Instructor's Guide: Introduction to Conservation Paleobiology:

Comments and suggestions welcome!

This webinar consists of a 46 minute mp4 video and the following worksheet.

Access the video at this link: https://conservationpaleorcn.org/webinar-1-user-agreement-page/

Most of the topics in the video should be understandable by students who have had an introductory paleontology/paleobiology class. Or it can also be presented late in such a course.

Material that may be somewhat unfamiliar includes discussion of the use of oxygen isotopes in biogenic carbonates and the analysis of fish otoliths. Amino acid racemization is mentioned but is not explained.

Here's an outline of the topics covered:

- *What is conservation paleobiology and what can it do?*
- *The raw materials and the techniques*
- *Case study – The Colorado River Delta*
    - ➢ *Where did the water go?*
    - ➢ *Before the dams*
    - ➢ *Shells, shells and more shells – the bivalve Mulinia modesta*
    - ➢ *Insights from stable isotopes*
    - ➢ *Did Mulinia matter?*
    - ➢ *Totoaba: a fish out of water*
    - ➢ *Otoliths, isotopes and nursery grounds for Totoaba macdonaldi*
    - ➢ *Environmental flows: 2014-2019: a video tour*

We think that the video works best if students do the worksheet exercises in advance, although that's not essential. The worksheet can be completed in about two hours and can be done in lab, in class, at home, individually, in groups, or not at all. Whatever works best.

Feel free to use the video as you see fit: fast forward through the boring bits, spilt into two or more sessions to suit topics in your class syllabus – whatever works best.

Karl Flessa, the narrator of the video, is available for live, in-class Q & A or discussion, if schedules permit. kflessa@arizona.edu. He is in the Mountain Standard Time zone.

WORKSHEET (requires about 2 hours for completion)

Visit, calculate, listen, read

1. Visit

Do some field work on the Colorado River Delta
https://prezi.com/5qhsb2l-yahc/webinar-version_colorado-river-delta-vfe/?token=e107e178586411d3bf53e6b15c840416b017643e896ce8c668c57cdec3789ee2&utm_campaign=share&utm_medium=copy

This virtual field experience written by Jansen Smith (jansen.smith@fau.de) includes videos, maps, text, web links, and questions to be answered.

2. Calculate

Estimating Population Density

In this exercise, you will use a quantitative method to estimate the ecological responses of species to changes in their environment. Skeletal accumulations are one of the raw materials used in conservation paleobiology and you will be using the bivalve shell accumulations in the Colorado River Delta. You will estimate the population density of the shells accumulated before upstream water diversions and compare the value with the population density today. This is a measure of the human impact on the delta's productivity.

Learning Objectives & Outcomes

- Estimate population density using bivalve shell accumulations
- Compare the population densities of bivalves before and after water diversions

Instruction

Part I. Calculating total number of bivalves

Using satellite imagery, aerial photos and boreholes of the Colorado River Delta in the Gulf of California, the **volume of beach ridges** where shells are accumulated was determined as **2.4 x**

10^7 m^3. The **density of shells** was determined as **17.4 x 10^4/m^3** by counting shells that are larger than 12.5 mm in several buckets of shells in the field,

Q1. Using the above information, calculate the density of bivalves. [Note: Each bivalve has two shells.]

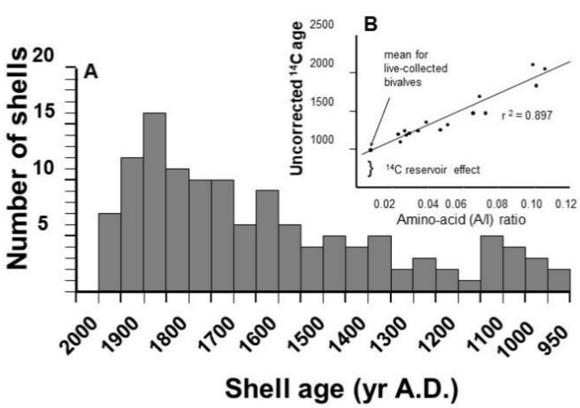
Number of shells divided by two estimates the density of individual bivalves
17.4 x 10^4/m^3 ÷ 2 = 8.7 x 10^4/m^3

Q2. What is the total number of bivalves in the shelly deposit?

