

Bahamas National Natural History Conference

**A Conference Highlighting the Importance of Research, Conservation,
and Environmental Stewardship in The Bahamas**

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GOLF COURSE FERTILIZER RUNOFF CAUSES NUTRIENT ENRICHMENT LEADING TO HARMFUL ALGAE BLOOMS ON A BAHAMIAN CORAL REEF

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PAST BAHAMIAN REEFS

- WERE FAMOUS FOR HUGE CORALS, HIGH COVERAGE BY LIVE CORALS
- LARGE SCHOOLS OF FISH
- NOW WE CAN SEE HOW THEY WERE ONLY IN THE OLDEST PHOTOGRAPHS
- NONE OF THE CURRENT GENERATION OF DIVERS REMEMBERS HOW MAGNIFICENT THEY ONCE WERE

The first high quality underwater color photograph ever made
F. W. Goreau, Bimini, 1948





Figure 1. Panshoal Coral. The ecological form of the elk-horn coral *Acropora palmata* when growing on the reef platform (reef 3). It is 8 feet across. The tips of the coral will be almost exposed at low tide. The conulose surface is typical of this form. A similar growth form is reported by Wells (1954) found in a comparable zone in the Pacific reefs.

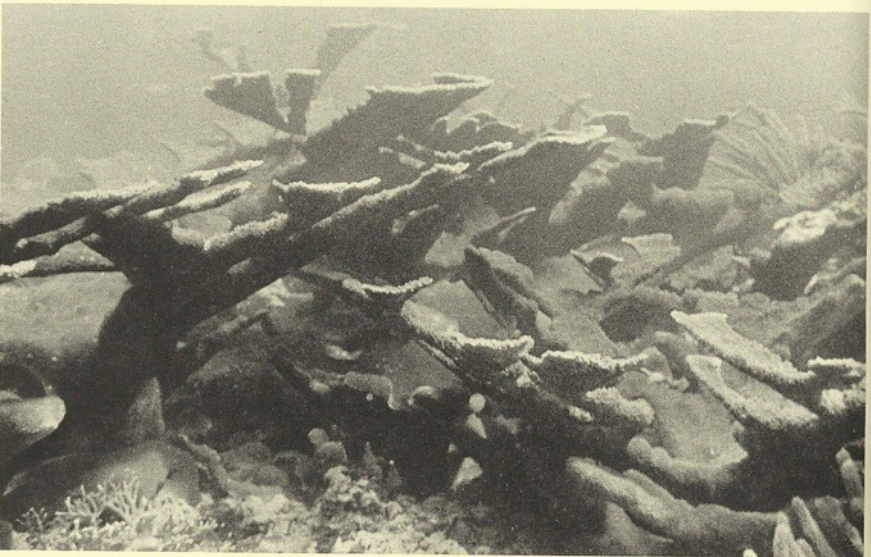


Figure 2. Acropora Zone. The massed corals or coral forest is typical of the dense growth of *Acropora palmata* found in the outer parts of the Acropora Zone. In many cases the tips of all the coral branches reach the same height marking the normal low-tide level.

ECOLOGICAL VARIATIONS OF *ACROPORA PALMATATA*

STORR, PLATE 6

Geological Society of America, Special Paper 79

STORR, 1964, HOPETOWN, ABACO



Figure 1. Seaward slope of the main reef. Typical appearance of the talus slope of the reef barrier of the Hopetown reef tract. The dominant coral growths are the branching *Acropora palmata* and the rounded masses of the club coral *Porites porites*.

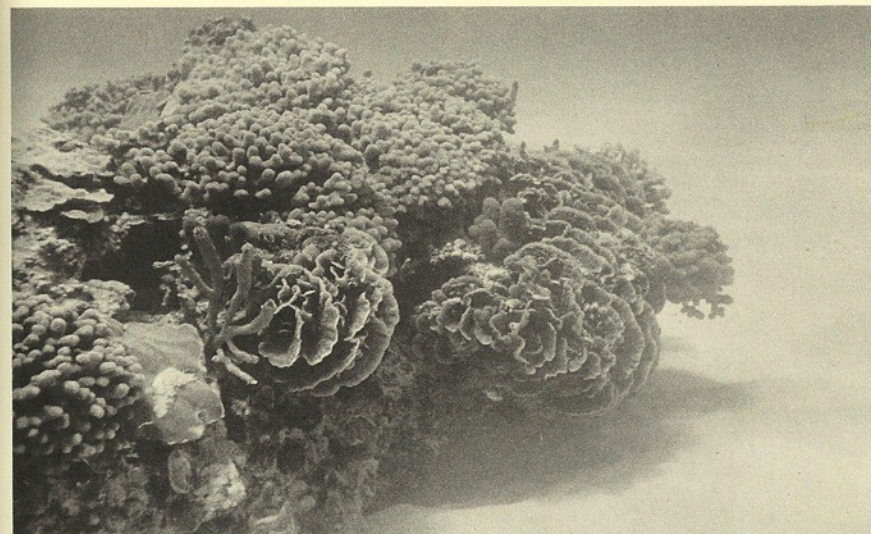


Figure 2. Leaf (or lettuce) Coral. Leaf Coral *Agaricia agaricites* is growing in the typical habitat at the edge of a developing basal cavern. Club coral *Porites porites* and fungal-shaped *Montastrea* occupy the remainder of the mound, along with growths of soft coral such as the pillar-shaped *Briareum asbestinum* (seen just right of the center). It is probable that this coral mass represents the origins of a coral mound.

STRUCTURE AND DETAIL OF THE MAIN REEF BARRIER,
ABACO ISLAND, BAHAMAS

STORR, PLATE 3

Geological Society of America, Special Paper 79

BAHAMIAN REEFS ARE NOW RAPIDLY COLLAPSING

- **LIVE CORAL COVER DECREASED 77% BETWEEN 1991 AND 2004 AT A REMOTE REEF WITH NO SIGNS OF DISEASE IN THE EXUMAS (PANTE ET AL., 2008)**
- **GLOBAL WARMING, NEW DISEASES, LAND-BASED SOURCES OF POLLUTION, DREDGING, DEFORESTATION, AND DESTRUCTIVE FISHING METHODS ARE LARGELY TO BLAME (only first two here)**

Does development hurt coral reefs?

- Dead reefs next to tourism developments all around the world
- Impacts of sewage and fertilizer nutrients cause massive growth of weedy algae
- Algae then smother and kill coral
- Higher incidence of coral diseases associated with sewage wastes
- NO before and after studies on either hotels or Golf Courses

GOLF AND TOURISM: HOW GREEN IS IT?

