REPORT: Bonaire National Marine Park—Algal Survey and Inventory

Date: 12 December 2006
To: Ramon de Leon, Manager - Bonaire National Marine Park
P.O. Box 368, Bonaire - Netherlands Antilles

CC: Mike Smith, Conservation International
Larry J. Gorenflo, Conservation International
Paul C. Hoetjes, Senior Policy Advisor, MINA, Netherlands Antilles

From: D.S. Littler & M.M. Littler, Smithsonian Institution, Botany, NMNH

Purpose: Assess the Current Status of Bonaire’s Marine Reefs

The Littler’s team [including Barrett Brooks, Don Hurlbert, Barbara Watanabe and Larry Gorenflo (Conservation International)] traveled to the island of Bonaire, Netherlands Antilles (1 Nov 06 to 14 Nov 06). The purpose of this expedition was to assist the Ministry of Nature Affairs for the Netherlands Antilles (MINA) and the Center for Applied Biodiversity Science at Conservation International to assess the current status of Bonaire’s marine flora. The team collected over 300 specimens from the upper reef to a depth of 56 m. This assessment increased the known species reported from Bonaire by 35% (Appendix II, List of Species). The marine flora is typical of many Caribbean reefs with no specific areas of extremely high diversity or unique species composition. Also included in this evaluation are over 100 digital images (Appendix III), properly identified to the species level in most cases. These images may be used by managers in web sites, oral presentation, training manuals, brochures, etc., to make marine plant identification possible for Bonaire’s many divers, volunteers, conservationists or interested agencies.

The team surveyed the health of the reefs using key indicator species (recognized from our >30 continuous years of coral-reef research) in reference to the growing problems associated with eutrophication and overfishing along tropical and subtropical shorelines worldwide. The ecological responses of corals and macroalgae to nutrient enrichment and release from predation have been repeatedly cited as priority areas in need of further research (National Research Council, 2000; Littler & Littler 2006).

Fig 1. A. Acropora cervicornis debris from recent hurricanes showing only Millipora recruiting (Millipora can develop under elevated nutrient levels). B. Brain coral recruiting on Klein Bonaire.
Herbivory:

Bonaire's reefs seemed in excellent shape with respect to fish populations. Large numbers of herbivorous fishes occur at nearly all of the 21 sites surveyed. Fish population surveys directed by Bonaire National Marine Park personnel, with the many competent volunteers, should be continued and supported by the MINA as an important part of monitoring reef health.

Eutrophication:

The problem of eutrophication is of paramount importance to the economy of Bonaire, since the vast majority of tourists are divers. The Antilles government (presently funding our colleague Dr. Brian E. Lapointe to coordinate nutrient monitoring) and many in the local community are aware of the need to reduce the nutrient load to improve coral recruitment following the last several hurricanes, which destroyed most of the shallow coral populations (Figs. 1A). The devastated reefs are now turf-algal dominated, having lost sufficient levels of resiliency (likely due to cultural eutrophication) and are not likely to recover their former coral populations. Those tourists who only snorkel will be very disappointed, since the shallow reefs (above 10 m) are in extremely poor condition. The only shallow reefs remaining in a healthy condition are on the west side of the small offshore island, Klein Bonaire, with substantial recruitment of coral (Fig. 1B) and a high diversity of other organisms. The west coast of Klein Bonaire is the area most distant from anthropogenic effects of Bonaire proper. The deeper reefs (below 10 m) are still in relatively good health with abundant hard corals and gorgonians (Fig. 2A) dominating the seascape.
However, there is a disturbing abundance of dead and diseased coral (Fig. 3) at these depths, with Black Band (Fig. 3B) and Dark Spot (Fig. 3C) diseases being the most prevalent. These coral diseases are indicative of an overly stressed environment most likely due to high nutrient and/or sediment levels. The windward coast represents a vast wave-shocked habitat dominated by healthy stands of large rockweeds (e.g., *Sargassum, Turbinaria*, Fig. 2B). Most of the other sites surveyed were dominated by noxious Cyanobacteria (blue-green algae). This harmful bloom of unpalatable (chemically-defended) Cyanobacteria is smothering most other organisms (Figs. 4A, 4B) and occupying much of the available space (Fig. 2C), precluding settlement of desirable coral species.

