CONGRESSIONAL TESTIMONY FOR A HEARING ON:

CORAL REEF CONSERVATION ACT OF 2000
AND
THE IMPACT OF CLIMATE CHANGE ON CORAL REEF ECOSYSTEMS

"Coral Death and Ocean Warming:
Unprecedented Increases in the Last Two Decades"

PRESENTED TO:
THE U.S. HOUSE OF REPRESENTATIVES
RESOURCES SUBCOMMITTEE ON OCEANS, FISHERIES CONSERVATION AND WILDLIFE

THURSDAY, JUNE 27, 2002

BY:
DR. ANNE COHEN
RESEARCH ASSOCIATE
WOODS HOLE OCEANOGRAPHIC INSTITUTION
WOODS HOLE, MASSACHUSETTS

My name is Anne Cohen. I am a scientist at the Woods Hole Oceanographic Institution, in the Department of Geology and Geophysics. My research involves the reconstruction of climate variability over the past 1000 years. The goals of this research are threefold: first, to place our direct observations (i.e. experience) of climate over the past century within the context of longer term climatic variability; second, to enable recognition of the impact of human activity on climate and third, to enable assessment of the impact of climate variability on marine ecosystems, specifically on coral reefs.

The thrust of my comments today is that the climate change that we observe in the instrumental records since the middle of last century **are unprecedented in the past 1000 years**. The climate change to which I refer includes the observed increases in ocean and atmospheric temperature, changes in atmospheric circulation patterns and increases in atmospheric CO_2. The increases that we have experienced during our lifetimes and which we have directly measured fall outside of the range of natural variability as we know it to have been prior to the industrial revolution.

Large-scale eradication of coral reef ecosystems is one of the risks of continued anthropogenic interference with the climate system. The two major threats of the current climate change to coral reef health are

(1) increased surface ocean temperature, which causes coral bleaching and death,

(2) increased atmospheric CO_2, which may acidify the ocean causing reefs to dissolve, and reducing the ability of corals to make new skeleton.

My testimony today will focus on the threat to coral reef ecosystems of increased surface ocean temperature due to greenhouse gas emissions. In the past two decades, frequent and severe episodes of coral reef bleaching (see figure below) have occurred on a scale that is unprecedented in the history of coral reef observations. These episodes are coincident with a rapid rise in global temperatures recorded since the mid-1970's. I will demonstrate, using several independently derived datasets, that the rate and magnitude of global warming observed in recent decades is unprecedented in the past 1000 years of Earth's climate

history.

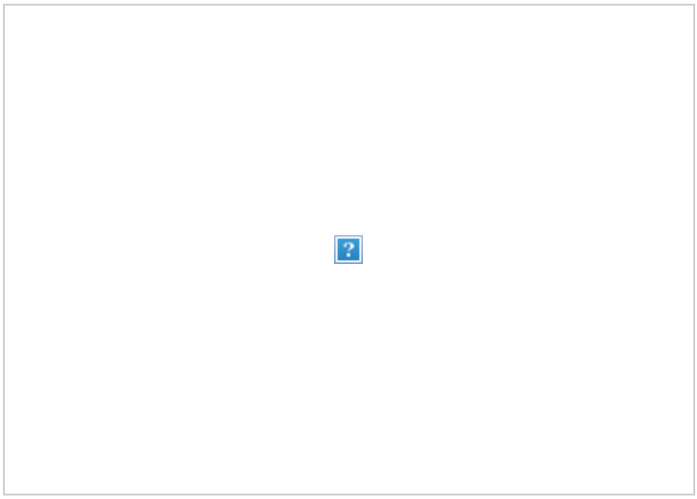
CORAL POLYP

LIVE CORAL WITH POLYPS **BLEACHED DEAD CORAL NO POLYPS**

CORAL DEATH AND CLIMATE CHANGE: OUR DIRECT OBSERVATIONS

Since the early 1980's we have witnessed extensive, basin-wide coral reef bleaching and mortality that have claimed, on some reefs, up to 90% of the living corals. While localized and reversible bleaching events had been recorded by scientists since the 1920's (Williams and Bunkley-Williams, 1990), these are dwarfed by the global extent, frequency and severity of the bleaching episodes of the past 20 years.

