Dodging Extinction

(Part 1: The Climate Story)

Anthony D. Barnosky
UCMP, IB, and MVZ
The Sixth Mass Extinction?

<table>
<thead>
<tr>
<th>Event</th>
<th>When</th>
<th>Duration</th>
<th>% Extinction Genus [Species]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Max</td>
<td>Min</td>
</tr>
<tr>
<td>Ordovician</td>
<td>443 Ma</td>
<td>3.3 Ma</td>
<td>1.9 Ma</td>
</tr>
<tr>
<td>Devonian</td>
<td>359 Ma</td>
<td>29 Ma</td>
<td>2 Ma</td>
</tr>
<tr>
<td>Permian</td>
<td>251 Ma</td>
<td>2.8 Ma</td>
<td>160 Ka</td>
</tr>
<tr>
<td>Triassic</td>
<td>200 Ma</td>
<td>8.3 Ma</td>
<td>600 Ka</td>
</tr>
<tr>
<td>Cretaceous</td>
<td>65 Ma</td>
<td>2.5 Ma</td>
<td>&lt; 1 Yr</td>
</tr>
</tbody>
</table>

Barnosky et al., *Nature* 2011
Barnosky et al., Nature 2011

% Extinction in last 500 years

IUCN STATUS

Big 5 Mass Extinctions

Mass Extinction

Extinct

Threatened
State of our knowledge

- Percentage loss of species is nowhere near mass extinction levels yet
- Current extinction rates much too high: at least 3-12 times above background levels
- Sixth Mass Extinction arrives in 3-22 centuries, if current rates remain constant

Will extinction rates speed up or slow down?
Extinction drivers today
Extinction drivers today

- Energy Needs
- Global Climate Disruption
- Human Population Growth
- Habitat Loss
- Over-exploitation and Short-term profit
- Extinction
Ultimately controlled by solar insolation

The global energy budget
Human-Appropriated NPP

We take about 1/3 of all that is available

Haberl et al., 2007, PNAS 104:12942
We also add energy
What humans produce (mostly from fossil fuels) + NPP

Total global energy budget

People use: 761 ej/yr

We co-opt 30% (211 ej/yr)

728 exajoules/yr available from NPP

WE ADD: 550 ej/yr

http://www.neb-one.gc.ca/clf-nsi/rnrgynfmrtn/nrgyrprt/l/tghtdvlpmntwc02011/mg/fg07-eng.jpg
Correlation between produced energy and population growth

Energy produced and consumed from fossil fuels

Population Growth

Future

Energy (Exajoules)

Human Population (Billions)

Calendar Year
New baseline for megafauna biomass

The present human population cannot be sustained without producing ‘extra’ energy for the global ecosystem.
World Population Growth 1950 to 2100

- Orange line: Average ½-child above replacement fertility rate
- Blue line: Fertility rate falls to replacement (2 children per family) in countries where it currently is higher
- Green line: Average ½-child below replacement fertility rate

If recent growth trends continued

Billions of people

Data and projections from Population Division of the Department of Economic and Social Affairs of the United Nations Secretariat
Oil has been essential!

Oil’s tipping point has passed. The economic pain of a flattening supply will trump the environment as a reason to curb the use of fossil fuels, say James Murray and David King.
Per capita oil consumption averages \(~4.6\) barrels /person/year

(Let’s say we can drop to \(~3-4\) barrels /person/year)

Numbers from CIA Factbook (2013), for 2011
Minimum amount of recoverable oil

- *Oil + Oil Sand + Oil Shale (EROI)* Year 2139
- *Oil + Oil Sand* Year 2107
- *Oil* Year 2088
- *Oil + Oil Sand + Oil Shale (Energy Return On Investment)* Year 2180

Minimum 70-100 years left

Without counting natural gas or coal

Minimum amount of recoverable oil

- *Oil + Oil Sand + Oil Shale (EROI)* Year 2139
- *Oil + Oil Sand* Year 2084
- *Oil* Year 2070

Years into future starting with 2011

- Minimum amount of recoverable oil
  - 3 bbl/person
  - *Oil + Oil Sand + Oil Shale (EROI)* Year 2139
  - *Oil + Oil Sand* Year 2084
  - *Oil* Year 2070

- 4 bbl/person
  - *Oil + Oil Sand + Oil Shale (EROI)* Year 2107
  - *Oil + Oil Sand* Year 2088
  - *Oil* Year 2088

Minimum 70-100 years left

Without counting natural gas or coal
Climate Disruption

Moritz & Agudo, Science, 2013
Biodiversity consequences: More than we’ve been thinking

Bloomberg Businessweek
News From Bloomberg

Too late for two degrees?
Low carbon economy index 2012

The U.S. met 83 percent of its energy needs in the first six months of this year, on track to be the highest annual level since 1991, according to Energy Department data. Photographer: Patrick T. Fallon/Bloomberg

Bloomberg News
U.S. Oil Output to Overtake Saudi Arabia’s by 2020

By Lananh Nguyen on November 12, 2012 | 2 Comments
All Fossil Fuels

Reduce rate by 5.1% per year for 50 years

Same per capita rate as 2010

Years into future starting with 2010

CO₂ ppm

2000
1500
1000
500
0

+9°
+6°
+4°
+3°
+2°
All Fossil Fuels

Years into future starting with 2010

CO₂ ppm

300 400 500 600 700 800 900 1000 1100 1200 1300 1400 1500 1600 1700 1800 1900 2000

Kids grow up

1 human lifetime

Reduce rate by 5.1% per year for 50 years

Same per capita rate as 2010

+2° +3° +4° +6° +9°
All Fossil Fuels

38 million years ago
14 million years ago

Reduce rate by 5.1% per year for 50 years

Same per capita rate as 2010

Years into future starting with 2010

CO₂ ppm

300 400 500 600 700 800 900 1000 1100 1200 1300 1400 1500 1600 1700 1800 1900 2000

+2° +3° +4° +6° +9°
Expect this much change

Today

14 my

40 my
Biological responses

Move
Evolve

YES

Survive

NO

Extinction
Moving is not an option!

