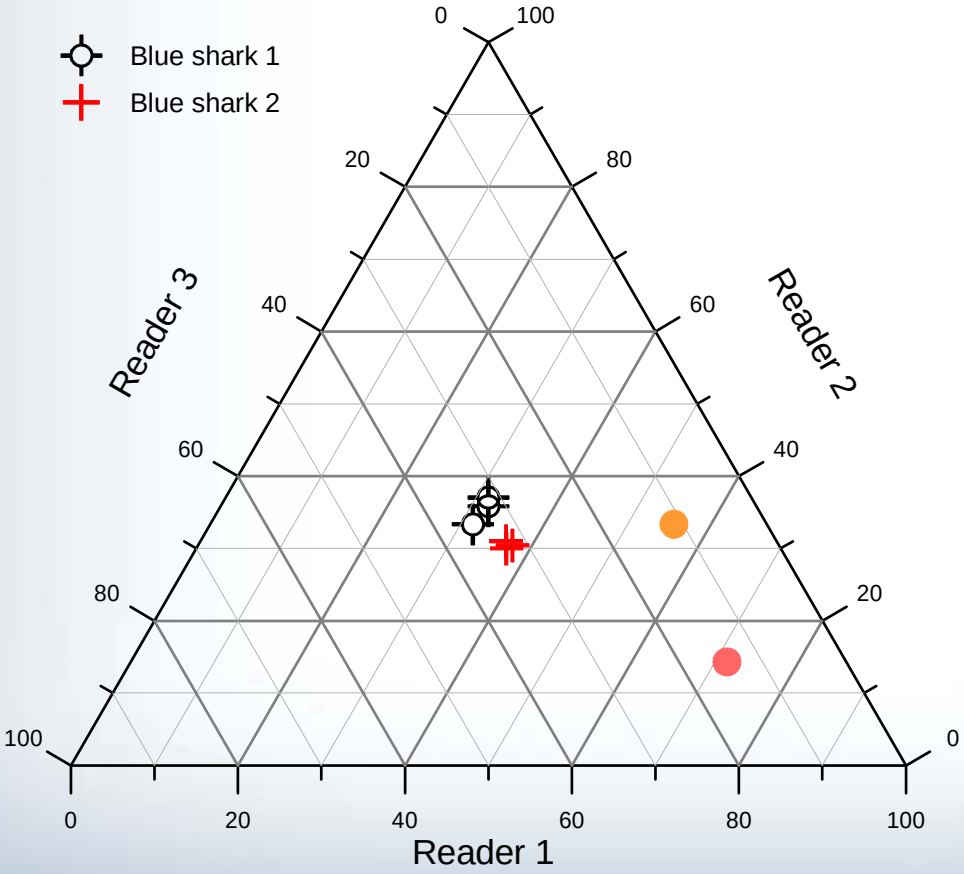
- Example of three readers disagreement

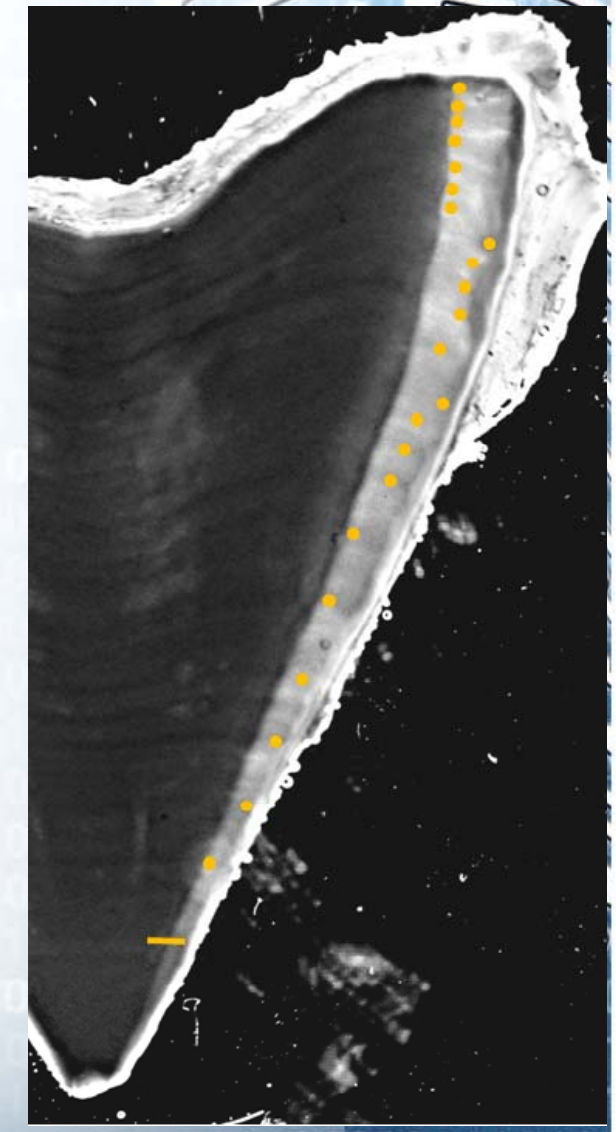




BSH No 2: Southwest Indian Ocean, 270 cm FL, 1983