![Fig 3. A. White Plague Disease caused by a bacterial pathogen. B. Black Band Disease caused by a consortium of microbial pathogens including Cyanobacteria. C. Dark Spot Disease, cause unknown.](image)

Our own published work in Belize (Littler et al., 2006) found that abundances of blue-green algae (Cyanobacteria) were significantly elevated by SRP (phosphates) in the Carrie Bow Cay Lagoon site, consistent with earlier findings (Miller et al., 1999). Cyanobacteria are considered harmful to coral-reefs and have increased in abundance and importance in association with world-wide coral-reef declines. Many blue-green algal species can fix atmospheric nitrogen and appear to be among the first to bloom when SRP concentrations are elevated above the universal 0.1 µM tipping-point level or when SRP:DIN (soluble reactive phosphate:dissolved inorganic nitrate) ratios increase in general. Therefore, the dominance of blue-green algae is often an indicator of SRP nutrient levels higher than the above mentioned tipping-point for coral resilience/recoverability. These elevated nutrient levels are most likely caused by groundwater incursions due to the lack of sewage treatment facilities on the island.
Recommendations:

We recommend immediate change to some form of centralized tertiary treatment facilities that will remove phosphates and nitrates before the water is discharged or reused. Since Bonaire is primarily a carbonate island, any nutrients not removed prior to release (e.g., secondary treatment) would again leach back into the shallow-water reef habitats. The effects of secondary treatment release would be little different from the present situation. Therefore, in our opinion, the removal of nutrients is of paramount importance to restoring Bonaire’s shallow reef habitats.

References cited:


APPENDIX - I
SUGGESTED MANAGEMENT STRATEGIES

See attached pdf files of the following articles


APPENDIX - II
LIST OF ALGAL SPECIES FROM BONAIRE BASED ON PAST RECORDS AND THE PRESENT EXPEDITION

APPENDIX - III
IMAGES OF ALGAL SPECIES COMMONLY FOUND ON BONAIRE'S REEFS
### APPENDIX - II

**LIST OF ALGAL SPECIES FROM BONAIRE BASED ON PAST RECORDS AND THE PRESENT EXPEDITION**

**CHLOROPHYTA (Green Algae)**

*Bold = new records*

<table>
<thead>
<tr>
<th>Species</th>
<th>Species</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acetabularia crenulata</td>
<td>Cladophoropsis macromeres</td>
</tr>
<tr>
<td>Acetabularia schenckii</td>
<td>Codium cf. repens</td>
</tr>
<tr>
<td><strong>Anadyomene saldanhae</strong></td>
<td><strong>Codium intertextum</strong></td>
</tr>
<tr>
<td>Anadyomene stellata</td>
<td>Codium isthmocladum</td>
</tr>
<tr>
<td>Avrainvillea asarifolia</td>
<td>Codium taylorii</td>
</tr>
<tr>
<td><strong>Avrainvillea levis f. translucens</strong></td>
<td>Dictyosphaeria cavernosa</td>
</tr>
<tr>
<td>Avrainvillea digitata</td>
<td>Dictyosphaeria vanbosseae</td>
</tr>
<tr>
<td>Avrainvillea longicaulis</td>
<td>Diplochaete solitaria</td>
</tr>
<tr>
<td>Avrainvillea nigricans</td>
<td>Enteromorpha cf. erecta</td>
</tr>
<tr>
<td>Avrainvillea rawsonii</td>
<td>Enteromorpha chaetomorphoides</td>
</tr>
<tr>
<td>Batophora oerstedii</td>
<td>Enteromorpha clathrata</td>
</tr>
<tr>
<td>Boodlea composita</td>
<td>Enteromorpha flexuosa</td>
</tr>
<tr>
<td>Boodleopsis pusilla</td>
<td>Enteromorpha lingulata</td>
</tr>
<tr>
<td>Bryopsis hypnoides</td>
<td>Enteromorpha plumosa</td>
</tr>
<tr>
<td>Bryopsis pennata</td>
<td>Enteromorpha prolifera</td>
</tr>
<tr>
<td>Bryopsis plumosa</td>
<td>Ernodesmis verticillata</td>
</tr>
<tr>
<td>Cladophoropsis membranacea</td>
<td>Halimeda copiosa</td>
</tr>
<tr>
<td>Caulerpa cupressoides</td>
<td>Halimeda simulans</td>
</tr>
<tr>
<td><strong>Caulerpa macrophysa</strong></td>
<td>Halimeda incrassata</td>
</tr>
<tr>
<td>Caulerpa mexicana</td>
<td>Halimeda opuntia</td>
</tr>
<tr>
<td>Caulerpa microphysa</td>
<td>Neomeris annulata</td>
</tr>
<tr>
<td>Caulerpa peltata</td>
<td>Neomeris mucosa</td>
</tr>
<tr>
<td>Caulerpa racemosa</td>
<td>Penicillus capitatus</td>
</tr>
<tr>
<td><strong>Caulerpa racemosa var occidentalis</strong></td>
<td>Penicillus pyriformis</td>
</tr>
<tr>
<td>Caulerpa sertularioides</td>
<td>Penicillus sp.</td>
</tr>
<tr>
<td><strong>Caulerpa serrulata</strong></td>
<td>Phaeophila dendroides</td>
</tr>
<tr>
<td>Caulerpa verticillata</td>
<td><strong>Phyllodictyon anastomosans</strong></td>
</tr>
<tr>
<td>Caulerpa vickersiae</td>
<td>Rhizoclonium hookeri</td>
</tr>
<tr>
<td><strong>Caulerpa webbiana</strong></td>
<td>Rhizoclonium kerneri</td>
</tr>
<tr>
<td>Chaetomorpha area</td>
<td>Rhizoclonium riparium</td>
</tr>
<tr>
<td>Chaetomorpha crassa</td>
<td>Rhizoclonium totuosum</td>
</tr>
<tr>
<td>Chaetomorpha gracilis</td>
<td>Struvea anastomosans</td>
</tr>
<tr>
<td>Chaetomorpha linum</td>
<td><strong>Udotea cyathiformis</strong></td>
</tr>
<tr>
<td>Chaetomorpha media</td>
<td>Udotea flabellum</td>
</tr>
<tr>
<td>Cladophora cf. brasiliana</td>
<td>Ulva fasciata</td>
</tr>
<tr>
<td>Cladophora cf. submarina</td>
<td>Ulva lactuca</td>
</tr>
<tr>
<td>Cladophora dalmatica</td>
<td>Ulva rigida</td>
</tr>
<tr>
<td>Cladophora jongiorum</td>
<td>Ulvella lens</td>
</tr>
<tr>
<td>Cladophora laelevirens</td>
<td>Valonia aegagropila</td>
</tr>
<tr>
<td>Cladophora prolifera</td>
<td>Valonia macrophysa</td>
</tr>
<tr>
<td>Cladophora socialis</td>
<td>Valonia ocellata</td>
</tr>
<tr>
<td>Cladophora vagabunda</td>
<td>Ventricaria ventricosa</td>
</tr>
</tbody>
</table>
PHEAOPHYTA (Brown Algae)

Chnoospora minima
Colpomenia sinuosa
Dictyopteris delicatula
Dictyota bartayresii
Dictyota cervicornis
Dictyota crispa
Dictyota (divaricata) mertensii
Dictyota (jamaicensis) crenulata
Dictyota dichotoma
Dictyota pfaffii
Dictyota pinnatifida
Dictyota (Dilophus) guineensis
Ectocarpus breviarticulatus
Ectocarpus rhodochortonoides
Feldmannia elachistaeformis
Feldmannia indica
Giffordia conifera
Giffordia duchasaingiana
Giffordia mitchelliae
Hydroclathrus clathratus
Lobophora variegata
Padina gymnospora
Padina sanctae-crucis
Padina spp.
Pseudolithoderma extensum
Rosenvingea sanctae-crucis
Sargassum cf. rigidulum
Sargassum hystrix
Sargassum polyceratium
Sargassum vulgare
Spatoglossum Schroederi
Sphacelaria furcigera
Sphacelaria novae-hollandiae
Sphacelaria rigidula
Sphacelaria tribuloides
Styopodium zonale
Taonia abbottiana
Turbinaria tricostata
Turbinaria turbinate