All major events in the past 2 decades coincide with extended periods of anomalous **warming of the surface ocean**. Although most of the damage thus far has been to tropical reefs, the cooler, more northerly reefs of Hawaii, Johnston Atoll and Bermuda (see below) first showed signs of bleaching in the late 80's and continued through the 90's.



(left) Extensive coral bleaching was recorded at Bermuda (32ºN) in 1988 and 1998, and to a lesser extent in 1993. Bleaching events were coincident with warmer than usual ocean temperatures, indicated by the arrows. The warming of Bermuda waters is related to a change in the atmospheric circulation over the North Atlantic since 1960.

HAS THIS HAPPENED BEFORE ?

Intensive scientific monitoring of coral reefs and scientific understanding of the factors affecting coral reef health are relatively recent. Observations of extensive reef bleaching and mortality began in the early

1980's, following the 1982/1983 El Nino. From field observations and laboratory experiments we know that corals bleach when sea temperatures increase about 1ºC above the normal summer ambient temperature for that region. We also know from information stored in coral skeletons (the work that I do), tree rings and other biological archives, that climatic conditions have fluctuated significantly in the geologic past. Ocean temperatures have oscillated between periods of cool and periods of warmth and coral reefs have survived these fluctuations. Is it possible that bleaching events of the severity and extent of the past 2 decades have occurred in the past in response to natural fluctuations in the climate system?

To answer this question we need to look into the distant past. Scientists have not yet developed a technique by which we can tell whether a fossil coral died from bleaching. However, we can tell what the ocean temperatures were at the time of death. We also know that the species found on reefs in the past 1000 years were the same as they are today and that they tolerated the same range of temperature. Therefore, to answer the question posed above, we need to address the question posed below:

Are the ocean temperature anomalies of the past 2 decades unprecedented in history or are they part of the natural cycle of climate variability to which corals have adapted?

The instrumental record of temperature indicates that the 1990's were certainly the warmest decade on record (see below). However, the instrumental record is short, giving us a limited perspective of variability through time. For example, a program to monitor ocean temperatures off Bermuda (Hydrographic Station S) began in 1954; global sea surface temperatures have been recorded remotely, by satellite, since 1981.

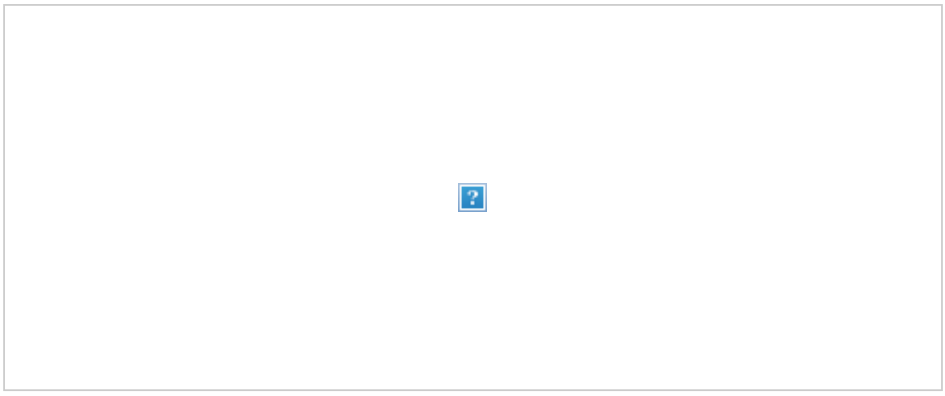
The figure at left shows the globally averaged surface ocean heat content since 1948. The data clearly show a net warming of the oceans since the late 1970's. The timing of the first observations of massive, basin wide coral reef bleaching is indicated by the arrow.

CLIMATE CHANGE: THE PAST 1000 YEARS

To gain some perspective on climate change over a longer period of time, we need an alternative source of climate information. Longer records of past climate are preserved in geological and biological archives - in deep ocean sediments, ice cores, in tree rings and in the skeletons of massive corals. These proxy records - many of which are based upon the biological response to climate change - enable us to see into the past, back beyond the start of instrumental recordings. While the sources of data, their resolution and their coverage in space and time are varied, they all show fairly large and consistent fluctuations in ocean and atmospheric temperatures over the past 1000 years. These fluctuations are associated with natural climate forcings including changes in solar output and volcanic eruptions.