~40% of Earth’s land now looks like this

Foley et al., 2011, Nature
And the rest looks like this…

http://globaia.org/en/anthropocene/gts.jpg
Evolution

Kovach et al., 2012, Proc. R. Soc. B


Evolution’s limits

Selection on existing variation

New mutations
Biological responses

Move Evolve

YES

Survive

NO

Extinction

- Physiology
- Development
- Species Interactions
- Wild Cards
  - Phenology
  - Lost Niches
  - Ecosystem Collapse
Physiology

_Pikas_
Death at 78 to 85°F (25.5 to 29.4°C)
~ 7°C increase: “small zones where metabolic heat dissipation would for the first time become impossible, calling into question their suitability for human habitation”

Sherwood & Huber, PNAS 107:9552 (2010)
Ocean acidification

Pre-Industrial Norm

In situ pH trend = -0.0019 ± 0.0002 y⁻¹
Disrupts development

Already observed:

*Oysters:*
*Shells fail to grow*

Experimentally shown:

*Inland silverside fish:*
*Severe organ damage*

*Damsel fish: Learning disabilities*
Ocean Acidification
(all fossil fuels)

Reduce rate by 5.1% per year for 50 years

Same per capita rate as 2010

2010
2050
2100

Years into future starting with 2010

CO₂ ppm

pH

2000
2050
2100

7.8
7.9
8.1
Ocean Acidification
(all fossil fuels)

Hönisch et al., Science 335:1058 (2012)

Mean ocean surface pH vs Time (millions of years before present)

CO₂ ppm vs Years into future starting with 2010

2010

2050

2100
Ocean Acidification
(all fossil fuels)

Hönisch et al., Science 335:1058 (2012)

Ocean Acidification

CO₂ ppm

pH

Years into future starting with 2010

2010

2050

2100

Hönisch et al., Science 335:1058 (2012)

Modern (pre-industrial)
Ocean Acidification
(all fossil fuels)

Hönisch et al., Science 335:1058 (2012)

Mean ocean surface pH vs. time (millions of years before present)

Modern (pre-industrial)

Years into future starting with 2010

CO₂ ppm
Ocean Acidification (all fossil fuels)

- CO₂ ppm:
  - 0
  - 300
  - 600
  - 900
  - 1200
  - 1500
  - 1800
  - 2100

- pH:
  - 7.4
  - 7.6
  - 7.8
  - 8.0
  - 8.2

- Years into future starting with 2010:
  - 0
  - 50
  - 100
  - 150
  - 200

Hönisch et al., Science 335:1058 (2012)

- Modern (pre-industrial) mean ocean surface pH:
  - 7.4
  - 7.6
  - 7.8
  - 8.0

- Future projections:
  - 2050: CO₂ ppm
  - 2100: CO₂ ppm

- Climate change impact:
  - Ocean acidification
  - pH decrease from 8.1 to 7.8

- Fossil fuels:
  - All fossil fuels
>90% of species die from warming and acidification

End-Permian Mass Extinction

Hönisch et al., Science 335:1058 (2012)
Species interactions

Phenology

Marmots emerge from hibernation earlier

Woodpeckers miss cactus bloom
Species interactions

Coral Death
(by 2070?)

- 25% of all fish species in the sea
- 10% of ocean’s fisheries
- Billions of dollars
- Hungry people
Lost ecological niches

Williams et al., 2007 PNAS
The bottom line

We need to produce an enormous amount of energy or humanity crashes.

Current reliance on fossil fuels inevitably increases extinction rates.

The Sixth Mass Extinction is probably unavoidable if we don’t shift away from fossil fuels.
50-year window to shift over to carbon-neutral energy production

FAIL
- Continued reliance on fossil fuels
- Some development of alternative energy portfolio
- Major climate adaptation (humans)
  
  **Sixth Mass Extinction occurs**

SUCCEED
- Rapid development of alternative energy portfolio
- Efficient use of fossil fuels as stop-gap
- Some climate adaptation
- Species rescue
  
  **Avoid Sixth Mass Extinction**

Integrate biodiversity impacts into planning and development

Short term

Long term
Can we do it?

- 7 years – 3000 to 300,000 planes
- 20 years – rebuild after World War II
- 30 years – 310 million dial-up phones to 6 billion cell phones
- 50 years – dams on 60% of world’s largest rivers
- 50 years – 47,000 miles of highway in USA (enough to encircle Earth twice)
What will it take?

Same as it took to end World War II, accomplish the Green Revolution, reverse ozone depletion, etc.

- Recognizing the need
- Individual Initiative
- Technology and infrastructure
- Co-operation
Hopeful Signs

Climate Agreements

• China-CA MOU
• Pacific Climate Pact
• Contributing to policy dialog locally to internationally
Communicating the Issues
Bridging the Gaps

- Scientists
- Government
- Business
- General Public

http://consensusforaction.stanford.edu
To Learn More

Dodging Extinction:
Power, Food, Money, and the Future of Life on Earth

(Island Press, 2009)

(Nature in an Age of Global Warming)

(UC Press, September 2014)