- EVERY MAJOR TROPICAL TOURIST DESTINATION HAS GOLF COURSES
- MOST ARE NEAR TO THE OCEAN
- HUGE AMOUNTS OF FERTILIZERS ARE USED
- TINY AMOUNTS OF FERTILIZER CAUSE ALGAE TO OVERGROW AND KILL CORAL
- EVERY GOLF COURSE ENVIRONMENTAL IMPACT ASSESSMENT SAYS NO DAMAGE WILL RESULT
- NO BEFORE AND AFTER STUDIES EVER DONE

BAHAMAS GOLF COURSES

- Baker's Bay Golf & Ocean Club, Great Guana Cay, Abaco
- Blue Shark Golf Club, Nassau, New Providence
- Fortune Hills Golf & Country Club, Freeport, Grand Bahama
- Lyford Cay Club, Nassau, New Providence
- Our Lucaya Resort - Lucayan Course, Freeport, Grand Bahama
- Our Lucaya Resort - Reef Course, Freeport, Grand Bahama
- Radisson Cable Beach & Golf Resort, Nassau, New Providence
- Sandals Emerald Reef Golf Club, Great Exuma
- South Ocean Golf & Beach Resort, Nassau, New Providence
- The Abaco Club on Winding Bay, Marsh Harbour, Abaco
- The Ocean Club, Paradise Island, New Providence
- Treasure Cay Golf Club, Treasure Cay, Abaco
- **MANY MORE ARE NOW PLANNED!**

HISTORY

- **Guana Cay, Abaco, is a native Bahamian fishing community**
- **Outside developers given Crown Lands to build golf course, mega-yacht marina, hotel, mansions**
- **Locals opposed this because it would kill their coral reefs and fisheries, to no avail**

BAKERS BAY WAS PRISTINE IN 2003 BEFORE DEVELOPMENT, WITH LUSH MANGROVES AND SOME OF THE FINEST CORAL REEFS IN THE BAHAMAS



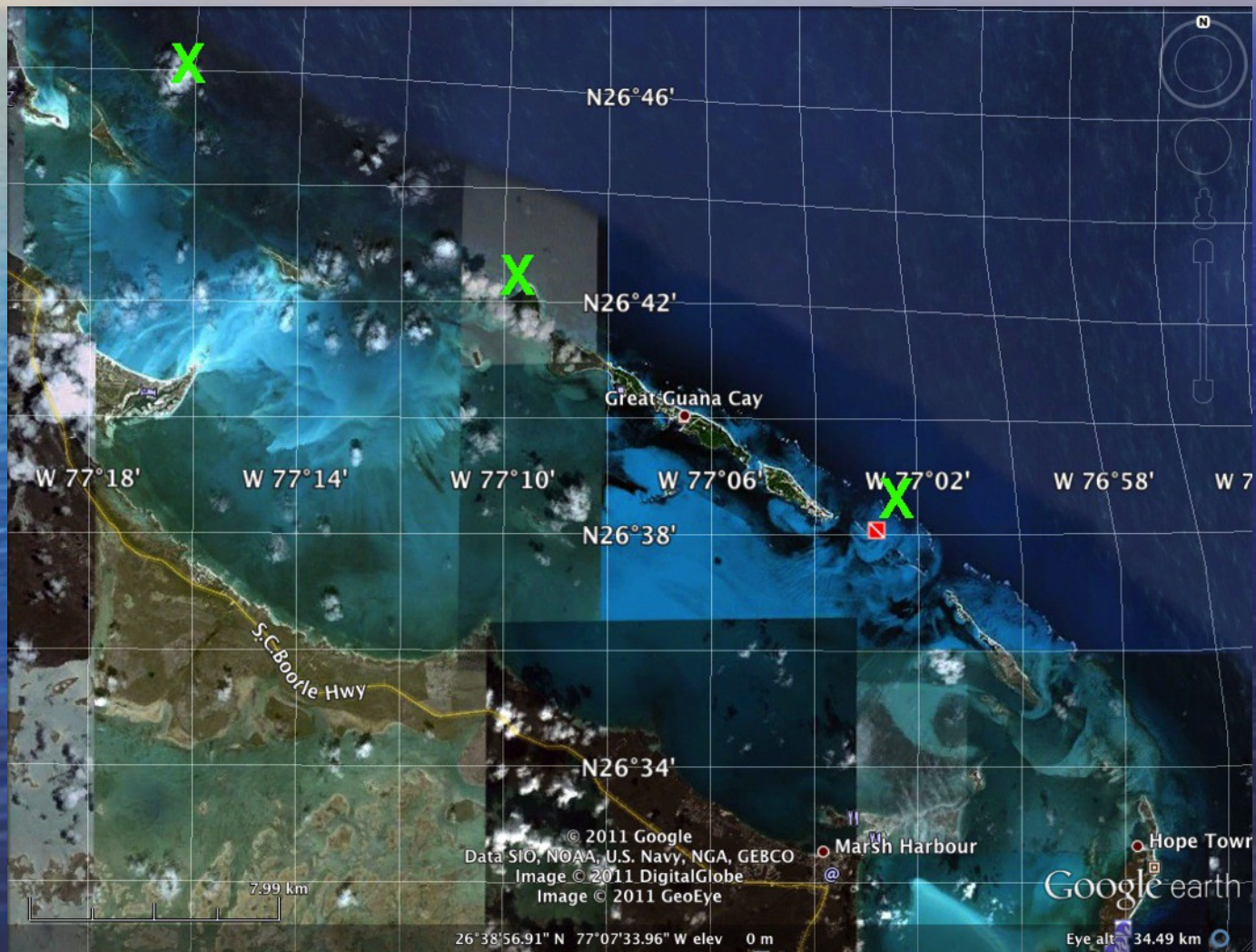
BAKERS BAY BEFORE



Prior to any development at Bakers Bay

- Three groups of scientists independently studied health of reefs at North Guana Cay and other sites in the region
- Dr. Michael Risk 2004
- Dr. James Cervino 2006 -2007-2012
- Dr. Thomas Goreau 2007 & 2012
- Found almost no coral diseases, low levels of nuisance algae

Coral reef health monitoring sites marked with green X



2004 Bakers Bay Environmental Assessment and Management Plan

- Claimed that there would be NO adverse effects of Golf Course, sewage, construction, or erosion on water quality due to “advanced” waste water treatment, lining of golf courses to prevent leaching, and construction of buffer zones to prevent chemicals washing into sea. Promised “*To maintain water quality parameters in coastal groundwater and near shore marine waters at pre-construction levels*”.

Environmental Impacts

- Dredging and sedimentation
- Deforestation, landfilling, bulldozing, construction of greens, mega-yacht marina, houses, restaurants, hotels, services
- Few homes occupied, so little or no sewage input
- Golf course built, fertilized, & maintained

BAKERS BAY AFTER



Baker's bay Marina and preserve
March 09
Photo Anyes adams



Silt curtains (yellow) failed to contain sediments that passed right under them.



AFTER GOLF COURSE

- Large increase in all coral diseases at the North End especially White Plague. This disease is the fastest spreading and kills most coral species
- Increase in this disease much less at other sites
- Increase in weedy algae overgrowth around coral bases
- Big increase in cyanobacteria

WHITE BAND DISEASE, THE MOST DANGEROUS OF CORAL DISEASES, SUDDENLY BECAME COMMON AT GUANA CAY REEF AFTER THE GOLF COURSE WAS ESTABLISHED, ALONG WITH ALGAE OVERGROWTH.



BLACK BAND AND MANY OTHER CORAL DISEASES WERE VERY RARE AT GUANA CAY BEFORE THE GOLF COURSE WAS ESTABLISHED, BUT BECAME COMMON RIGHT AFTER.