RHODOPHYTA (Red Algae)

Acanthophora spicifera
Acrochaetium microscopicum
Acrochaetium pulchellum
Aglaothamnion cf. furcellariae
Amphiroa brasilianna
Amphiroa fragilissima
Amphiroa hancockii
Amphiroa rigida var antillana
Amphiroa tribulus
Anotrichium tenue
Antithamnion antillarum
Antithamnion cruciatum
Asparagopsis taxiformis
Bostrychia binderi
Bostrychia scorpioides
Bostrychia tenella
Botryocladia caraibica
Botryocladia spinulifera
Bryothamnion triquetrum
Callithamnion byssoides
Callithamnion corymbosum
Caloglossa leprieurii
Catenella repens
Catenella caespitosa
Centroceras clavulatum
Ceramium byssoideum
Ceramium codii
Ceramium dawsonii
Ceramium gracillimum
Ceramium Leutzelburgii
Ceramium nitens
Ceramium tenerrimum
Champia parvula
Chondria collinsiana
Chondria curvilineaata
Chondria dasyphylla
Chondria sedifolia
Chondrophycus gemmifera
Chondrophycus papillosa
Chroodactylon ornatum
Coelothrix irregularis
Colaconema caespitiforme
Colaconema flexuosum
Colaconema netrocarpum
Colaconema seriatum
Cryptonemia cruciata
Cryptonemia sp.
Dasya cf. corymbifera
Dasya rigidula
Dasya spinuligera
Digenea simplex
Erythrotrichia cornea
Fosliella farinosa
Galaxaura comans
Galaxaura marginata
Galaxaura rugosa
Gametophyte Stage (squalida)
Galaxaura rugosa
Tetrasporophyte Stage
Ganoporella farinosa
Gelidiella acerosa
Gelidiella sanctarum
Gelidiopsis intricata
Gelidiopsis planicaulis
Gelidium pusillum
Goniolithon spectabile
Goniolithon strictum
Goniotrichum alsidii
Gracilaria damaecornis
Gracilaria foliifera
Gracilaria mammillaris
Grateloupia filicina
Griffithsia tenuis
Herposiphonia secunda
Herposiphonia tenella
Heterosiphonia crispella
Hydrolythion boergesenii
Hypnea cervicornis
Hypnea cornuta
Hypnea musciformis
Hypnea spinella
Hypneocolax stellaris
Jania adhaerens
Jania capillacea
Jania pumila
Jania rubens
Laurencia chondrioides
Laurencia coralloides
Laurencia intricata
Laurencia obtusa
Laurencia poiteaui
Lejolisia exposita
Liagora ceranoides
Liagora farinosa
Lithophyllum congestum
"Lithothamnion"
Lophosiphonia cristata
Melobesia spp.
Murrayella pericldos
Ochtodes secundiramea
Peyssonnelia boergesenii
Peyssonnelia conchicola
Peyssonnelia simulans
Peyssonnelia spp
Pleosporium caribaeum
Polysiphonia atlantica
Polysiphonia binneyi
Polysiphonia cf. subtilissima
Polysiphonia ferulae
Polysiphonia havanensis
Polysiphonia macrocarpa
Polysiphonia howei
Polysiphonia scopulorum var. villum
Polysiphonia subtilissima
Polysiphonia sphaerocarpa
Porolithon craspedium ?
Porolithon pachydermum
Pterocladiella capillacea
Pterocladiad americana
Pterocladiad bartletti
Pterocladiad pinnata
Pterocladiophila hemisphaerica
Spermothamnion investiens
Spyridia aculeata
Spyridia filamentosa
Taenioma perpusillum
Titanoderma sp
Tricleocarpa fragilis
Wrangelia argus
Wrangelia penicillata
Wurdemannia miniata
**CYANOBACTERIA (Blue Green Algae)**

