# The Past is Important – Conservation Paleobiology Data in Restoration and Conservation

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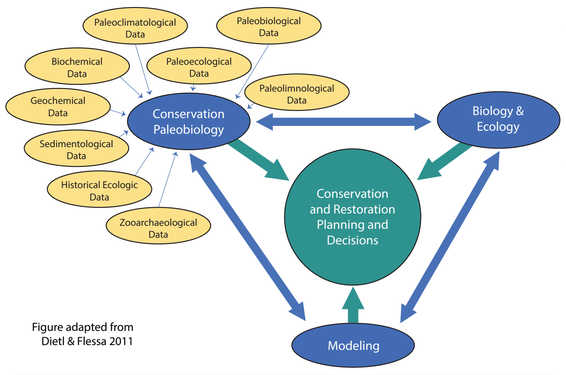



Figure adapted from Dietl & Flessa 2011

Conservation Paleobiology Network — To learn more about CPB please join the Conservation Paleobiology Network (free).

## What is conservation paleobiology (CPB)?

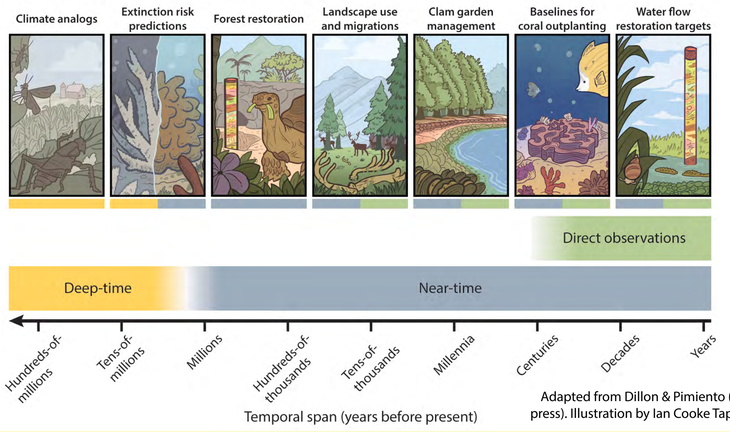
Conservation paleobiology integrates information from geohistorical proxies, such as those available from paleontology, sedimentology, archaeology, and geobiochemistry. By collaborating with biologists, ecologists and modelers, conservation paleobiologists can play a vital role in restoration and conservation decision making.

## What type of information can CPB data provide resource managers?

The history of life on earth contains the results of past natural experiments - the record of how ecosystems and species responded to changes in climate, sea level, the development of agriculture and industrialization, and changes to the natural landscape. This information from the past provides many valuable insights, including:

- Pre-disturbance and/or natural states and variability of species and ecosystems.
- Responses to past climate change and other disturbances, which provides insights into future responses to change.
- Shifts in geographic distribution, community restructuring, and locations of refugia.
- Comparison of biodiversity and habitat structure at different time periods and under different climate conditions.
- Attributes of species, habitats and ecosystems over time.

### Conservation paleobiology in action




Adapted from Dillon & Pimiento (in press). Illustration by Ian Cooke Tapia

## How has CPB data been applied to Everglades restoration?

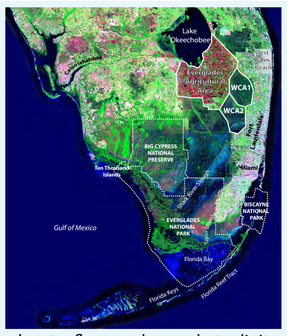
Problem:

Restoration planners are focused on restoring more natural hydrologic patterns - the flow through the wetlands and the salinity in the estuaries that will support the iconic biota of the Everglades, but ...

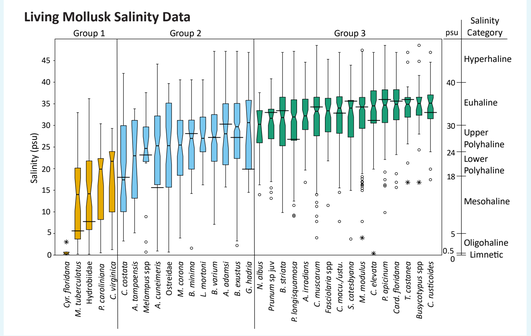
- The ecosystem was already altered prior to instrumental measurements so how do we set targets for historical baselines?
- Large-scale hydrologic models used for planning do not produced documented historical conditions.