**SOFT CORAL BEING
OVERGROWN AND
KILLED BY TOXIC
CYANOBACTERIA
ON REEF NEAR
GOLF COURSE. THE
PROBLEM BEGAN
ONLY AFTER THE
GOLF COURSE WAS
ESTABLISHED.**



Next to Golf Course

- Big increase in high-nutrient “end of sewer pipe” algae species
- Weedy algae cover beach rock areas near golf course, but not away from it
- Algae are bright green and red from high nutrient levels from golf course fertilizers
- Reef is in early stages of very rapid eutrophication: overgrowth by harmful algae blooms

The morning sun shines right through the “impermeable barrier” at the seaward edge of the Bakers Bay golf course green. It retains soil but water and dissolved nutrients flow right through it.



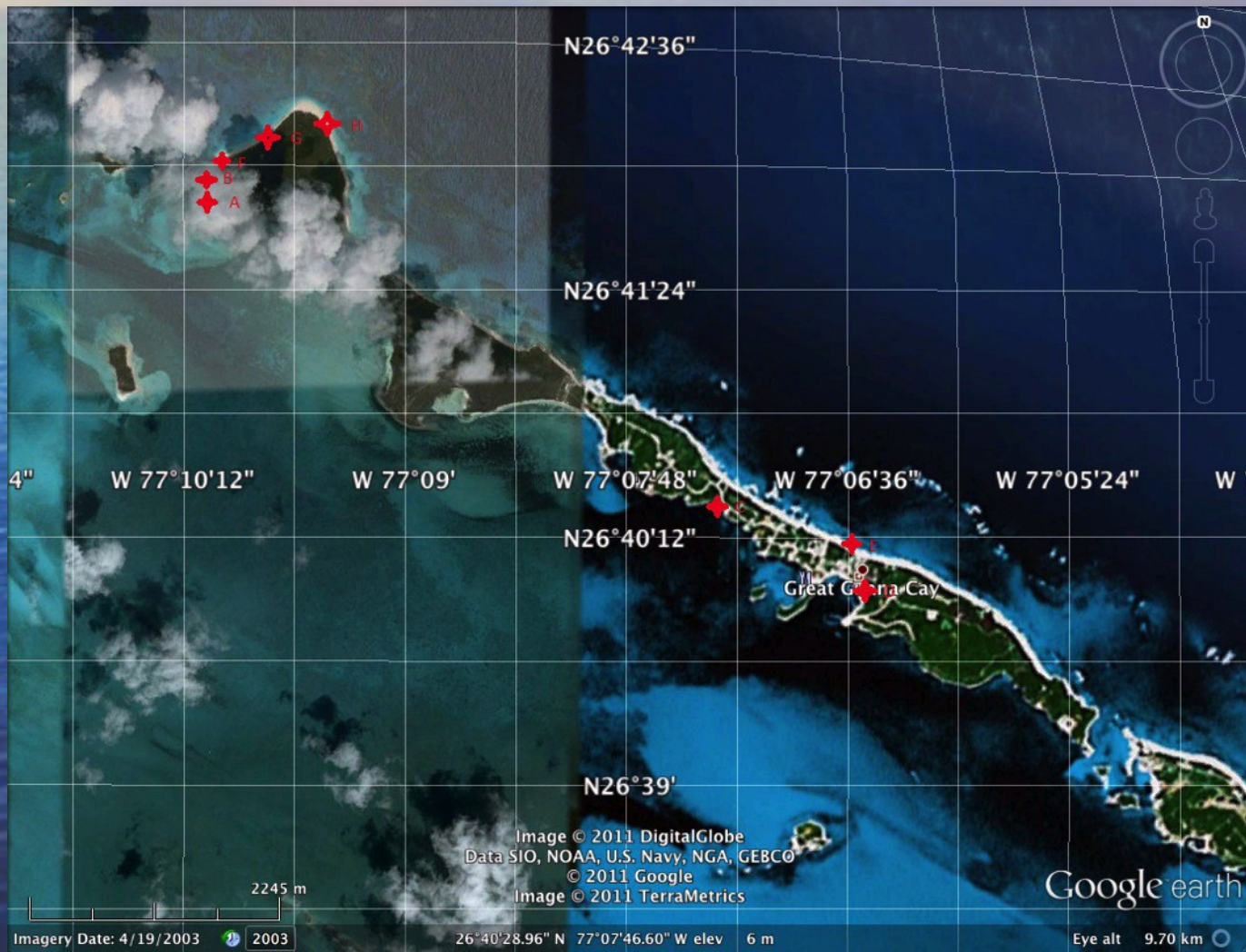
WATER NUTRIENT ANALYSIS PROBLEMS

- **MEASURING DISSOLVED NUTRIENTS IS EXTREMELY EXPENSIVE, PRONE TO SAMPLING, STORAGE, AND ANALYTICAL ERRORS**
- **DUE TO RAPIDLY VARYING CONCENTRATIONS IN TIME AND SPACE ONE NEEDS A VAST DATA BASE TO BE MEANINGFUL, WHICH IS ALMOST NEVER MEASURED**