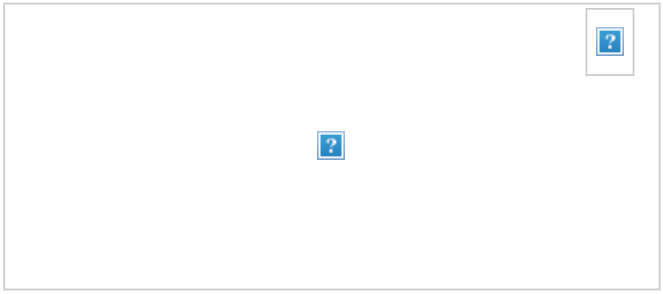
However, all records show a large, rapid and unprecedented increase in temperature over the last half of the 20th century.

PAST OCEAN TEMPERATURES: From brain corals at Bermuda, we get a record of ocean temperatures since 1725 AD. The density of the skeleton, shown by the x-radiograph below left, increases when it is warm and decreases when it is cool. The coral record (below right) shows that water temperatures on the Bermuda platform have fluctuated over the past 300 years, but the magnitude and persistence of the warm temperatures since 1980 are clearly a recent phenomenon. The timing of the first extensive reef bleaching at Bermuda is indicated by the arrow.

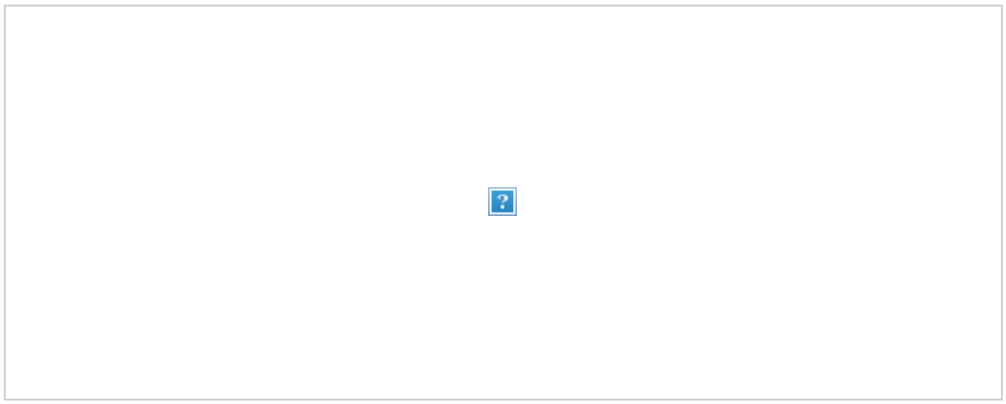


The temperature record from sediments cored nearby on the Bermuda Rise (from Keigwin 1997) enables us to see even further back into the past, although in less detail. The record shows that open ocean temperatures oscillated between generally warmer and generally cooler periods between 3500 and 250 AD (open circles, below).

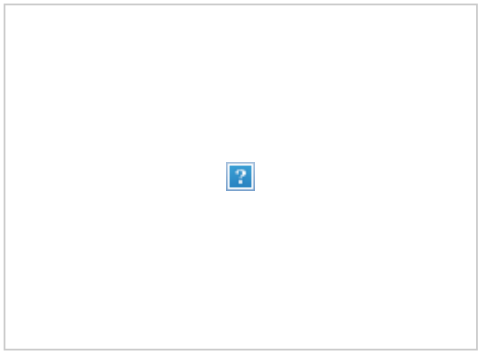
However, these historical fluctuations are small when seen against the most recent recorded summertime temperatures on Bermuda (below). The red circle indicates the temperature at which corals bleached at Bermuda in 1998. The temperature obtained at this time is unprecedented in the past 3500 years.



