

Investigation of an introduced
subtropical alga (*Lyngbya wollei*)
in Whiteshell Provincial Park, Manitoba

by

Ainslie J. Macbeth

A Thesis
Submitted to the Faculty of Graduate Studies
In Partial Fulfillment of the Requirements
For the Degree of

Master of Science

Department of Botany
University of Manitoba
Winnipeg, Manitoba

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Table of Contents

Acknowledgements	i
List of Figures	viii
List of Tables	xi
Abstract.....	xiv
Chapter 1: Introduction.....	1
1.1 Objectives	2
1.2 Hypotheses	2
Chapter 2: Literature Reviews	3
2.1 <i>Lyngbya wollei</i>	3
2.11 Introduction.....	3
2.12 Taxonomy	3
2.13 Morphology	6
2.14 Ecological Adaptation.....	6
2.15 Management Techniques	13
2.16 Summary.....	15
2.2 <i>Whiteshell Provincial Park</i>	16
2.21 Geography & Geology	16
2.22 Whiteshell Development	17
2.23 Current Whiteshell	18
2.24 Economic Resources.....	23
2.25 Infestation Related Practices in Whiteshell Provincial Park	24
2.3 <i>Paleolimnology</i>	26
2.31 Introduction.....	26
2.32 Sediment Sources	26
2.33 Sediment Composition and Deposition	27

2.34 Lake productivity	28
2.35 Whiteshell Sediment Geochemistry	31
Chapter 3: Methods and Materials	35
3.1 <i>Lyngbya wollei</i>	35
3.11 Study Area	35
3.12 Study Organism	35
3.13 <i>Lyngbya wollei</i> Distribution	42
3.14 <i>Lyngbya wollei</i> Biomass	44
3.15 <i>Lyngbya wollei</i> Desiccation Experiments	45
3.16 <i>Lyngbya wollei</i> Toxicology	47
3.2 <i>Water Sampling</i>	48
3.21 Water Sampling 2002	48
3.22 Water Sampling 2003	54
3.3 <i>Sediment Core Collection</i>	57
3.31 Coring and Core Processing	57
3.32 Core Collection	58
3.33 Core Subsampling	62
3.34 Sediment Geochemistry	62
3.35 Water, Organic Matter and Carbonate Content	62
3.36 Chlorophyll Analysis	64
3.37 Sediment Dating	66
3.4 <i>Whiteshell Environmental Quality</i>	66
3.41 Whiteshell Resident Survey 2002	66
3.42 Enumeration of Whiteshell Development	67
3.43 Recreational Boating	68

3.5 <i>Statistical Analysis</i>	70
3.51 Univariate Statistical Analysis	70
3.52 Multivariate Statistical Analysis	70
Chapter 4: Results	74
4.1 <i>Lyngbya wollei</i>	74
4.11 Distribution	74
4.12 Biomass	77
4.13 Desiccation Experiments	79
4.2 <i>Water Chemistry 2003</i>	79
4.21 Photosynthetically Active Radiation	81
4.3 <i>Statistical Analysis of Group 12</i>	81
4.31 Intensity of Land-Use	81
4.32 Lake Morphology	88
4.33 Water Chemistry: Summer 2002	88
4.34 Group 12 Summary	89
4.4 <i>Statistical Analysis of Group 13</i>	89
4.41 Water Chemistry: July 2002	89
4.42 Water Chemistry: Winter 2002 - 2003	92
4.43 Sediment Chemistry	92
4.44 Group 13 Summary	95
4.5 <i>Sediment Geochemistry</i>	97
4.51 Description of Whiteshell Cores	97
4.52 Sediment Composition	97
4.52-1 Barren Lake	97
4.52-2 Betula Lake	100
4.52-3 Brereton Lake	100
4.52-4 Caddy Lake	101

4.52-5 Florence Lake	101
4.52-6 Hunt Lake	101
4.62-7 Jessica Lake	102
4.52-8 Madge Lake	102
4.52-9 Marion Lake	106
4.52-10 Red Rock Lake	106
4.52-11 Shirley Lake	106
4.52-12 Star Lake	110
4.52-13 White Lake	110
4.53 Sediment Dating	110
4.54 Sediment Geochemistry Introduction	113
4.55 Nutrients	113
4.55-1 Total Kjeldahl Nitrogen	113
4.54-2 Phosphorus	116
4.55-3 Iron and Manganese	116
4.55- 4 Iron	116
4.55-5 Manganese	120
4.55-6 Available Phosphorus	120
4.55-7 Calcium	120
4.55-8 Boron.....	127
4.56 Non-essential Heavy Metals	127
4.56-1 Arsenic	127
4.56-2 Cadmium	134
4.56-3 Lead	134
4.56-4 Mercury	134
<i>Results Summary</i>	137