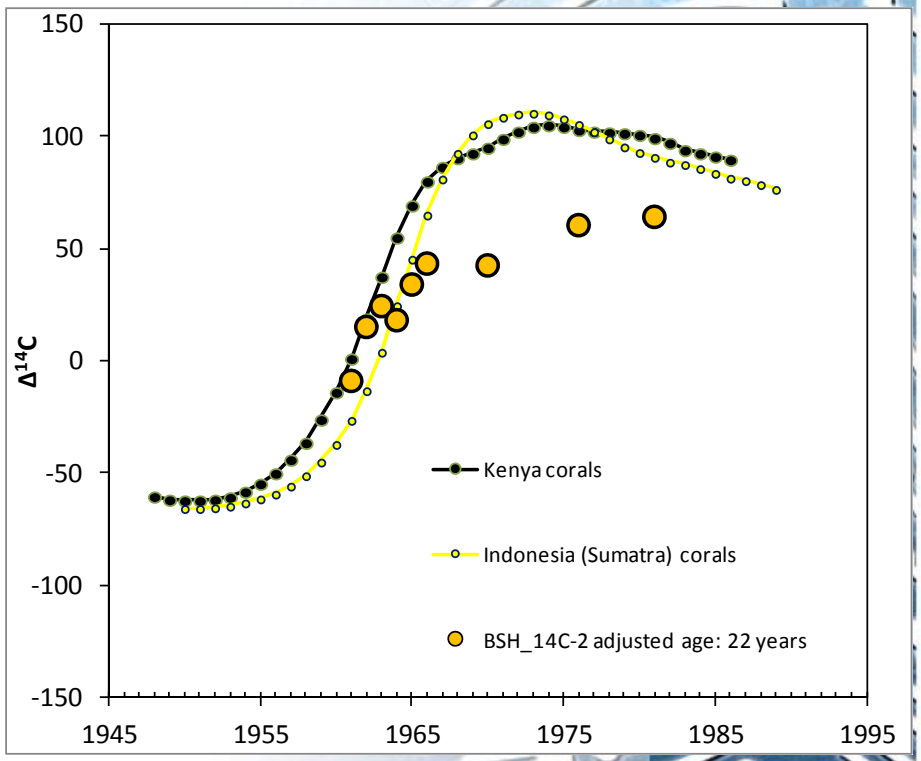
- Example of one reader disagreement





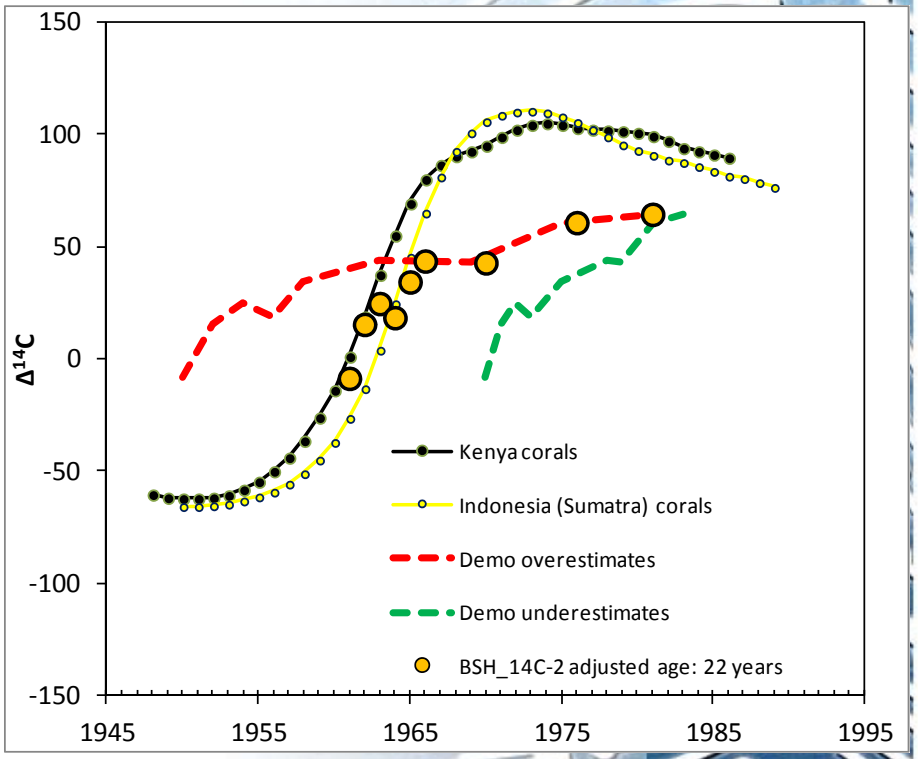
BSH No 2: Southwest Indian Ocean, 270 cm FL, 1983