PAST ATMOSPHERIC TEMPERATURES: Tree rings (below left) preserve a record of atmospheric temperature. The combined northern and southern hemisphere tree ring record shows atmospheric temperature changes over the past 1800 years (red line, below right - from Cooke 2002). Oscillations between warmer and cooler periods are seen throughout the record, but the magnitude and rate of warming of the atmosphere in the past 2 decades clearly exceeds all previous warm events. The timing of the 1983 Pacific bleaching event is indicated by the arrow.



UNDERGROUND TEMPERATURES: Underground temperature measurements were examined from a database of over 350 bore holes in eastern North America, Central Europe, Southern Africa and Australia (from Pollack et al.) The data below show the 20th century to be the warmest of the past five centuries. The timing of the first observations of extensive coral reef bleaching is indicated by the arrow.



WHERE TO FROM HERE?

Coral reefs as we know them have been in existence for millions of years. They have survived major changes in the climate system, including oscillations between glacial and interglacial cycles that involved fluctuations in mean air temperature of 7-10 ºC over fairly short periods of time. They have survived through periods of sea level rise and fall, meteor impacts, volcanic eruptions and changes in solar activity, and somehow the reefs have recovered. But the time scales of those recoveries were long, often many thousands of years and certainly outside of the time frame of our comparably short-term interests.

If we kill the reefs, the waiting time to get them back may be tens of thousands of years.

The frequency, severity and extent of coral reef bleaching and mortality that we have witnessed over the past 2 decades coincide with a rapid warming of the surface oceans. The evidence from proxy records over the past 1000 years indicates that atmospheric and oceanic temperatures have oscillated during this time between periods of relative warmth and periods of relative cooling. However, the **rate** and **magnitude** of the recent warming is unprecedented. Therefore, it is probable that the extent and severity of the observed coral reef bleaching is unprecedented as well, at least in the past 1000 years. Corals today show no signs of adapting to the rise in ocean temperatures and physiological constraints prevent corals from retreating to deeper waters or to higher latitudes to escape warming in the tropics. We can relieve coral reefs of the additional stresses imposed by pollution, development, exploitation and recreation that may slow the recovery from severe bleaching events. However, the evidence indicates that the impact of global warming affects coral reefs indiscriminately, independent of their health.

Modeling studies show that the warming of the past 2 decades is <u>not</u> due to natural forcing; it is anthropogenic in origin (Levitus et al., Science, 2002).

If preserving these unique and valuable ecosystems is considered to be in our best interest, then defining a long-term goal for climate change policy remains a critical international challenge. A long-term target of 1 ºC above 1990 global temperatures would prevent severe damage to at least some reef ecosystems. However, the implications of this target for limiting CO_2 emissions is uncertain because the extent to which biological uptake of CO_2 will counteract the build-up is not predictable at this stage (O'Neill and Oppenheimer 2002). Model predictions for CO_2 stabilization at 450 ppm by 2100, i.e. the Kyoto target, predict an average global warming of between 1.2 and 2.3 ºC (Cubasch et al. 2001), insufficient to prevent loss of many reef systems and widespread reduction in reef health. Therefore, preservation of coral reef ecosystems requires immediate implementation of globally co-ordinated actions to stabilize greenhouse gas concentrations at a level that avoids dangerous anthropogenic interference with the climate system.

<u>DISCLOSURE REQUIREMENT</u>
Required by House Rule XI, clause 2(g)
And Rules of the Committee on Resources

1. Name: Dr. Anne Cohen

2. Business Address: Department of Marine Geology and Geophysics
Clark Laboratory, Room 118A
Mail Stop #23
183 Oyster Pond Road
Woods Hole Oceanographic Institution
Woods Hole, MA 02543

3. Business Phone Number: 508-289-2958

4. Organization you are representing: None

5. Any training or educational certificates, diplomas or degrees or other educations experiences which add to your qualifications to testify on or knowledge of the subject matter of the hearing: See attached Curriculum Vitae

6. Any professional licenses, certifications, or affiliations held which are relevant to your qualifications to testify on or knowledge of the subject matter of the hearing: See attached Curriculum Vitae

7. Any employment, occupation, ownership in a firm or business, or work-related experiences which relate to your qualifications to testify on or knowledge of the subject matter of the hearing: See attached Curriculum Vitae