Solution:

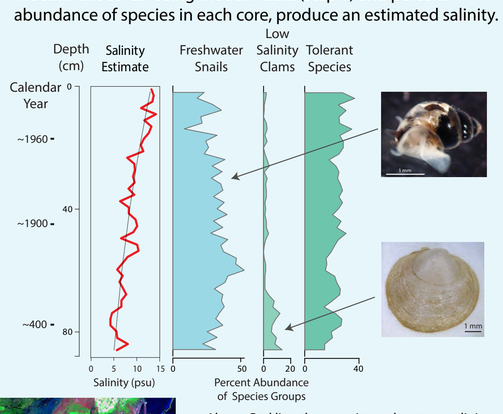
Use information preserved in sediment cores to adjust hydrologic models to pre-alteration salinity and flow.

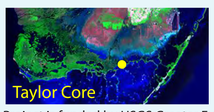



**Step 1: ECOLOGY** - Collect data on the distribution of living species. Here salinity of mollusks is used as our modern analog.




**Step 2: PALEOECOLOGY** - Analyze distribution of species remains in sediment cores. Using modern data (step 1) and percent abundance of species in each core, produce an estimated salinity.



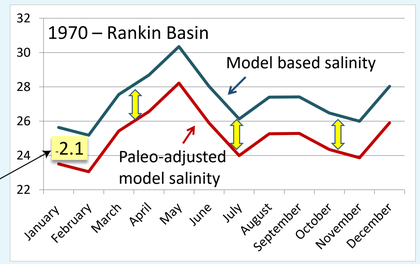

Above: Red line shows estimated average salinity based on % abundance of species. Downcore plots show distribution of taxa grouped by salinity preference for Taylor core (location shown on left).

Project is funded by USGS Greater Everglades Priority Ecosystem Science Program. For more information visit our website or see Marshall et al. 2014, Est. & Coasts.

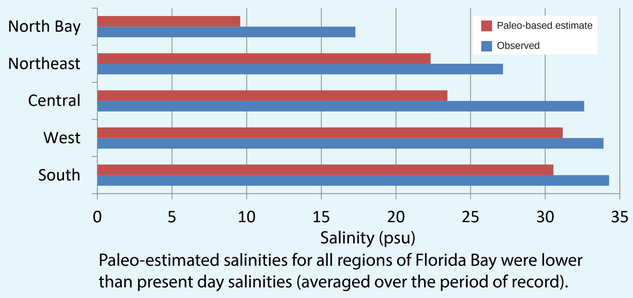
**Step 3: MODELING** - A) Develop linear regression models based on the modern hydrology ... how much freshwater flow produces what salinity.
B) Calculate the difference between the paleo-estimated salinity and the salinity produced by the large scale hydrologic models used by the ACOE.
C) Use the difference to adjust the hydrologic models.

Step B,C - Example Rankin Core

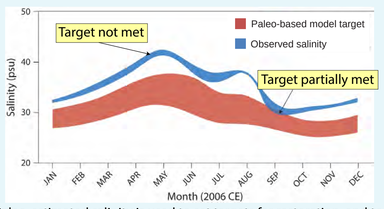
| | |
|---|---|
| Hydrologic model (NSM) mean salinity (1965-2000) | 30.4 |
| Paleosalinity estimate | 28.3 |
| Adjustment needed to create paleo-salinity time series | -2.1 |




**Results for Florida Bay:**




Paleo-estimated salinities for all regions of Florida Bay were lower than present day salinities (averaged over the period of record).




Paleo-estimated salinity is used to set targets for restoration, and to test whether observed salinity is meeting the target. The width of the red band takes year-to-year seasonal variation into account.

**Application to Restoration:**

- Estimates of paleosalinity provide empirical pre-disturbance salinity data, that extend the record of instrumental salinity.
- Pre-disturbance salinity values are used to adjust the regional hydrologic models to pre-alteration stage and flow, and produce the circa 1900 salinity.
- The paleo-based modeled salinity is the current target salinity for Everglades Restoration.

## What does CPB data tell us about migrations patterns in the Arctic NWR?

Problem:

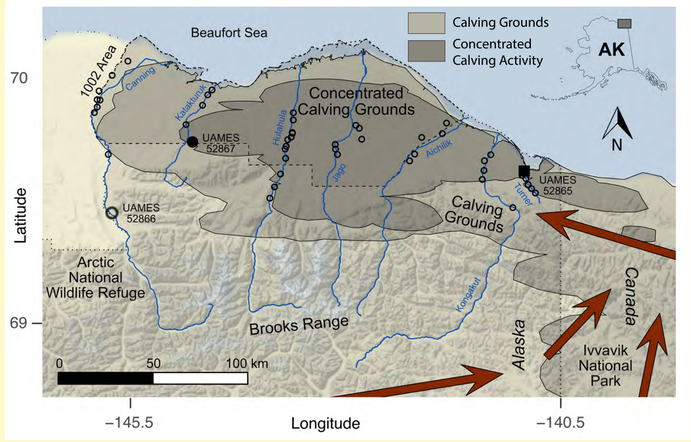
A primary priority in caribou management is maintaining access to spring calving grounds and migration routes. Over the last few decades of climatic and ecological change, some herds have demonstrated high annual variability in calving ground geography. Key conservation questions:

- How long have herds used today's calving grounds?
- Are current patterns representative of calving geographies prior to recent climatic perturbations and increased anthropogenic stresses?

Solution:

Use shed antlers from past generations of female caribou found on the tundra to evaluate historical calving geographies.

Caribou antler (94.5% probability of being female) found on tundra, radiocarbon dated to ~3,157 cal years before present. Antlers shed by females in the spring (within days of giving birth) can persist on the Arctic landscape for 1000s of years.

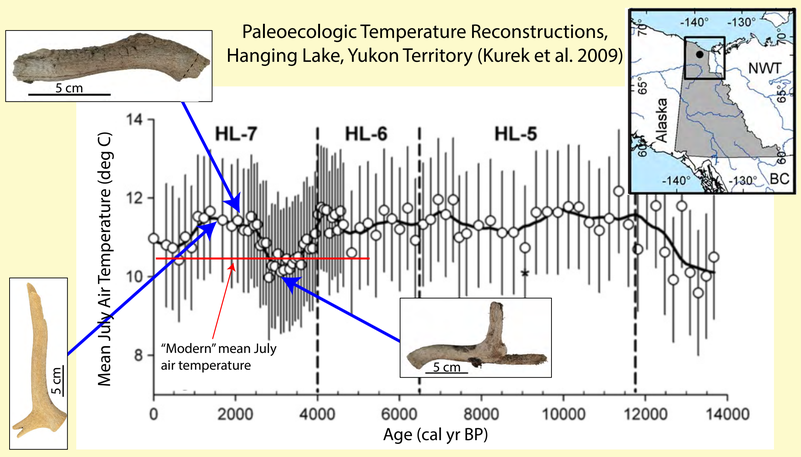



*Left:* Calving grounds used by the Porcupine Caribou Herd (PCH) in the Arctic National Wildlife Refuge (ANWR) in Alaska and Ivvavik National Park (Yukon, Canada), since the 1980s. The PCH is one of the largest herds in the world (~218,000 caribou). Antler surveys (2010-2018) on the Coastal Plain are shown as open circles. Large filled symbols show locations of three antlers radiocarbon-dated to more than 1,000 years old. Red arrows show generalized migration of the PCH to their spring calving grounds.

### Findings for Resource Managers

Antler surveys document calving activity on the ANWR Coastal Plain across >3,000 years, providing insights into consistency in caribou migration amidst large climatic variability.

- Substantiates the millennial-scale legacy of the ANWR Coastal Plain as a caribou calving ground.
- Using Holocene temperature proxies (lake core), antlers indicate calving activity on Coastal Plain even when summer temperatures were higher than those during the last several decades of monitoring.
- Shed antlers expand the range of climatic settings in which caribou are known to use today's PCH calving grounds.
- Results suggest the Coastal Plain ANWR is likely to continue being an important calving ground during at least the early phases of climate warming.
- Temperature records indicate calving grounds were used across the range of temperatures since the last Ice Age.




Temperature records indicate calving grounds were used across a range of climate since the last Ice Age.

For more information: Miller et al. 2023, Front. Ecol. Evol.

## What can CPB data tell us about climate tracking of species and conservation?

Problem:

Only 50% of all continental taxa today are exhibiting climate tracking (Parmesan et al. 2022) – the ability to move to higher latitudes and/or altitudes in response to ongoing climate change.

- Resource managers need to develop conservation strategies and prioritize the most vulnerable taxa.
- Will suitable habitats for animals be maintained as ranges of plants may not shift at the same pace or in the same direction as the animals that depend on them?