Calothrix aeruginea  
Calothrix confervicola  
Chroococcus turgidus  
Dichothrix sp.  
Entophysalis deusta  
Hormothamnion enteromorphoides  
**Hydrocoleum sp.**  
Lyngbya aestuarii  
Lyngbya majuscula  
Lyngbya penicilliformis  
Lyngbya sordida  
Lyngbya semiplena  
Microcoleus chthonoplastes  
Microcoleus tenarrimus  
Oscillatoria nigro-viridis  
Phormidium corallyticum (Black band)  
Phormidium crosbyanum  
Phormidium hendersonii  
Polythrix corymbosa  
Symploca sp.

**Sea Grasses**

Halodule beaudetii  
Rhizophora mangle  
Thalassia testudinum  
Syringodium filiforme
Chlorophyta

Acetabularia crenulata 68517
Anadyomene saldanhae 68319

Avrainvillea digitata 68504 (11)
Avrainvillea levis f

Batophora oerstedii 68523
Caulerpa macrophysa (1)

Caulerpa racemosa 68315 (5)
Caulerpa sertularioides 68459

Caulerpa serulata 68467
Caulerpa webbiana 68596

Chaetomorpha linum 68333
Codium taylorii 68440

Dictyospheria cavernosa 68403
Ernodesmis verticillata 68377

Halimeda copiosa 68606 (4)
Halimeda incrassata (1)

Halimeda opuntia
Neomeris annulata 68429

Neomeris annulata 68475 (5)
Penicillus capitatus 68528

Phyllodictyon anastomosans 68312
Udotea cyathiformis 68466 (6)

Udotea flabellum 68524
Phaeophyta

Dictyopteris delicatula 68499
Dictyota bartayresiana 68421

Dictyota bartayresiana
Dictyota crispata 68498

Dictyota martensii 68511 (2)
Dictyota pulchella 68610 (5)

Dictyota sp
Lobophora variegata

Padina sp
Pseudolithodermam extensum 68593 (3)

Sargassum hystrix
Sargassum sp drift 3 (1)

Taonia abottiana 68492
Turbinaria tricostata 68417

Turbinaria turbinata 68445
Rhodophyta

Acanthophora spicifera 68379
Amphiroa brasiliana 68385

Amphiroa hancockii 68603
Bostrychia sp 68533 (4)

Botryocladia caraibica 68501
Botryocladia spinulifera 68350

Ceramium 68355
Ceramium nitens 2

Ceramium nitens
Chondrophyccus gemmifera 68530

Chondrophyccus papillosa 68392
Coelothrix irregularis

Copy of Galaxaura rugosa gametophyte 68412 b
Copy of *Galaxaura rugosa* tetrasporophyte 68414

Copy of *Ganonema farinosum* 68423 b
Galaxaura comans 68413

Galaxaura marginata 68329
Galaxaura rugosa gametophyte 68412 b

Galaxaura rugosa tetrasporophyte 68414
Ganonema farinosum 68423 b

Ganonema farinosum 68423
Hydrolithon boergesenii 68604

Hypnea musciformia 68358
Laurencia cf intricata 68476

Laurencia chondrioides 68581 a
Lithophylum congestum 68599

-Lithothamnion- ridge 1
Peyssonnelia simulans

Porolithon pachydermum
Pterocladiella capillacea 68380

Titanoderma sp with CLOD patch
Tricleocarpa fragilis 68487

Wrangelia argus 68391
Wrangelia penicillata
Cyanobacteria
Phormidium corallyticum - black band - 1

Phormidium corallyticum - black band - 3
Phormidium hendersonii 68453

Symploca sp
Seagrasses

Thalassia testudinum