8. Any offices, elected positions, or representational capacity held in the organization on whose behalf you are testifying: No known conflicts of interests

B. To be completed by nongovernmental witnesses only:

1. **Any federal grants or contracts (including subgrants or subcontracts) which you have received since October 1, 1999. Include the source and the amount of each grant or contract:** See attached Curriculum Vitae

2. **Any federal grants or contracts (including subgrants or subcontracts) which were received since**

October 1, 1999 which you represent at this hearing, including the source and amount of each grant or contract: None

3. **Any other information you wish to convey which might aid the members of the Committee to better understand the context of your testimony:** See attached Curriculum Vitae

ANNE LOUISE COHEN
Research Associate
Department Geology and Geophysics
Woods Hole Oceanographic Institution
Woods Hole, MA, 02543.

EDUCATION: all degrees obtained University of Cape Town (UCT), South Africa

December 1993: PhD, Faculty of Science, University of Cape Town. THESIS TITLE: "A Holocene Sea Surface Temperature Record in Mollusc Shells from the Coast of Southern Africa". THESIS ADVISORS: Professor Nikolaas van der Merwe, Archaeometry Laboratory, UCT and Peabody Museum, Harvard University; Professor George Branch, Department of Zoology, UCT

1987: BSc honours

1986: Bachelor of Science (BSc) (Marine Biology, Archaeology)

PEER REVIEWED PUBLICATIONS

Cohen, A.L., Owens, K.E., Layne, G.D. and Shimizu, N. 2002b. The Effect of Algal Symbiosis on the accuracy of Sr/Ca paleotemperatures from Coral. *Science* 296(5566):331-334 (Also online at www.sciencexpress.org, 7th March 2002 and reported in Science News 161(18) 285)

Cohen, A.L., McCartney, M.S., Smith, S.R. and van Etten, J. 2002a. How Brain Corals Record Climate: An Integration of Skeletal Structure, Growth and Chemistry in *Diploria labyrinthiformis* on Bermuda. Accepted for publication in 2002 in *Coral Reefs*.

Cohen, A.L., Layne, G.D., Hart, S.R. and Lobel, P.S. 2001. Kinetic control of skeletal Sr/Ca in a symbiotic coral: implications for the paleotemperature proxy. *Paleoceanography,* 16(1): 20-26

Cohen, A.L. and McCartney, M. S. 1999. Seasonally-Resolved records of Oceanic Surface Conditions in Brain Corals from Bermuda. In: *Papers on Atlantic Climate Variability*, Atlantic Climate Change Program, Office of Global Programs, NOAA.

Cohen, A.L. and Hart, S.R. 1997. The Effect of Colony Topography on Climate Signals in Coral Skeleton. *Geochemica et Cosmochimica Acta,* 61(18):3905-3912

Hart, S.R., Cohen, A.L. and Ramsay P.B. 1997. Microscale analysis of Sr/Ca and Ba/Ca in *PORITES*. IN: Lessios, H. A., Macintyre, I.G. (eds). Proceedings of the 8th International Coral Reef Symposium, 2:1707-1712

Cohen, A.L., Lobel, P.S. and Tomasky, G.L. 1997. A Coral Bleaching Event on Johnston Atoll, north-central Pacific. *Biological Bulletin*, 193:276-279

Ramsay, P. J. and Cohen, A.L. 1997. Coral paleoclimatology research on the Southeast African Shelf. IN: Lessios, H. A., Macintyre, I.G. (eds). Proceedings of the 8th International Coral Reef Symposium, 2:1731-1734.

Hart, S.R. and Cohen, A.L. 1996. Sr/Ca in Corals: An Ionprobe Study of Annual Cycles and Microscale Coherence with Other Trace Elements. *Geochemica et Cosmochimica Acta,* 60:3075-3084.