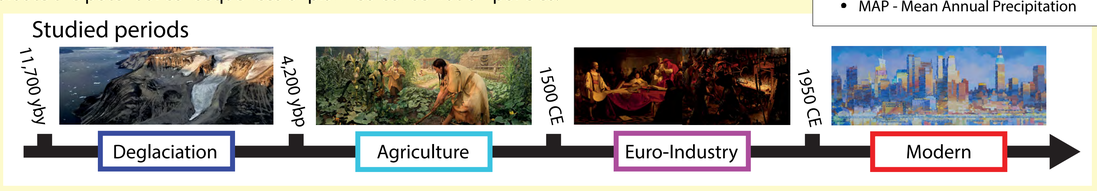
Solution:

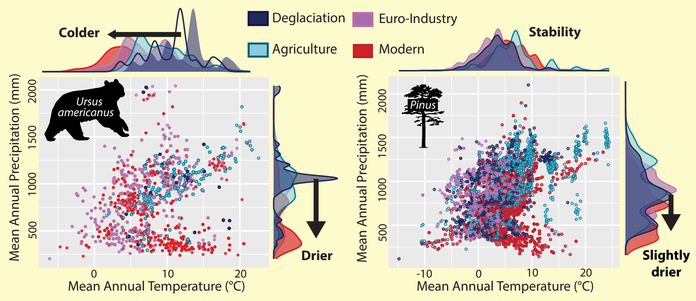
Use the paleoecologic record to:

- Reconstruct climate niches of mammals and plants over extended time periods and compare their responses to climate changes.
- Measure the impact of anthropogenic change versus climate change on range shifts and species distributions.
- Evaluate the potential consequences of planned conservation policies.

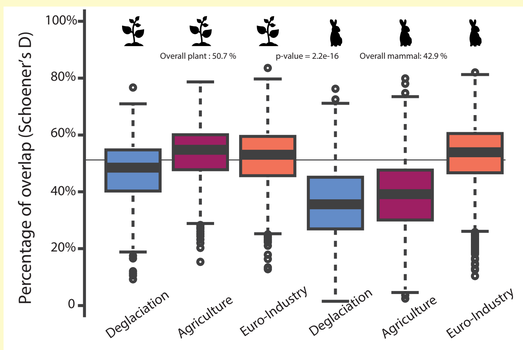
Data:

- Occurrences of 45 mammal species and 16 plant genera from 11,700 years before present (ybp) extracted from Neotoma database (over 58,000 fossil records of recent organisms & 89,000 modern records).
- Global Climate Model simulated or measured at occurrence sites:
  - MAT - Mean Annual Temperature
  - MAP - Mean Annual Precipitation

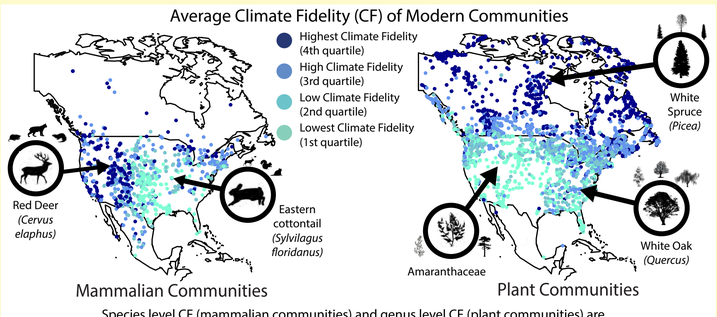



Climate niche (MAT and MAP) reconstruction of 45 mammalian genera and 16 plant genera during 4 studied periods were constructed. Black bear and Pine niche depicted.




Overlap of all mammalian and plant climatic niches with their modern equivalent




Species level CF (mammalian communities) and genus level CF (plant communities) are computed on the two oldest time-bins in order to estimate CF before strong human impact and during intense climate change.

**Findings for large scale conservation planning:**

- On average, plants have tracked climate better than mammals since deglaciation (plant CF ~10% > mammal CF).
- Arrival of Europeans and industrialization of North America significantly altered climate niches of mammals.
- Climate niches of plants are relatively stable through time, although some trees adapt to drier niches as they disperse into grass/crop lands.
- Mammal climate fidelity is affected by human land use and elevation, while plant climate fidelity is not.

Across the landscape, geohistorical data have identified which taxa have previously shifted ranges to track climate conditions and highlight what species are most vulnerable and in need of conservation strategies to facilitate range shifts as climate changes.

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## How does CPB data help us reconstruct preanthropogenic shark baselines?

Problem:

Sharks are a vital component of marine ecosystems, and historical accounts depict Caribbean coral reefs brimming with sharks, yet their populations are depleted on many reefs today. We lack long-term empirical data to quantify this change.

Solution:

Use the paleo record of sharks - the microscopic, tooth-like scales called dermal denticles that are shed and accumulate in marine sediments, where they preserve a long-lasting record of shark occurrences.