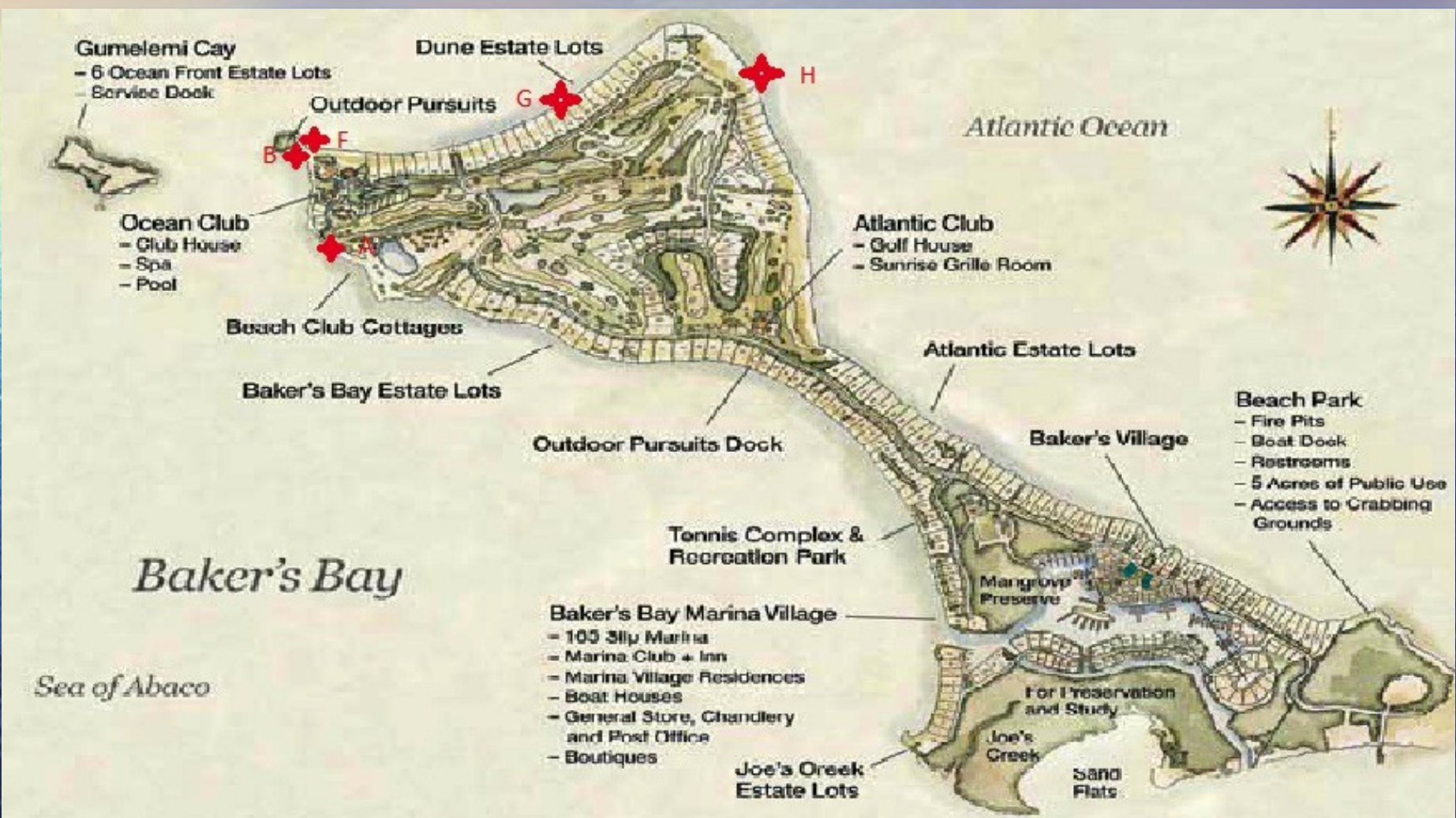
ALGAE NUTRIENT MONITORING

- ALGAE CONTINUALLY TAKE UP NUTRIENTS AND INTEGRATE THE VARIATIONS OVER THEIR LIFETIME
- ONE CAN MAP NUTRIENT DISTRIBUTIONS MORE ACCURATELY AND CHEAPLY FROM ANALYZING ALGAE CARBON, NITROGEN, & PHOSPHORUS CONTENTS, & THEIR C-13/C-12 AND N-15/N-14 RATIOS

Algae sampling locations around Guana Cay. Aerial image taken before golf course and marina construction.



Algae sampling sites in NW Guana Cay near the Bakers Bay golf course. Adapted from Bakers Bay golf course brochure. The golf course is at upper left, the marina at lower right. None of the house lots have been occupied.



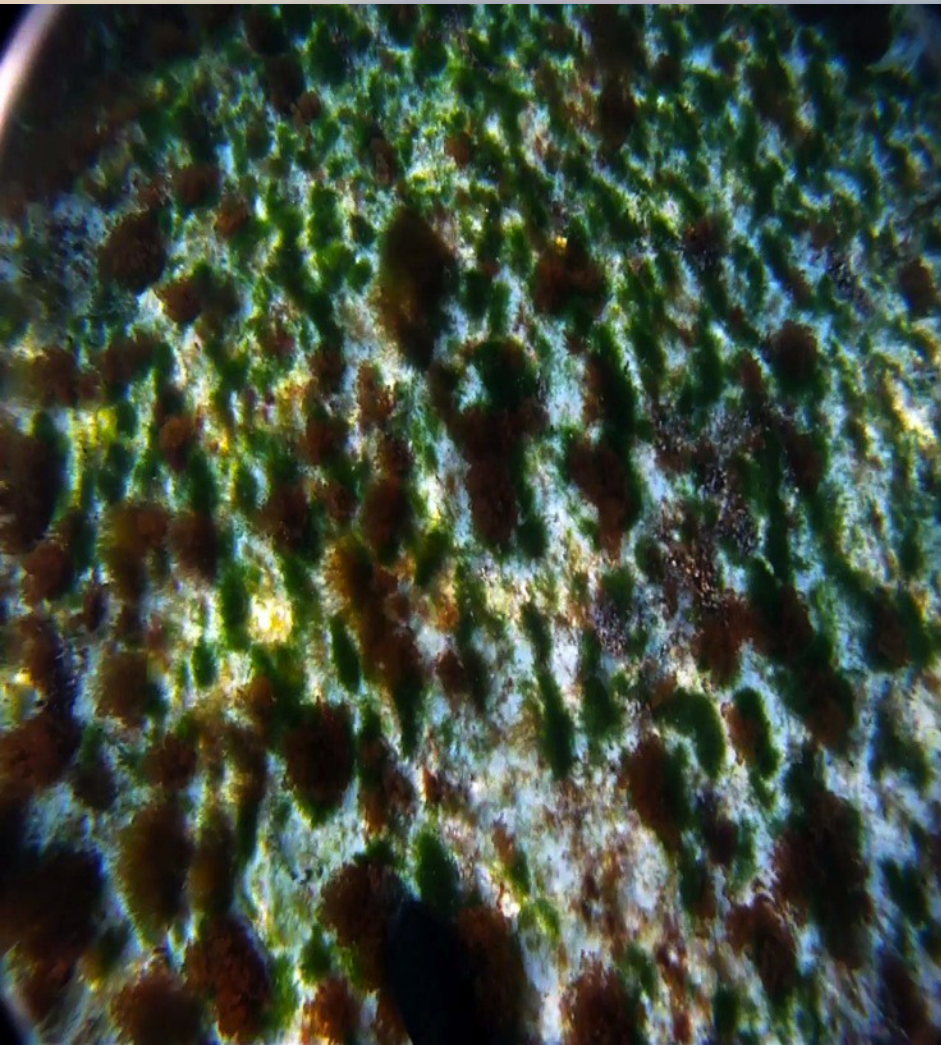
Northwest Guana Cay from the air. The algae bloom off the golf course closest to the shore is the brown fringe right along the shore at A. The dark patch in the algae bloom area is due to algae growing directly on the sand in front of the beach where fertilizer runoff leaches into the water, with no beachrock present. Dark areas at bottom left are eroded limestone rock with relatively little algae, dark areas along the upper left beach (G) are beachrock, with some algae but much less than the bloom area, dark patches offshore at upper left are coral reefs undergoing coral disease outbreaks, and dark patches at lower right and right are seagrass beds. The letters show near shore algae sampling sites.



THE GOLF COURSE GREENS COME RIGHT NEXT TO THE SEA, WITH LITTLE OR NO VEGETATED BUFFER ZONE. THE ALGAE ARE RIGHT IN FRONT OF THEM.



IN FRONT OF THE GOLF COURSE THE BOTTOM IS COVERED WITH BRIGHTLY COLORED ALGAE THAT HAD NOT BEEN THERE BEFORE. THEY DECREASE AWAY FROM THE SHORE (RIGHT).



