Lophelia II: Growth Rate and Age Distribution of Deep-Sea Black Corals in the Gulf of Mexico

Nancy G. Prouty
USGS Pacific Coastal and Marine Science Center

E. Brendan Roark
Texas A&M

Noreen Buster & Chuck Holmes
USGS–St. Petersburg

Alan Koenig
USGS–Denver

Steve W. Ross
University of North Carolina–Wilmington
Introduction: Black Corals

Colonial cnidarians
Order Antipatharia

Greater than 30 m water
Tropical western Atlantic & SW Pacific

20 species in GOM
4 species at Viosca Knoll; one of largest megafauna taxa at VK (Sulak et al. 2008)
Introduction: Skeletal Growth

Chitin fibrils mixed with proteins

10–15% chitin
50% protein (e.g., histidine)
2-3% halogens (e.g., iodine)

( Goldberg et al. 1994)
Introduction: Food Source

\[ \delta^{13}C \%o \]

- SOM (box core) \((Demopoulos et al. 2010)\)
- POM (surface) \((Demopoulos et al. 2009)\)
- Coral Tissue \((Demopoulos 2011, \text{pers. comm.})\)
- Coral Skeleton \((\text{this study})\)

- Methane Seeps \((Brooks et al. 1987)\)
- Chemoautotrophic OM \((Paull et al. 1984)\)
Introduction: Food Source

Sinking Particulate Organic Matter
~zooplankton, phytoplankton

Organic Carbon Sources
DOC -210 ‰
SOC -170 ‰ \{ \sim1,000 \text{ m} \}

POC +128 ‰ \text{ (Druffel et al. 1995)}

Gulf of Mexico
Coral $\Delta^{14}C$ +47 to +72 ‰
Collected at $\sim$ 300 m
Introduction: Growth Rate and Ages

Roark et al. 2009

<5 μm yr⁻¹
4,200±70 Cal. YR BP

Hawaii

GOM
14.5 μm yr⁻¹
386 years

Williams et al. 2006
Methods: Study Site

TOW: De Soto Canyon
VK: Viosca Knoll
- fine-grained aggregates
- riverine origin
- high organic carbon content
(Davies et al. 2010)

Johnson-Sea-Link

Methods: Sampling

Skeleton black chitin

Cross-sectional disc

after soaking in KOH

Delaminated layers
Methods: SEM

Coral thin section

Tree Ring

Coral SEM

The Earth Institute at Columbia University
Methods: $^{14}$C chronology

- $^{12}$C, $^{13}$C (stable)
- $^{14}$C (radioactive) \( t_{1/2} = 5568 \pm 30 \) yrs
  \[
  t(BP) = \frac{1}{\lambda} \ln \frac{N}{N_0}
  \]
- Conventional Radiocarbon Age  Calibrated/ Cal. Yr
- Reservoir corrected
  Reservoir age = 240\( \pm 10 \) $^{14}$C yrs
  \((\Delta R = -30 \pm 24 \, \text{^{14}C yrs})\)

Wagner et al. 2009
Methods: “Bomb Curve”

Gulf of Mexico
“Surface water” $\Delta^{14}C$

Baker and Wilson 2001
Wagner 2009
Results: “Bomb Curve”

Viosca Knoll

Prouty et al. 2011
Results: Radiocarbon Age

<table>
<thead>
<tr>
<th>Sample</th>
<th>$^{14}$C age inner</th>
<th>$^{14}$C age outer</th>
<th>Outer $\Delta^{14}$C (%)</th>
<th>Inner $\Delta^{14}$C (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>GOM-TOW-BC1$^1$</td>
<td>1090 ± 35</td>
<td>550 ± 35</td>
<td>-73 ± 3.9</td>
<td>-133 ± 3.4</td>
</tr>
<tr>
<td>GOM-TOW-BC1$^2$</td>
<td>1080 ± 25</td>
<td>550 ± 60</td>
<td>-73 ± 3.5</td>
<td>-132 ± 2.7</td>
</tr>
</tbody>
</table>

KOH$^{2,3}$ \quad \text{Microdrill$^1$} \quad \{ \text{Adjacent discs} \}
### Results: Radiocarbon Age