Density of individual bivalves times volume equals total number of bivalves
8.7 x 10^4/m^3 x 2.4 x 10^7 m^3 = 2.1 x 10^{12} Approximately two trillion individual bivalves

Part II. Estimating average standing population

A thousand year record



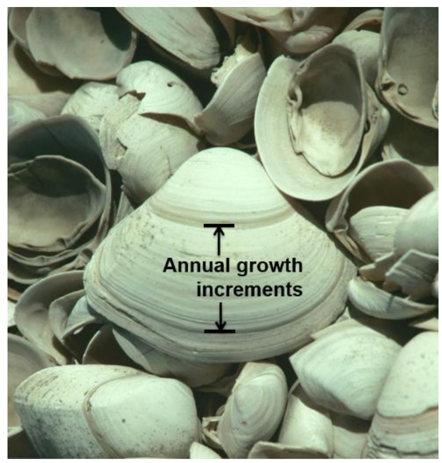
Radiocarbon dating and amino acid racemization indicate that the **age range** of the accumulated shells was **1,000 years**.

Age resolution is ±50 years.

Right skew may reflect taphonomic loss through time – or other factors.

The **growth lines** in average-sized shells indicate an average age of **three years**.

Q3. Using the above information and values from part I, estimate the number of bivalve generations in the shelly deposit.



One thousand years divided by three estimates the number of generations in the deposit

1000 years ÷ 3 years per generation = 333 generations

Q4. What is the number of individuals alive at any one time (the "standing population size")?

Total number of individuals divided by the number of generations equals the number of individuals alive at any time.

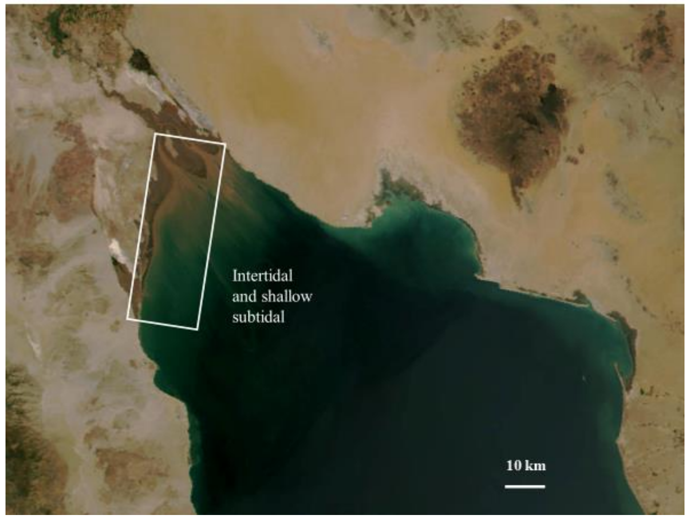
$2.1 \times 10^{12} \div 333 = 6 \times 10^{9}$ individual bivalves - approximately six billion alive at any one time during the past 1,000 years

Part III. Calculating average population density

Today, these bivalves live in the intertidal and shallow subtidal zone. Using satellite imagery and aerial photos of the Colorado River Delta in the Gulf of California, the **area of intertidal zone** is **1.2 x 10^8 m^2**.

Make one estimate using **1.2 x 10^8 m^2** as an estimate of habitat area.

Assuming the same area of the shallow subtidal, now use **2.4 x 10^8 m^2** as an estimate of the total area once inhabited by these bivalves.



Q5. Using the above information and values from Part II, estimate the population density of bivalves in the time before upstream water diversions.

Number of individuals alive at any one time divided by the habitat area

Estimate # 1: 6 x 10^9 individual bivalves ÷ 1.2 x 10^8 square meters = 50 individuals per square meter.

Estimate # 2: 6 x 10^9 individual bivalves ÷ 2.4 x 10^8 square meters = 25 individuals per square meter.

The **average population density** of bivalves in the study area **today** is **2.3 – 3.8** bivalves per square meter (ind/m^2) for shells that are larger than 12.5 mm in size.

Q6. Using the above information and estimates from the question 5, estimate the maximum and minimum changes in the population density since the upstream water diversions.