Cohen, A.L. and P.D. Tyson. 1995. Holocene Sea Surface Temperatures on the South Coast of Africa: Implications for Terrestrial Climate and Rainfall. *The Holocene,* 5(3):304-312

Schumann, E.H., Cohen, A.L. and Jury, M.R. 1995. Coastal sea surface temperature variability along the south coast of Africa and the relation to regional and global climate. *Journal of Marine Research*, 53:231-248

Cohen, A.L., J.E. Parkington, G.B. Brundrit and N.J. van der Merwe. 1992. A Holocene marine climate record in mollusc shells from the southwest African coast. *Quaternary Research*, 38:379-85

Cohen, A.L. and G.M. Branch. 1992. Geographic changes in the structure and mineralogy of the shell of *Patella granularis* along the coast of South Africa: implications for palaeotemperature assessments. *Paleoecology, Palaeogeography and Palaeoclimatology*, 91:49-57

Cohen, A.L. 1988. Isotopic and mineralogical variation in the shells of recent marine molluscs from the western Cape coast of South Africa. *South African Journal of Science*, 84 (11):917-918

NEWS AND VIEWS

Cohen, A.L. 1993. Oceanic Records of Climate Change. News and Views from the Fourth International Conference on Paleoceanography. *South African Journal of Science*, 89:258-259

POPULAR PAPERS

Thorrold, S. and Cohen A. Recorded in the ear bones – tracing fish movements through geochemical analyses of otoliths. *Oceanus, in press,* 2002

Cohen, A.L. 1999. Reconstructing Climate with Coral. Rinehart Coastal Research Center quarterly publication.

INVITED TALKS (*CONFERENCES)

*Cohen, A.L., McCartney, M.S. and Smith, S.R. *A History of Atlantic Decadal Variability Preserved in the Skeletons of Massive Brain Corals from Bermuda*. AGU Spring meeting Washington D.C., May 2002.

*Cohen, A.L. *Deciphering the Life Histories of Atlantic Tuna: the potential of otolith geochemistry*. American Society of Limnology and Oceanography, Victoria, British Columbia, June 2002.

Cohen, A.L. *The Secrets of Corals: what can they tell us and why we want to know*. Mass Maritime Educators Annual Meeting, Woods Hole, April 27th 2002.

Cohen A.L. *Accessing the Climate Record in Coral Skeleton*. Center for Subsurface Sensing and Imaging Systems (CenSSIS) Research & Industrial Collaborative Conference, Boston, January 29-30, 2002

*Cohen A. L. *Microstructure and Microscale Chemistry of Reef Coral Skeleton over the Diurnal Cycle.* Geological Society of America, annual meeting, Boston Nov. 1-10, 2001.

Cohen, A.L. *Paleohurricanes Day by Day: Can We Do It* ? Risk Prediction Initiative Workshop, Bermuda, June 7-8, 2001.

Cohen, A.L. *Coral Paleoclimatology from the Inside Out*. University of South Florida, St Petersburg FLA, February 2, 2001

Cohen, A.L. *Hurricane Tracking with Coral Chemistry*. Workshop on Atlantic Basin Paleohurricane Reconstructions from High Resolution Records, University of South Carolina, SC, March 24-28, 2001.

Cohen, A.L. *A New Nighttime PaleoThermometer in Symbiotic Corals*. Brown University, R.I., March 12, 2001

*Cohen, A.L. and Layne, G.D. *Exploring the nighttime thermometer in symbiotic corals*. G.A. Decadal periodicity in Agulhas Current SST measured in Coral from SE Africa. *Eos*, *Trans. AGU,* 81, 19 (Suppl.) Spring Meet., 2000.

*Cohen, A.L., Ramsay, P.B. and Jones, G.A. *Decadal periodicity in Agulhas Current SST measured in Coral from SE Africa. Eos, Trans. AGU*, 76, 46 (Suppl.) Fall meet. 1995.

AWARDS AND MEDALS

1997: Oliver Davies Medal (South African Young Scientist Award for Research Contributions in South African Paleoclimate)

1994: Woods Hole Oceanographic Institution Post-Doctoral Fellowship

1987: Class Medal

1986: Class Medal (highest overall grade; undergraduate class)