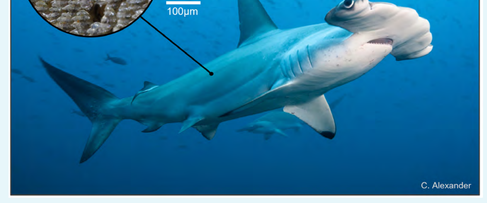
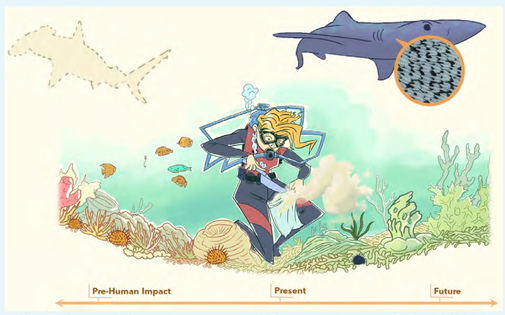
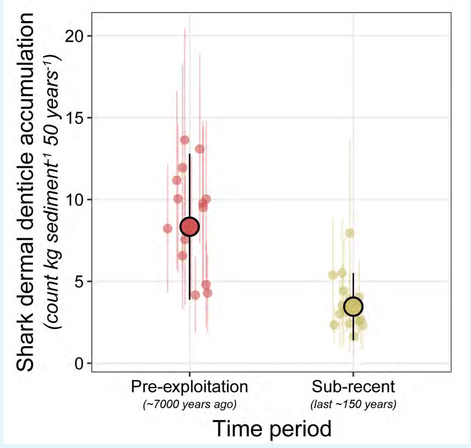



Illustration of a shark denticle.

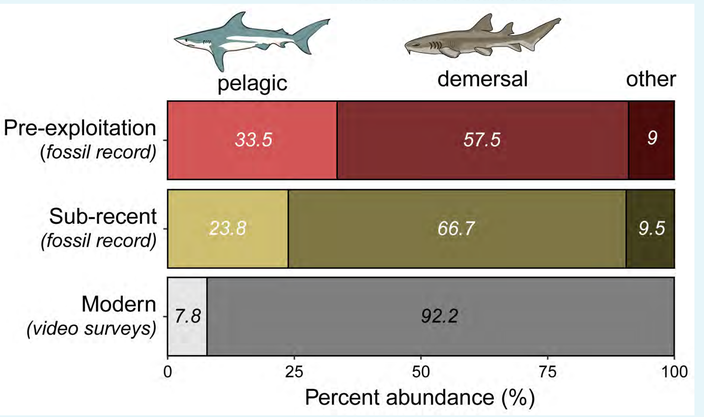



Shark dermal denticles recovered from modern and fossil (7000 year old) coral reefs provide information about reef shark communities in Bocas del Toro, Caribbean Panama, before major human impact.




The rate of shark dermal denticle accumulation—a proxy for relative shark abundance—declined by ~60% between the pre-exploitation (red) and sub-recent (gold) time periods.

- Accumulation rates are calculated as the number of dermal denticles that would accumulate in 1 kg sediment over 50 years (mean sample time-averaging).
- Smaller points show the model predictions for each sample (mean and standard error), and the larger points show the estimated marginal means and standard errors for each time period.




The functional composition of shark communities has also shifted over the last 7000 years (pre-exploitation) in Caribbean Panama, reflecting a selective loss of pelagic sharks. The dominance of demersal species like nurse sharks (*Ginglymostoma cirratum*) recorded in modern baited remote underwater video surveys (Chevis et al. 2022; bottom gray bar) likely deviates from the historical state of shark communities in the area from two time periods (Dillon et al. 2021): 1) pre-exploitation ~7000 ybp (top red bar) and 2) even sub-recent (averaged over last 150 yrs; middle gold bar). The shading indicates the relative abundances of pelagic (light), demersal (darker), and other (darkest) sharks in each record.

**Findings for marine resource management:**

1) **Quantifying ranges of natural variation**: Fossil dermal denticles suggest that there were >2X more sharks in Bocas del Toro, Caribbean Panama, before major human impact, providing local baselines to measure the magnitude of ecological change and inform context-specific management targets.
2) **Revealing the causes and consequences of ecological change:** Fossil dermal denticles also document the millennial-scale impact of human activities on Caribbean ecosystems and highlight vulnerable taxa. Pelagic sharks declined the most over the last 7000 years in Bocas del Toro, likely due to overfishing, which shifted the functional composition of shark communities.

Illustrations by Ian Cooke Tapia and Ashley Diedenhofen.
For more information: Dillon et al., 2021, Proc. National Acad. Sci.