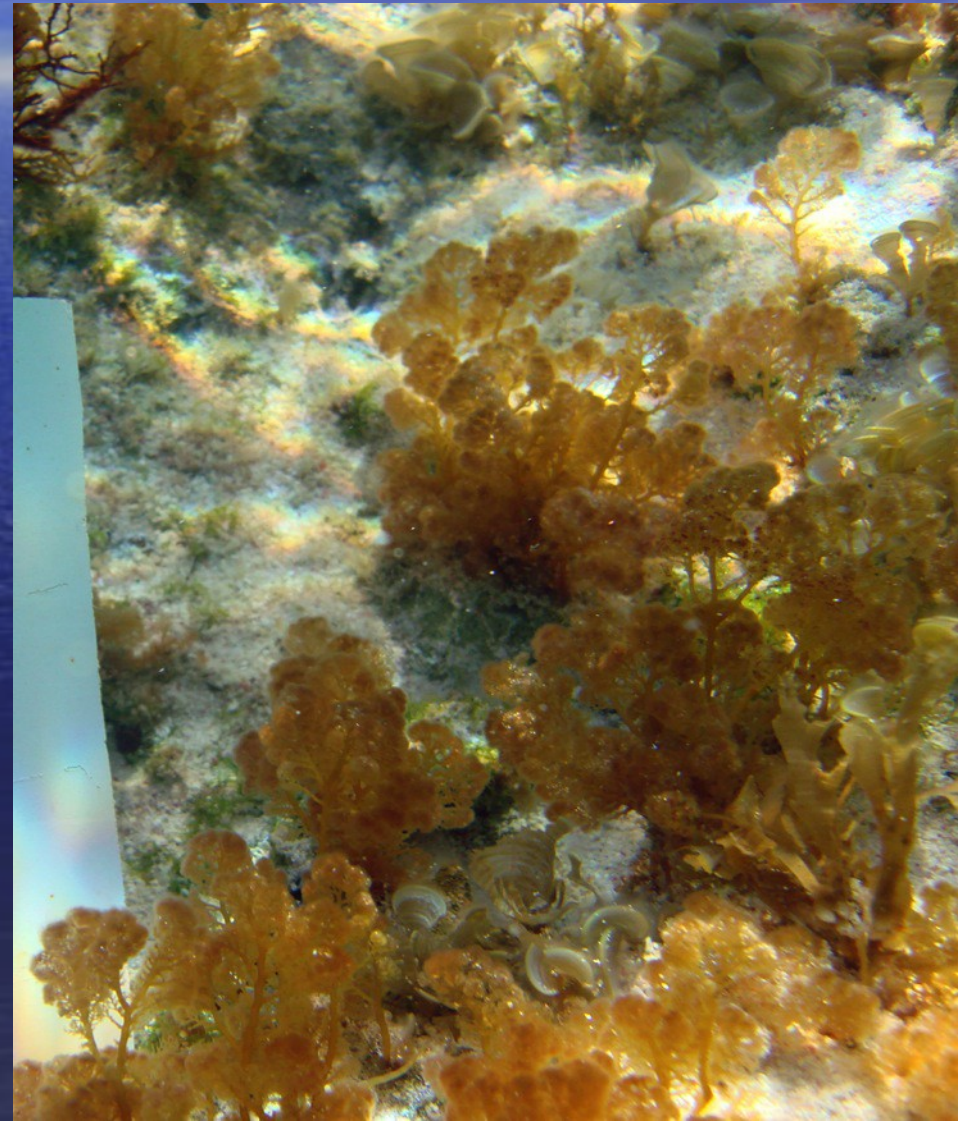
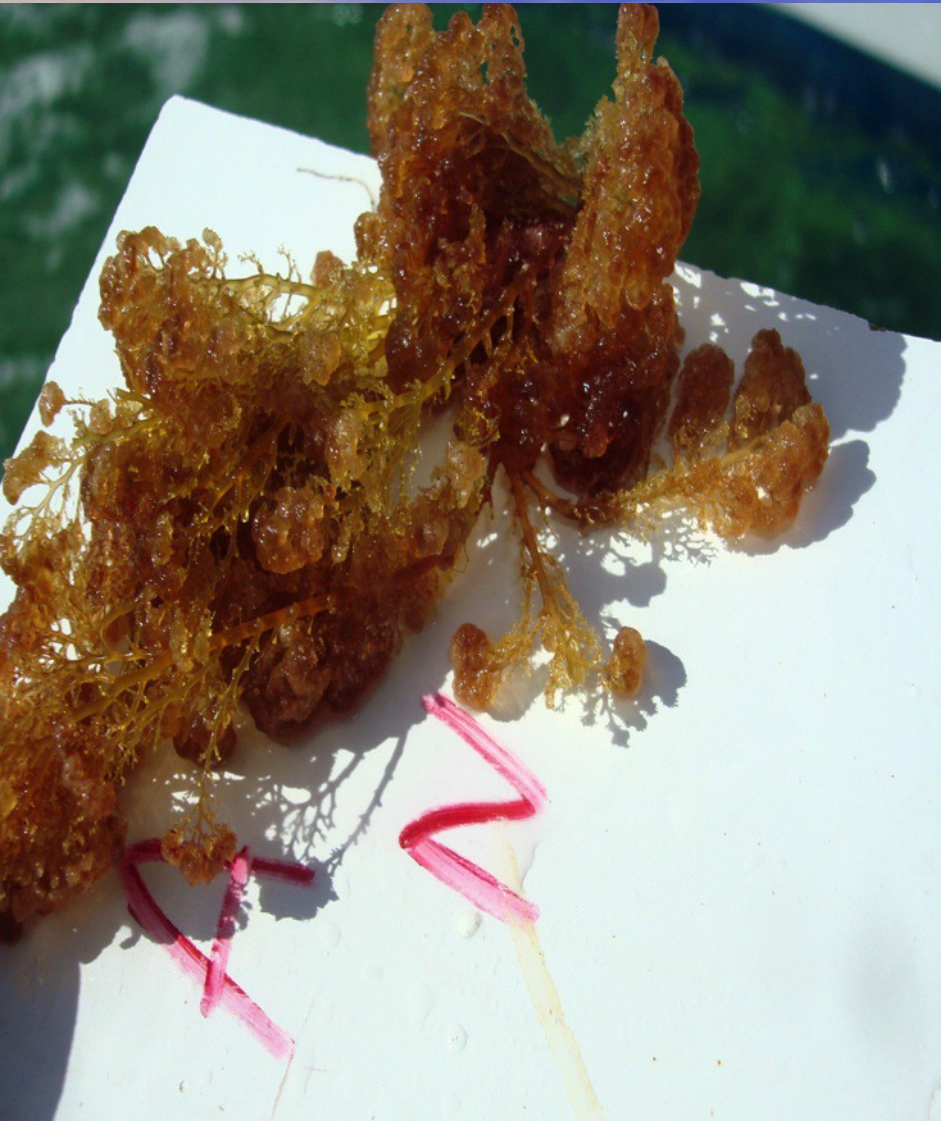
ALGAE IN GUANA CAY HARBOUR, NEXT TO TOWN, ARE PALE, INDICATING LOWER NUTRIENTS.