GRANTS

2001: WHOI Climate Institute Award (A.L. Cohen and M.S. McCartney)
2000: NSF Biological Oceanography (A.L. Cohen and G.D. Layne)
NSF Atmospheric Sciences (L.J. Moore and A.L. Cohen)
1999: NSF Atmospheric Sciences (A.L. Cohen and G. D. Layne)
Rinehart Coastal Research Center Award (A.L. Cohen and G. D. Layne)
1998: NOAA Atlantic Climate Change Program (A.L. Cohen and M.S. McCartney)
1996: NSF Earth Systems History (S.R. Hart & A.L. Cohen)
1992: SACCAIM (South African Climate Change Institute) Graduate Research Award
South African Foundation for Research Development (FRD) Graduate Fellowship
International Council for Scientific Unions travel grant (to attend ICP IV in Kiel)
1991: South African Foundation for Research Development Graduate Fellowship
South African De Beers Chairmans Fund Graduate Research Award
South African Society for Quaternarists (SASQUA) Travel Grant
1988: Harry Oppenheimer Graduate Research Award

ORGANIZATIONAL/COMMITEES/PANELS

- CHAIR: Special Symposium, Goldschmidt Conference, Switzerland, August 18-23rd, 2002
- PANELIST: Center for Subsurface Sensing and Imaging Systems (CenSSIS) Research & Industrial

Collaborative Conference, Boston, January 29-30, 2002

- CICOR member (WHOI-NOAA Co-operative Institute for Climate and Ocean Research), 2000-
- Representative: PAGES (PEP III) Workshop, Switzerland, December 1993
- Committee Member, South African Marine Change Co-ordinating Committee, 1991-1993

SYNERGISTIC ACTIVITIES

- INVITED SPEAKER: Mass Maritime Educators Meeting, April 27th 2002
- JUDGE (Volunteer): Falmouth Schools Science Fair, March 2002
- STUDENT SUPERVISION: WHOI Summer Students (J. van Etten and K. Owens), May-August 2001
- COMMITTEES: CICOR Fellow (WHOI-NOAA Co-operative Institute for Climate and Ocean Research),
- PANELS: Center for Subsurface Sensing and Imaging Systems (CenSSIS) Research & Industrial Collaborative Conference, Boston, January 29-30, 2002
- PUBLIC OUTREACH:

  Television: Discovery Channel (Discovery Communications Incorporated) Discovery Science: Science of the Deep: Tuna Earbones.

  Magazines/Newspapers: I have been interviewed by Science News, National Geographic magazine; New York Science Times; Swiss daily newspaper "Tages-Anzeiger". An article about my work will appear this semester in WHOI Currents magazine. I have contributed articles for Oceanus and the Rinehart Coastal Research Center newsletter.

  Current Website contributions: Presentations of my work can be found on the following websites: Center for Subsurface Sensing and Imaging Systems (www. censsis.neu.edu/); Risk Prediction Initiative (www.bbsr.edu/agcihome/rpi/rpihome.html); NOAA CLIVAR (www.ogp.noaa.gov/mpe/clivar/clivarmain.htm); NOAA Coral Health and Monitoring (www.coral.aoml.noaa.gov.themes/themes/html); Columbia University (www.ldeo.columbia.edu/NAO/conference/chapman_conf.html); WHOI's Rinehart Coastal Reserach Center (www.whoi.edu/coastalresearch/research/projects_cohen_presentation.htm)
- ANNUAL GUEST/PUBLIC LECTURES: Guest Lecturer, Bridgewater State College since 1995.

FIELD EXPERIENCE

From 1995 though 2002, I have led and/or participated in 20 field excusions in the US and abroad involving scuba diving, coral collection, sediment coring and/or deep sea fishing.

CONTRIBUTED ABSTRACTS

Cohen, A.L., McCartney, M.S. and Smith, S.R. *A History of Atlantic Decadal Variability Preserved in the Skeletons of Massive Brain Corals from Bermuda*. AGU Spring meeting Washington D.C., May 2002.

Van Etten, J.L.., Cohen, A.L. A study of microscale banding in reef coral skeleton. Geological Society of America, 2001 annual meeting, Abstracts with Programs - Geological Society of America, 33 (6), p. 19. Boston, MA, United States, Nov. 1-10, 2001.

Cohen, A.L., Layne, G.D. and Shimizu, N. Diurnal changes in microstructure and microscale chemistry of reef coral skeleton. *Eos Trans., AGU*, 82(47) Fall Meet. Suppl., 2001.

