The further Floridians look into the future, the more uncertain are the predicted consequences of climate change. This section identifies what is currently known, what is probable, and what is possible about the drivers of climate change and their effects on Florida.

IV

WHAT WE KNOW:

• From 1980 to 1989, the carbon content of the Earth's atmosphere is estimated to have risen by a rate of about 3.4 billion tons of carbon per year, with an estimated error of ± 0.2 billiontons (20, 21).
• Over the last 650,000 years, levels of atmospheric carbon dioxide have fluctuated between 180 to 280 parts per million by volume (5).
• The rate of change in increases in atmospheric carbon dioxide has been about 100 times faster in recent decades than over the past 650,000 years. Concentrations of other greenhouse gases, such as methane and nitrous oxide, have also increased significantly (5).
• Most of the increase in average atmospheric temperatures since the mid-20th century is due to increases in greenhouse gases.

WHAT IS PROBABLE:

• Atmospheric carbon dioxide will continue to increase at the rate of about 0.5 percent per year for at least the next few decades (22).
• Water quality will continue to change because of the absorption of increased greenhouse gases by the oceans (23).
• Increases in pollutant emissions will result in the increased introduction of nutrients and toxins into surface waters.
• Continued greenhouse gas emissions at or above current rates would cause further warming and induce many changes in the global climate system during the 21st century that would very likely be larger than those observed during the 20th century.

WHAT IS POSSIBLE:

• Atmospheric carbon dioxide will stabilize if global emissions are reduced by 30 percent or more despite increases in global population (5).
• The rate of atmospheric greenhouse gas increase will markedly accelerate due to positive feedback processes not currently accommodated in model projections (5).
Photo courtesy of Uwe Hermann

IV

WHAT WE KNOW:

• The average pH of the world's oceans has fallen by 0.1 pH unit since 1750 because of

the uptake of carbon dioxide created by human activities (24).
• Marine organisms with calcium carbonate shells or skeletons, such as corals, clams, and some plankton at the base of the food chain, can be adversely affected by decreases in pH and carbonate saturation state (5, 26). A higher carbonate saturation state favors the precipitation of calcium carbonate, a mineral in their shells, while a lower state supports its dissolution into the water.
• Ocean chemistry is changing at least 100 times more rapidly today than at any time during the 650,000 years prior to the industrial era (22).

- Arctic waters are rapidly turning acidic, even faster than originally thought. New research from oceanographer Dr. James Orr of the Laboratory for the Sciences of Climate and Environment in Paris predicts that the Arctic Ocean will be corrosive enough to dissolve shells of clams, mussels and others within the next decade.

- As seawater absorbs carbon dioxide, it changes the pH. And recent research indicates this acidification could come fastest in the Arctic Ocean. Oceanographer James Orr is with LSCE, the Lab for Sciences of Climate and the Environment in Paris. Dr. Orr, what's happening in the arctic waters? (New research from oceanographer Dr. James Orr of the Laboratory for the Sciences of Climate and Environment in Paris)

- Ocean acidification can lead to excessive growth in a key component in the organ a fish uses to sense movement and orientation -- analogous to the human inner ear.

I

(David M. Checkley, Jr.,[*] Andrew G. Dickson, Motomitsu Takahashi,[†] J. Adam Radich, Nadine Eisenkolb,[‡] Rebecca Asch

Elevated CO_2 Enhances Otolith Growth in Young Fish, *Science* 26 June 2009: Vol. 324. no. 5935, p. 1683; DOI: 10.1126/science.1169806)

- A loss of larval olifactory capacity in marine organisms through acidification could have significant consequences for marine biodiversity

by Philip L. Munday[a,b,1], Danielle L. Dixson[a,b], Jennifer M. Donelson[a,b], Geoffrey P. Jones[a,b], Morgan S. Pratchett[a], Galina V. Devitsina[c] and Kjell B. Døving[d] Ocean acidification impairs olfactory discrimination and homing ability of a marine fish; PNAS **February 10, 2009** vol. 106 no. 6 **1848–1852**

- The impact of elevated atmospheric pCO_2 on marine calcification is more varied than previously thought.

Justin B. Ries1,*Anne L. Cohen1 and Daniel C. McCorkle1: Marine calcifiers exhibit mixed responses to CO_2-induced ocean acidification. Geology **December 2009** v. 37 no. 12 **p. 1131-1134**

- The acidification caused by the dissolution of anthropogenic carbon dioxide (CO_2) in the ocean changes the chemistry and hence the bioavailability of iron (Fe), a limiting nutrient in large oceanic regions. The bioavailability of dissolved Fe may decline because of ocean acidification. Acidification of media containing various Fe compounds decreases the Fe uptake rate of diatoms and coccolithophores to an extent predicted by the changes in Fe chemistry. A slower Fe uptake by a model diatom with decreasing pH is also seen in experiments with Atlantic surface water. The Fe requirement of model phytoplankton remains unchanged with increasing CO_2. The ongoing acidification of seawater is likely to increase the Fe stress of phytoplankton populations in some areas of the ocean. (This is part of the abstract of new research ...that has significant findings.)