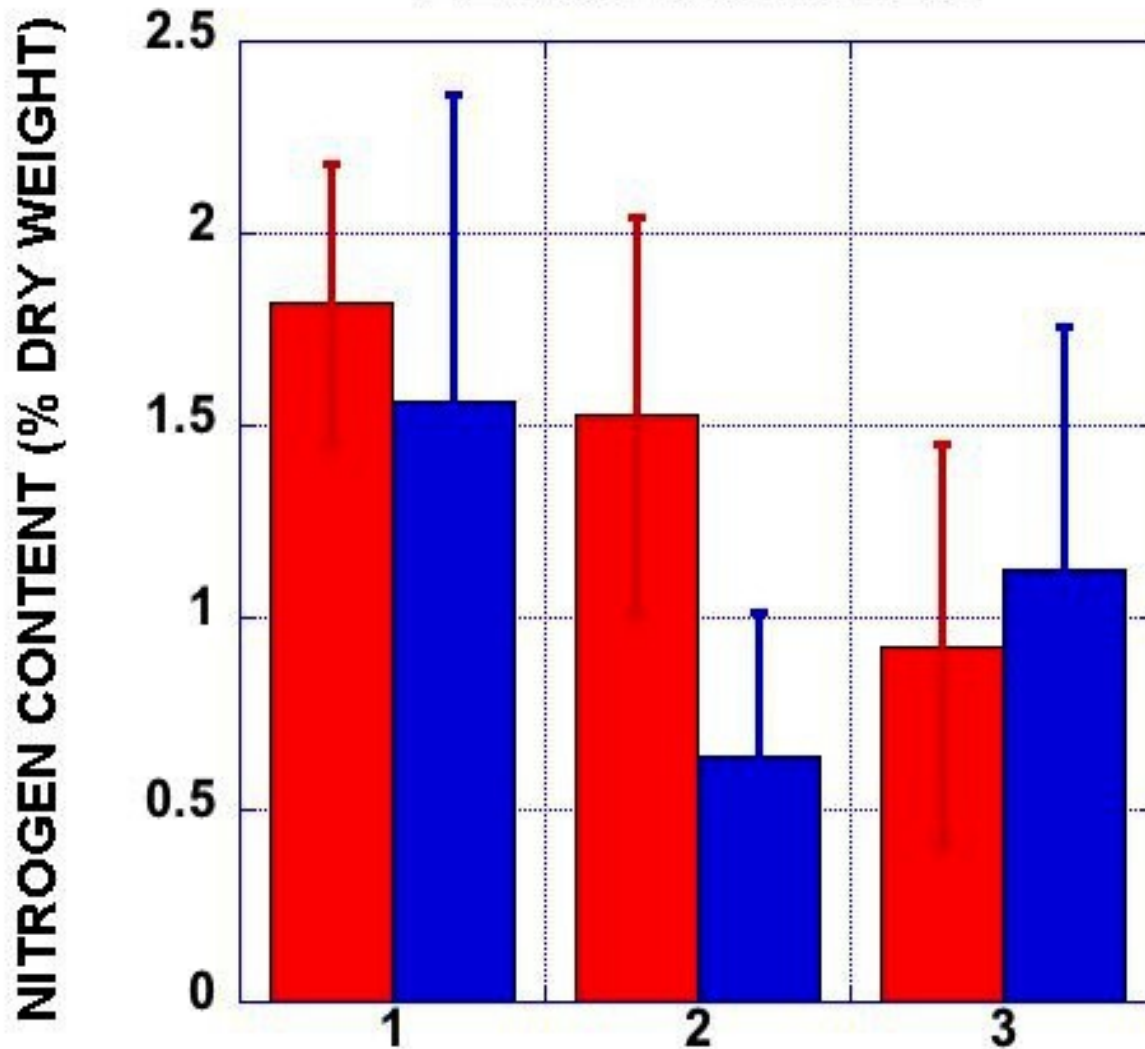
GREEN ALGAE HAVE MORE PIGMENT NEAR GOLF COURSE (LEFT) THAN AWAY FROM IT (RIGHT) INDICATING HIGHER NUTRIENTS