Owens, K.E., Cohen, A.L., Layne, G.D. and Shimizu, N. The Biological Nature of Geochemical Proxies: algal symbionts affect coral skeletal chemistry. *Eos Trans., AGU*, 82(47) Fall Meet. Suppl., 2001.

Cohen A L and Layne G D. Coral Sr/Ca thermometry with nighttime skeleton. 7th International Conference on Paleoceanography, Sapporo, Japan 2001.

COHEN, A.L., M.S. MCCARTNEY, J.VAN ETTEN AND S.R. SMITH. A HISTORY OF NORTH ATLANTIC CLIMATE IN BERMUDA BRAIN CORAL. INTERNATIONAL SOCIETY FOR CORAL REEFS (ICRS), 9TH INTERNATIONAL SYMPOSIUM, BALI INDONESIA, 23-27 OCTOBER 2000.

COHEN, A.L., E.H. GLADFELTER AND G.D. LAYNE. THE EFFECT OF SYMBIOSIS ON SKELETAL CHEMISTRY OF HERMATYPIC CORALS: IMPLICATIONS FOR INTERPRETING CORAL CLIMATE RECORDS. INTERNATIONAL SOCIETY FOR CORAL REEFS (ICRS), 9TH INTERNATIONAL SYMPOSIUM, BALI INDONESIA, 23-27 OCTOBER, 2000.

Heikoop, J.M., Hickmott, D.D., Risk, M. J., Hart, S.R., Cohen, A.L., Sandeman, I. M., Strontium/calcium and carbon and oxygen isotopic variability in corals from Discovery Bay, Jamaica. Geological Society of America, 31 (7), p. 461, Denver, CO, United States, Oct. 25-28, 1999.

Cohen, A.L., Layne, G.D., Hart, S.R. and Lobel, P.S. Kinetic control of skeletal Sr/Ca in a symbiotic coral: accounting for anomalous estimates of past sea surface temperature. *Eos, Trans., AGU*, 80, 46 (Fall Meet.

Suppl.) 1999.

Cohen, A.L., Hart, S.R. and Lobel, P.S. An exploration of the origins of microscale variability in proxy records from skeletal carbonates. *Eos, Trans., AGU*, 79, 45 (Suppl.) San Francisco 1998.

Cohen, A.L. Calibration of coral proxies in the s-w Indian Ocean. *Eos, Trans., AGU,* Fall Meeting 1997.

Hart, S.R. and Cohen, A.L. Delineating proxy records in corals. *Eos, Trans., AGU*, 76 (17, Suppl.), p. 180. Spring meeting, Baltimore, MD, United States, May 30-June 2, 1995

Cohen, A.L, Ramsay, P.B., Jones, G.A., A 50 year-long record of Agulhas Current variability in coral from 2-Mile Reef, South Africa. Lathuiliere, B.,Geister, J. (eds), Proceedings of the Second European regional meeting; Coral reefs in the past, present and future. Publications du Service Geologique du Luxembourg, 29, p. 149, 1995. ISBN: 2-919994-03-4. Luxembourg, Sept. 6-9, 1994

OTHER RELEVANT QUALIFICATIONS

AAUS (American Association of Underwater Scientists)

Buzzards Bay Power Squadron Small Boats Certification

Supplemental sheet

FOLLOW-UP ADDRESS

Dr. Anne Cohen
Department of Geology and Geophysics
Clark Laboratory, Room 118A
Woods Hole Oceanographic Institution
Woods Hole, MA 02543

508-289-2958
acohen@whoi.edu

TOPICAL OUTLINE TESTIMONY

- The past two decades have seen an increase in the frequency, severity and geographical extent of coral reef bleaching, with devastating consequences.
- The bleaching is coincident with (and caused by) a global increase in sea surface temperature.
- The rate and magnitude of oceanic and atmospheric warming over the past two decades is unprecedented in the past 1000 years of climate history and is directly related to human activity.
- The corals are not adapting to the current change in climate conditions.
- Preservation of coral reef ecosystems requires stabilization of greenhouse gas concentrations at a level that will prevent a rise in ocean temperatures more than 1 ºC above 1990's levels.