Dalin Shi,* Yan Xu, Brian M. Hopkinson, François M. M. Morel: Effect of Ocean Acidification on Iron Availability to Marine Phytoplankton: *Science* 5 February 2010: Vol. 327. no. 5966, pp. 676 - 679

- The world's oceans are becoming acidic at a faster rate than at any time in the last 55m years, threatening disaster for marine life and food supplies across the globe, delegates at the UN climate conference in Copenhagen have been warned.
- A report by more than 100 of Europe's leading marine scientists, released at the climate talks this morning, states that the seas are absorbing dangerous levels of carbon dioxide as a direct result of human activity. This is already affecting marine species, for example by interfering with whale navigation and depleting planktonic species at the base of the food chain.
- Ocean acidification – the facts says that acidity in the seas has increased 30% since the start of the industrial revolution. Many of the effects of this acidification are already irreversible and are expected to accelerate, according to the scientists.
- The study, which is a massive review of existing scientific studies, warns that if CO2 emissions continue unchecked many key parts of the marine environment – particularly coral reefs and the algae and plankton which are essential for fish such as herring and salmon – will be "severely affected" by 2050, leading to the extinction of some species.
- Dr Helen Phillips, chief executive of Natural England, which co-sponsored the report, said: "The threat to the delicate balance of the marine environment cannot be overstated - this is a conservation challenge of unprecedented scale and highlights the urgent need for effective marine management and protection."
- Although oceans have acidified naturally in the past, the current rate of acidification is so fast that it is becoming extremely difficult for species and habitats to adapt. "We're counting it in decades, and that's the real take-home message," said Dr John Baxter a senior scientist with Scottish Natural Heritage, and the report's co-author. "This is happening fast."

- The report, published by the EU-funded European Project on Ocean Acidification, a consortium of 27 research institutes and environment agencies, states that the survival of a number of marine species is affected or threatened, in ways not recognised and understood until now. These species include:

- whales and dolphins, who will find it harder to navigate and communicate as the seas become "noisier". Sound travels further as acidity increases. Noise from drilling, naval sonar and boat engines is already travelling up to 10% further under water and could travel up to 70% further by 2050.

- brittle stars (*Ophiothrix fragilis*) produce fewer larvae because they need to expend more energy maintaining their skeletons in more acid seas. These larvae are a key food source for herring.

- tiny algae such as *Calcidiscus leptoporus* which form the basis of the marine food chain for fish such as salmon may be unable to survive.

  young clownfish will lose their ability to "smell" the anemone species that they shelter in. Experiments show that acidification interferes with the species' ability to detect the chemicals that give "olfactory cues".

The report predicts that the north Atlantic, north Pacific and Arctic seas – a crucial summer feeding ground for whales - will see the greatest degree of acidification. It says that levels of aragonite, the type of calcium carbonate which is essential for marine organisms to make their skeletons and shells, will fall worldwide. But because cold water absorbs CO2 more quickly, the study predicts that levels of aragonite will fall by 60% to 80% by 2095 across the northern hemisphere.

"The bottom line is the only way to slow this down or reverse it is aggressive and immediate cuts in CO2," said Baxter. "This is a very dangerous global experiment we're undertaking here."

Written for policy makers and political leaders, the document is being distributed worldwide, with 32,000 copies printed in five major languages including English, Chinese and Arabic. Every member of the US congress, now struggling to agree a binding policy on CO2 emissions, will be sent a copy.

Congressman Brian Baird, a Democrat representative from Washington state, who championed a bill in Congress promoting US research on ocean acidification, said these findings would help counter climate change sceptics, since acidification was easily and immediately measurable.

"The consequences of ocean acidification may be every bit as grave as the consequences of temperature increases," he said. "It's one thing to question a computer extrapolation, or say it snowed in Las Vegas last year, but to say basic chemistry doesn't apply is a real problem [for the sceptics]. I think the evidence is really quite striking."

Severin Carrell: **Ocean acidification rates pose disaster for marine life, major study shows** This article was published on guardian.co.uk at 10.52 GMT on Thursday 10 December 2009. A version appeared on p16 of the Main section section of the Guardian on Friday 11 December 2009. It was last modified at 13.09 GMT on Thursday 10 December 2009.

W H A T I S P R O B A B L E :

• An additional decrease in pH is under way (25,27).
• With decreases in the pH of seawater, which is a measure of its relative acidity, some marine plants may show increases in production until a particular threshold is met, and then will decline.
• Some marine organisms will not be able to tolerate the predicted decreases in pH in the ocean.
• Carbonate sediment dissolution will accelerate as pH decreases (28).

W H A T I S P O S S I B L E :

• The average pH of the world's oceans may decrease by as much as 0.1 to 0.4 pH units over the next 90 years (29).
• Ocean acidification may lead to shifts in marine ecosystem structure and dynamics that can alter the biological production and export of organic carbon and calcium carbonate from the ocean surface (29).
• Important fisheries habitats, such as coral reefs, will markedly decline or disappear (22, 27).

Photo courtesy of Paige Gill — Florida Keys

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