- New adjusted curve well corresponds to reference curves
- We re reasonably confident in:
  - Age estimation 22 years, and
  - Annual growth rings deposition of blue shark



BSH No 2: Southwest Indian Ocean, 270 cm FL, 1983

- Overestimates vs. underestimates:
  - **Overestimated age curve**
  - **Underestimated age curve**

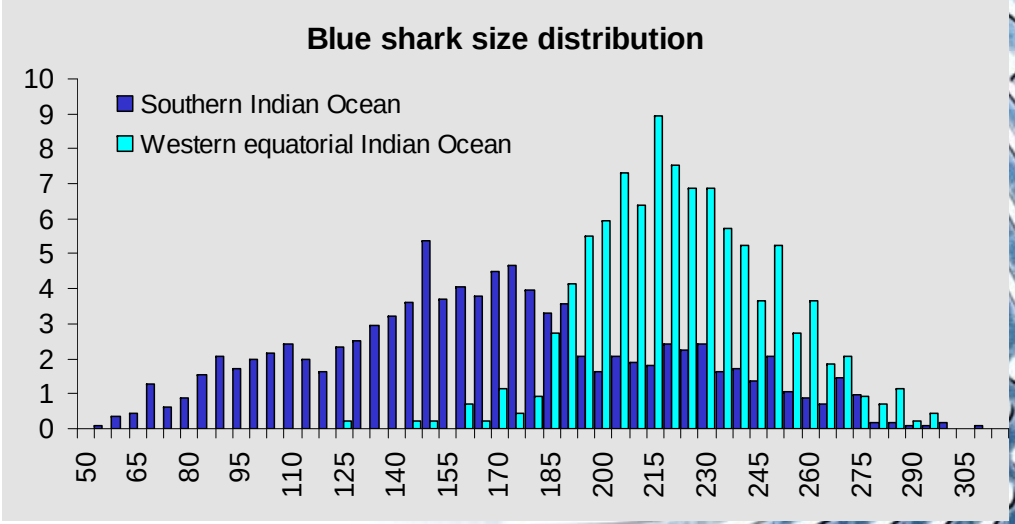


Where we are?

- Assumption on annual formation of growth bands on Indian Ocean blue shark vertebrae is correct;
- Age interpretation is relatively accurate;
- However, the bomb curve is incomplete (no data for early part of the curve). Therefore we doesn't obtained definitive accuracy validation.
- Nothing unusual in terms of bomb radiocarbon content and behaviour were found for Indian Ocean blue sharks.
- We are reasonable confident that a slightly older shark would produce excellent results.
- We need **another** blue shark vertebra from shark ~270-290 cm FL collected before 1983!!!

Where we are?

- Two sharks of the same sex and similar length (273 and 270 cm) had so different age (19 and 23 years) and growth rate.
- Size distributions of blue shark in tropical and temperate waters are differs also. What does it means?
- Separate stocks?
- Different growth rates in temperate and tropical waters?



- Migratory functional segregation of distribution areas between juveniles, males and females?
- Further studies of blue sharks biology in the Indian Ocean are **essential**!

Acknowledgements

- Indian Ocean blue sharks *Prionace glauca* for vertebrae donation;
- Vertebrae were collected during SIOTLLRP – a long-term research program of the Southern Scientific Research Institute of Marine Fisheries and Oceanography (YugNIRO), Kerch, Ukraine;
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