Maximum change is difference between 50 individuals per square meter and 2.3 individuals per square meter. A decrease of 47.7 individuals per square meter. 47.7 ÷ 50 = 95%

Minimum change is difference between 25 individuals per square meter and 3.8 individuals per square meter. A decrease of 21.2 individuals per square meter. 21.2 ÷ 25 = 85%

Note: given the uncertainties in the assumptions, reporting a range of estimates is better than asserting a single value as the answer.

Citation: Kowalewski, M., Avila Serrano, G.E., Flessa, K.W. and Goodfriend, G.A., 2000. Dead delta's former productivity: Two trillion shells at the mouth of the Colorado River. Geology, 28: 1059-1062. https://doi.org/10.1130/0091-7613(2000)28<1059:DDFPTT>2.0.CO;2

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3. Listen

To an indigenous voice from the Colorado Delta
https://www.youtube.com/watch?v=U39L2iTKGSE&feature=youtu.be

This three minute presentation is by a member of the Cocopah community in Mexico. How did this indigenous group use the river in the past? How does the speaker see the future?

4. Read

It takes more than water: Restoring the Colorado River Delta
https://doi.org/10.1016/j.ecoleng.2017.05.028 - the following article (as hard copy) in the worksheet.
Note: this short article was published before approval of Minute 323 to the U.S. Mexico Water Treaty. Minute 323 continues environmental flows until 2026.

In addition to water, what was necessary for the Pulse Flow of 2014, what was learned, and what is necessary for future restoration efforts? How was science used?

Additional reading suggestions

Cintra-Buenrostro, C.E., Flessa, K.W., and Avila-Serrano, G., 2005. Who cares about a vanishing clam? Trophic importance of *Mulinia coloradoensis* inferred from predatory damage. Palaios 20: 295-301. *Predatory damage to shells of Mulinia modesta, formerly known as M. coloradoensis.* *https://doi.org/10.2110/palo.2004.p04-21*

Dietl, G. Dietl, G.P., Kidwell, S.M., Brenner, M., Burney, D.A., Flessa, K.W., Jackson, S.T. and Koch, P.L., 2015. Conservation Paleobiology: Leveraging knowledge of the past to inform conservation and restoration. Annual Reviews of Earth and Planetary Sciences 43:79-103. *Expansive summary of the field and approaches.* https://doi.org/10.1146/annurev-earth-040610-133349

Dietl, G. and Flessa, K.W. 2011. Conservation paleobiology: Putting the dead to work. Trends in Ecology and Evolution 26: 30-37. *Short summary of the field and approaches.* *https://doi.org/10.1016/j.tree.2010.09.010*

Flessa, K.W., 2009. Putting the dead to work: Translational paleoecology, pp. 275-282, in Dietl, G.P. and Flessa, K.W., eds., 2009. Conservation paleobiology. Using the past to manage for the future. The Paleontological Society Papers., Vol. 15. The Paleontological Society, New Haven, CT. *Summary of Colorado delta conservation paleobiology research, with comments on intersection with policy.*

Hallett, L.M., Morelli, T.L., Gerber, L.RE., Moritz, M.A., Schwartz, M.W., Stephenson, N.I., Tank, J.L., Williamson, M.A. and Woodhouse, C.A., 2017. Navigating translational ecology: creating opportunities for scientist participation. Frontiers in Ecology and Environment 15: 578-586. *Examples of how to get involved in translational ecology.* **doi: 10.1002/fee.1734**

Rodriguez, C., Flessa, K.W. and Dettman, D.L., 2001. Effects of upstream diversion of Colorado River water on the estuarine bivalve mollusc *Mulinia coloradoensis*. Conservation Biology, 15: 249-258. *Short paper on the Colorado delta clam, Mulinia modesta, formerly known as M. coloradoensis.* *https://doi.org/10.1046/j.1523-1739.2001.99463.x*

Rowell, K., Flessa, K.W., Dettman, D.L., Román, M.J., Gerber, L. R. and Findley, L.T., 2008. Diverting the Colorado River leads to a dramatic life history change in a marine fish. Biological Conservation. 141, 1138-1148. *Research on conservation implications of oxygen isotopes in otoliths of endangered Totoaba macdonaldi.* *https://doi.org/10.1016/j.biocon.2008.02.013*