RED ALGAE HAVE MORE PIGMENT NEAR GOLF COURSE (LEFT) THAN AWAY FROM IT (RIGHT), INDICATING HIGH NITROGEN

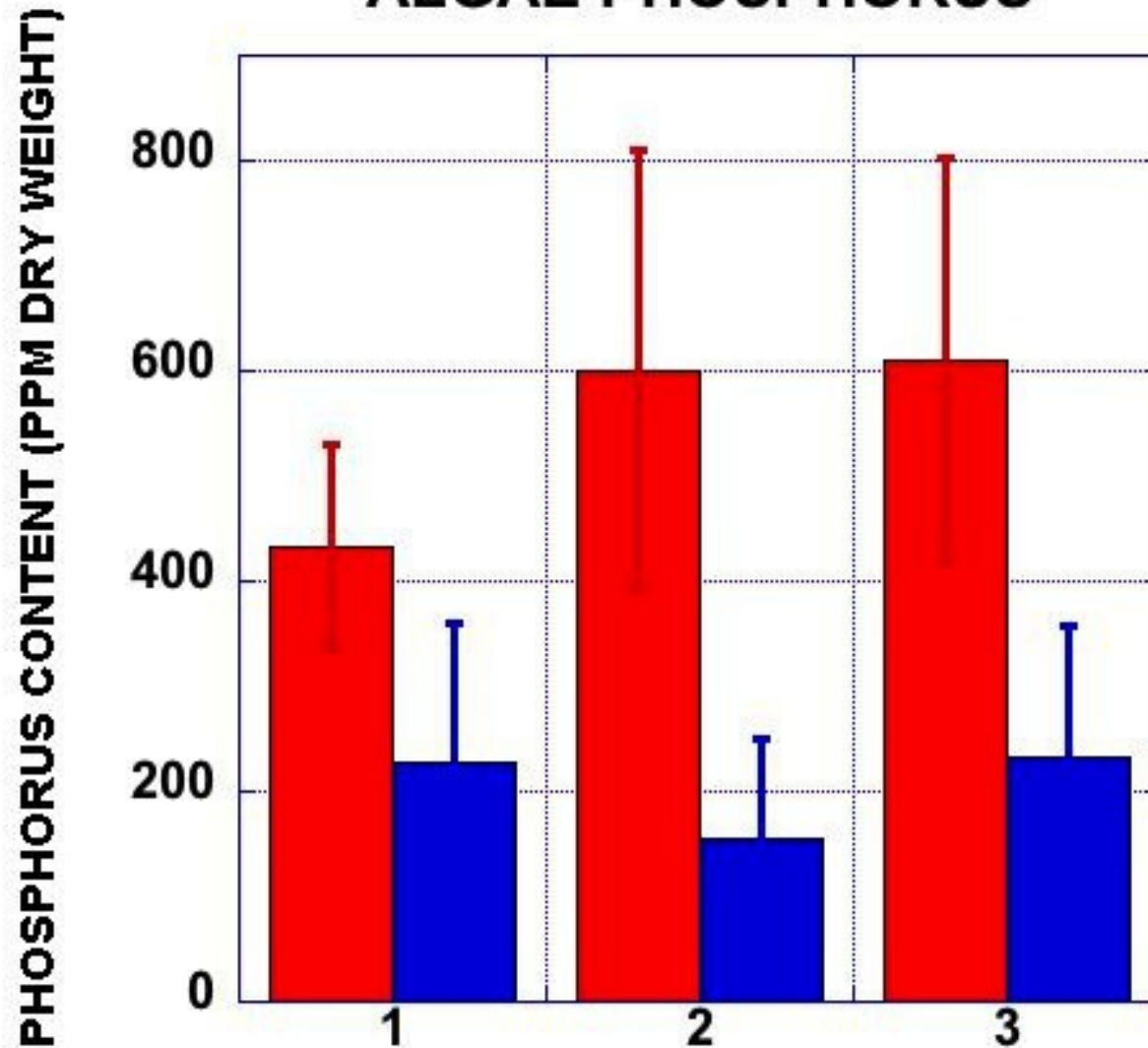


ALGAE NITROGEN



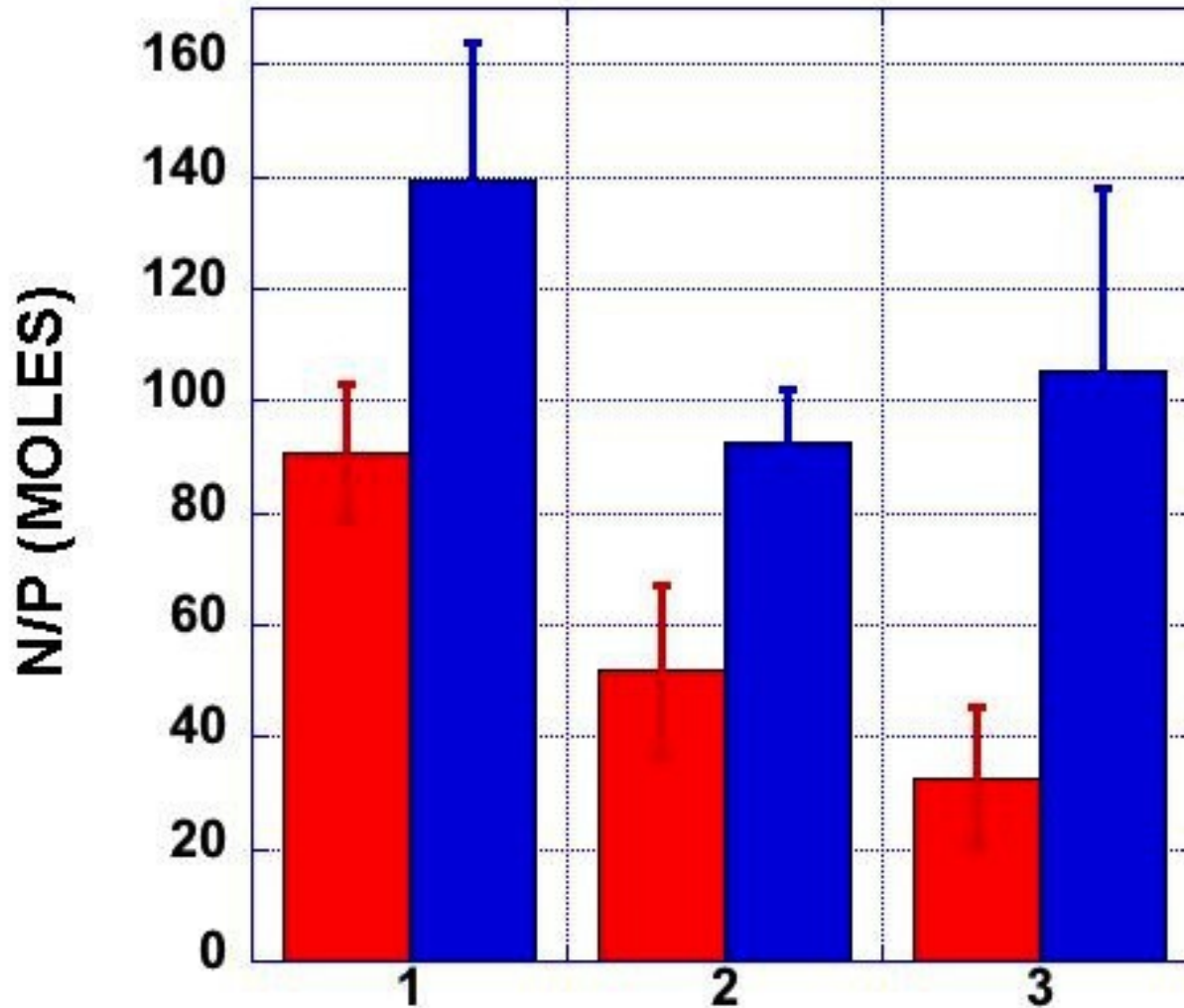
1: GOLF
COURSE

ALGAE PHOSPHORUS



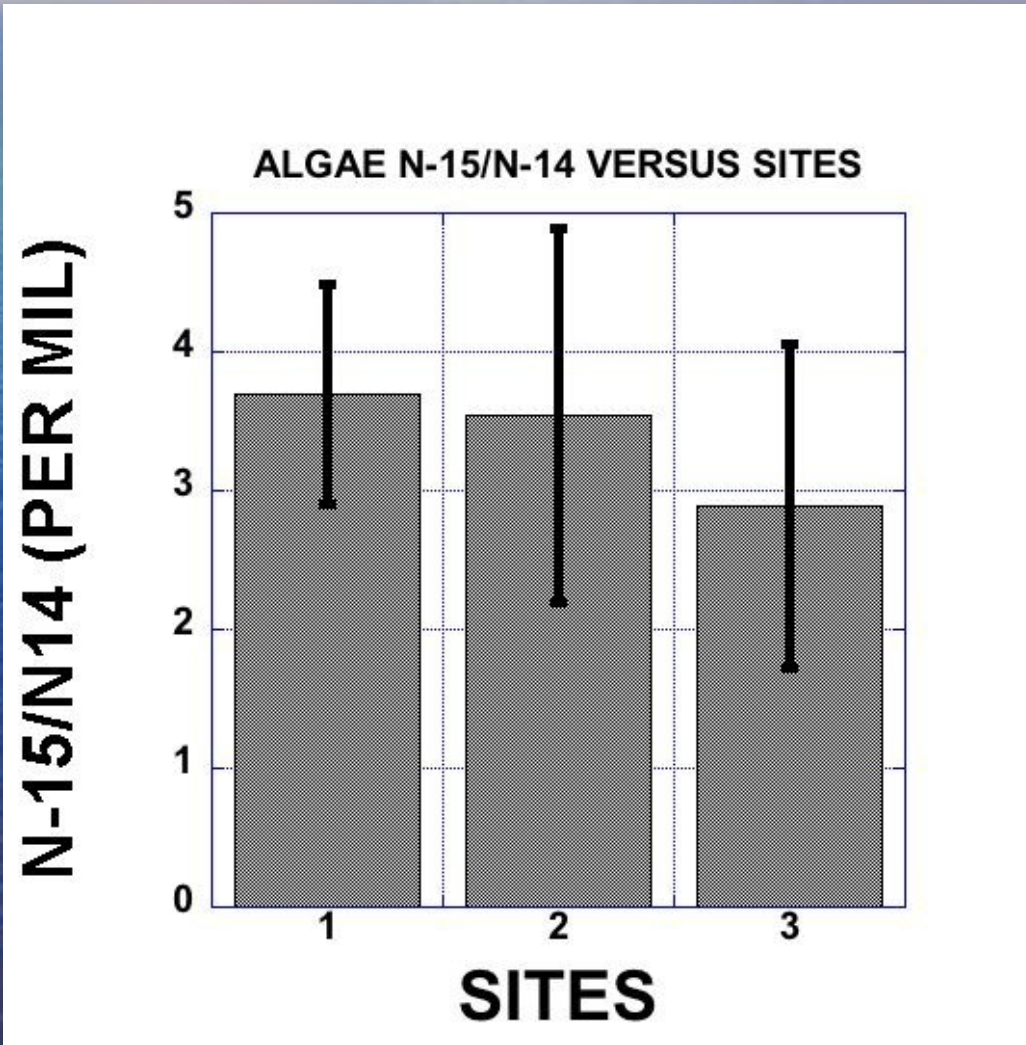
1: GOLF COURSE

NITROGEN TO PHOSPHORUS RATIO



1: GOLF
COURSE

**DRY SEASON NITROGEN ISOTOPE DATA (SHOWN)
INDICATES HIGHEST SEWAGE TYPE NITROGEN NEAR GOLF
COURSE, LEAST FURTHER AWAY. IN THE RAINY SEASON
THE RATIOS ARE LOWER, THAT IS TO SAY NATURAL
NITROGEN SOURCES PREDOMINATE.**



RAINY VERSUS DRY SEASONS

RAINY SEASON

- Slightly lower nitrogen
- Lower phosphorus
- More nitrogen limited
- Lower N-15 content
- More natural nitrogen
- More nitrogen cycling
- Less algae blooms

DRY SEASON

- Slightly higher nitrogen
- Higher phosphorus
- Near bloom conditions
- Higher N-15 content
- More sewage nitrogen
- Less nitrogen cycling
- More algae blooms

CLAIMS VERSUS DATA

BAKERS BAY CLAIMS

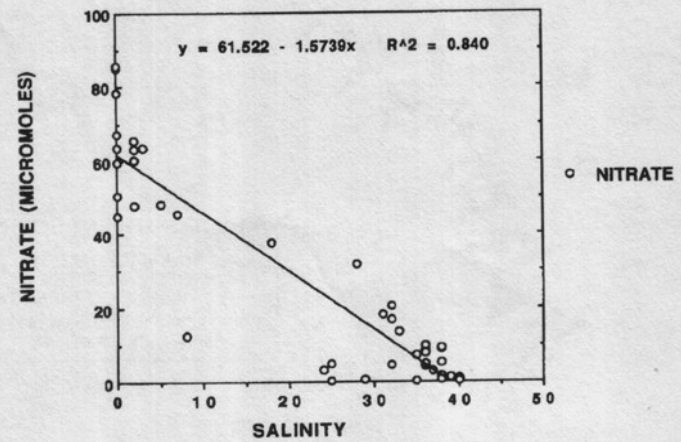
- NO ALGAE BLOOMS
- ALGAE BLOOMS ARE NATURAL
- ALGAE BLOOMS ALL OVER GUANA CAY
- CAUSED BY HURRICANES
- CAUSED BY SEWAGE
- NO FERTILIZER LEAKS INTO GROUNDWATER

REALITY

- ALGAE BLOOMS
- ALGAE BLOOMS CAUSED BY NUTRIENTS
- ALGAE BLOOMS NEAR NUTRIENT SOURCES
- DOES NOT FIT PATTERN
- BIGGEST BLOOMS, HIGHEST NITROGEN BY GOLF COURSE GREENS, NOT NEAR POPULATED AREAS