<table>
<thead>
<tr>
<th>Sample</th>
<th>$^{14}$C age inner</th>
<th>Cal yr BP</th>
<th>$^{14}$C age outer</th>
</tr>
</thead>
<tbody>
<tr>
<td>GOM-TOW-BC1</td>
<td>1080 ± 25</td>
<td>670 ± 36</td>
<td>550 ± 60</td>
</tr>
<tr>
<td>GOM-TOW-BC2</td>
<td>2030 ± 15</td>
<td>1630 ± 30</td>
<td>Modern</td>
</tr>
<tr>
<td>GOM-JSL04-4734-BC1</td>
<td>1020 ± 30</td>
<td>620 ± 40</td>
<td>Modern</td>
</tr>
<tr>
<td>GOM-JSL05-4876-BC1</td>
<td>1260 ± 30</td>
<td>830 ± 40</td>
<td>Modern</td>
</tr>
<tr>
<td>GOM-JSL09-3728-BC1</td>
<td>2380 ± 30</td>
<td>2040 ± 40</td>
<td>Modern</td>
</tr>
</tbody>
</table>

- 4 samples contain modern $\Delta^{14}$C (1960 or younger)
- Oldest sample dated to $2040\pm40$ Cal yr B.P. (90 B.C.)
- Youngest sampled dated to $620\pm40$ (1330 A.D.)
Results: Life Spans

Prouty et al. 2011
Results: SEM

Band Counting
576 ± 37 years

$^{14}$C age
670 ± 40 years
Results: Growth Rates

14 µm yr\(^{-1}\)
R\(^2\)=0.96

8 µm yr\(^{-1}\)
R\(^2\)=0.97

8 µm yr\(^{-1}\)
R\(^2\)=0.87

17 µm yr\(^{-1}\)
R\(^2\)=0.85

Distance from outer edge (mm)
Results: Life Span vs. Growth Rate

![Graph showing the relationship between life span and growth rate with an R² of 0.88.](image)
Results: Stable Isotopes

\[ \delta^{15}N_{\text{tissue}} = 10.76 \, \text{‰} \]

\[ \delta^{15}N_{\text{POM}} = 3.8 \, \text{‰} \]

\[ TP = \left[ (\delta^{15}N_{\text{con}} - \delta^{15}N_{\text{base}}) \Delta^{15}N \right] - TL_{\text{base}} \]

- Consumer = black coral
- Base = copepod (Demopoulos et al. 2010)

\[ TP = 3.6 \]
Results: Trace Metals

Mississippi River has $[\text{Re}] \ 40\times > \text{global average}$ (Rahaman and Singh 2010)
Increased $[\text{I}]$ positive correlation with Mississippi R. flow rate (Oktay et al. 2001)
Results: Stable Isotopes

\[ \delta^{13}C_{\text{tissue}} = -19.95 \% \]
\[ \delta^{13}C_{\text{POM}} = -19.8 \% \]

(Demopoulos et al. 2010)
Results: Stable Isotopes

DSC Suess Effect:
1800-2005 $0.019 \%_o \text{ yr}^{-1}$
1900-2005 $0.036 \%_o \text{ yr}^{-1}$
1960-2005 $0.072 \%_o \text{ yr}^{-1}$

Keeling 2005

La Jolla, CA

Swart et al. 2010
Results: Stable Isotopes

DSC Suess Effect:
- 1800-2005 0.019 ‰ yr\(^{-1}\)
- 1900-2005 0.036 ‰ yr\(^{-1}\)
- 1960-2005 0.072 ‰ yr\(^{-1}\)

\[ \delta^{13}C_{\text{tissue}} \approx -19.95 \, \text{‰} \]
\[ \delta^{13}C_{\text{POM}} \approx -19.8 \, \text{‰} \]

Swart et al. 2010

(Demopoulos et al. 2010)
Summary

- Black corals can be accurately dated using $^{14}$C analysis; validated through replicate analysis and SEM comparison.

- GOM black corals growing continuously for at least the last two millennia, with growth rates ranging from 8 to 22 $\mu$m yr$^{-1}$.

- Unlikely renewable in context of fishery management or human life span.

- Robust chronologies applied to paleo-climate studies.

- Coupling of $\delta^{15}$N with Re and I increases suggests recent increase in fluvial nutrient input.

- Increased anthropogenic CO$_2$ input captured in $\delta^{13}$C record (proxy for CO$_2$ inventory related to biological pump).
Acknowledgments

Ecosystems Program
DiSCoVRE team
Pacific Coastal & Marine Science Center
Coastal Ecology and Conservation Research Group

(BOEMRE Environmental Studies Program)

TAMU
College of Geosciences
Results: Growth Rates

22 μm yr\(^{-1}\)
R\(^2\)=0.46
References


References (continued)


References (continued)


References (continued)


References (continued)