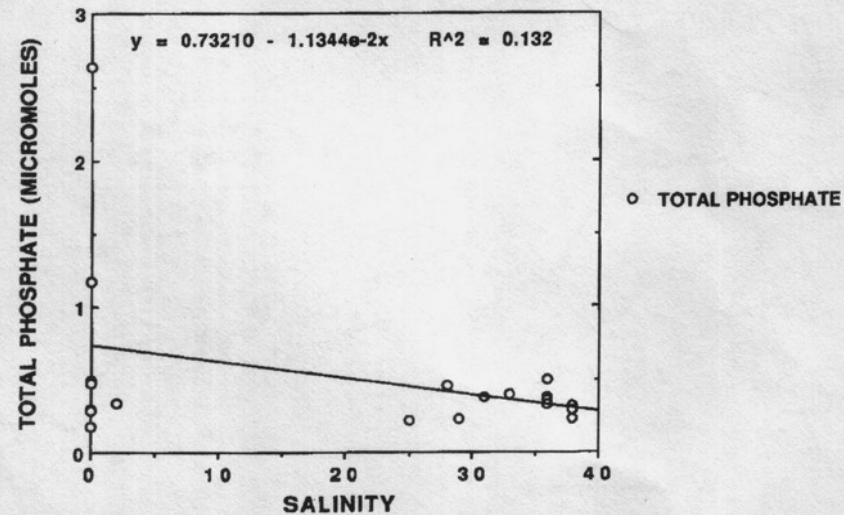
T. Goreau, 1994,
Coral reefs,
sewage, and
quality standards,
Proceedings of the
Caribbean Water
and Wastewater
Association
Conference, 3:98-
116

FIGURE 3



Nitrate concentrations along the north coast of Jamaica as a function of salinity. Nitrate is enriched in fresh water sources by around a hundred times over sea water values. Almost every measurement exceeds the critical level.

FIGURE 4



Total soluble reactive phosphate concentrations, including both orthophosphate and organophosphate, along the north coast of Jamaica as a function of salinity. Phosphate is only very weakly enriched in fresh water sources over marine values due to strong adsorption by limestone and soils. As a result direct sewage releases of phosphate to the coastal zone probably dominate over groundwater sources.

SEVERE EUTROPHICATION, NASSAU



CONCLUSIONS

- **GOLF COURSE FERTILIZERS CAUSE HARMFUL ALGAE BLOOMS**
- **APPEAR TO BE RELATED TO CORAL DISEASE**
- **DENSELY POPULATED AREAS ARE ALREADY EUTROPHIC**
- **MANY OTHERS ARE ON THE VERGE OF EUTROPHICATION**

RECOMMENDATIONS

- **GOLF COURSES SHOULD NOT BE LOCATED NEAR COASTAL CORAL REEFS**
- **MUCH BETTER MANAGEMENT OF FERTILIZER AND SEWAGE NUTRIENTS IS NEEDED TO PREVENT LARGE SCALE EUTROPHICATION**
- **ECOLOGICALLY SOUND WATER QUALITY STANDARDS ARE NEEDED**
- **THEY MUST BE RIGOROUSLY ENFORCED**