Chapter 5: Discussion	140
5.1 Objective 1	140
5.11 <i>Lyngbya wollei</i> Distribution	140
5.12 <i>Lyngbya wollei</i> Inoculation Source	144
5.13 <i>Lyngbya wollei</i> Inter-Lake Transfer	147
5.2 Objective 2	148
5.21 Land-Use Intensity	148
5.22 Lake Morphology	149
5.23 Water Chemistry	149
5.24 Sediment Chemistry	151
5.25 Multivariate Statistical Analysis Summary	152
5.26 Bulk Sediment Composition: Loss on Ignition	153
5.27 Sediment Dating	154
5.28 Sediment Geochemistry	155
5.29 Sediment Geochemistry: Nutrients & Heavy Metals	156
5.3 Comparison Between Whiteshell and American <i>L. wollei</i> Infestations	161
Chapter 6: Conclusions	163
Chapter 7: Recommendations	165
7.1 Recommendations for Researchers	165
7.2 Recommendations for Managers	167
7.3 Recommendations for Cottagers	169
Chapter 8: Literature Cited	170
Chapter 9: Appendix	177

List of Figures

1A.	Whiteshell Provincial Park map showing Betula, White, Jessica and Red Rock Lakes. Labeled lakes were sampled monthly in 2002	36
1B.	Whiteshell Provincial Park map showing Big Whiteshell and Green Lakes. Labeled lakes were sampled monthly in 2002	37
1C.	Whiteshell Provincial Park map showing Brereton Lake. Labeled lake was sampled monthly in 2002	38
1D.	Whiteshell Provincial Park map showing intensive-use and backcountry lakes. Labeled lakes were sampled monthly or in July (*) in 2002	39
1E.	Whiteshell Provincial Park map showing the Mantario Wilderness Area. Labeled lakes were sampled monthly or in July (*) in 2002	40
2.	Betula Lake water sampling sites and <i>L. wollei</i> distribution	49
3.	White Lake water sampling sites and <i>L. wollei</i> distribution	50
4.	Barren Lake water sampling site	51
5.	Big Whiteshell Lake water sampling site	51
6.	Brereton Lake water sampling site	51
7.	Caddy Lake water sampling sites	51
8.	Falcon Lake water sampling site	52
9.	Green Lake water sampling site	52
10.	Hunt Lake water sampling site	52
11.	Jessica Lake water sampling sites	52
12.	Red Rock Lake water sampling site	53
13.	Star Lake water sampling site	53
14.	Schematic diagram of a modified Kajak-Brinkhurst miniature gravity coring system	63
15.	Mean oxygen evolution by <i>L. wollei</i> treatments in July desiccation experiment...	85

16.	Mean oxygen evolution by <i>L. wollei</i> treatments in August desiccation experiment	87
17.	Correspondence analysis ordination biplot showing lake associations based on intensity of land-use variables	91
18.	Correspondence analysis ordination biplot of lake morphology parameters	93
19.	Principal component analysis ordination biplot of mean monthly water chemistry from 2002	94
20.	Principal component analysis ordination biplot of July 2002 water chemistry	96
21.	Principal component analysis ordination biplot of winter water chemistry	98
22.	Principal component analysis ordination biplot of current sediment chemistry	99
23.	Loss on ignition of bulk sediment composition for Barren Lake	104
24.	Loss on ignition of bulk sediment composition for Betula Lake	105
25.	Loss on ignition of bulk sediment composition for Brereton Lake	107
26.	Loss on ignition of bulk sediment composition for Caddy Lake	108
27.	Loss on ignition of bulk sediment composition for Florence Lake	109
28.	Loss on ignition of bulk sediment composition for Hunt Lake	111
29.	Loss on ignition of bulk sediment composition for Jessica Lake	112
30.	Loss on ignition of bulk sediment composition for Madge Lake	114
31.	Loss on ignition of bulk sediment composition for Marion Lake	115
32.	Loss on ignition of bulk sediment composition for Red Rock Lake	117
33.	Loss on ignition of bulk sediment composition for Shirley Lake	118
34.	Loss on ignition of bulk sediment composition for Star Lake	119
35.	Loss on ignition of bulk sediment composition for White Lake	121

36.	Sediment accumulation rates for three Whiteshell sediment cores over 150 years of deposition	126
37.	Sediment total kjeldahl nitrogen concentration profiles for 13 Whiteshell Lakes	132
38.	Sediment phosphorus concentration profiles for 13 Whiteshell Lakes	133
39.	Sediment iron concentration profiles for 13 Whiteshell Lakes	135
40.	Sediment manganese concentration profiles for 13 Whiteshell Lakes	136
41.	Sediment available phosphorus concentration profiles for 13 Whiteshell Lakes	138
42.	Sediment calcium concentration profiles for 13 Whiteshell Lake	139
43.	Sediment boron concentration profiles for 13 Whiteshell Lakes	141
44.	Sediment arsenic concentration profiles for 13 Whiteshell Lakes	142
45.	Sediment cadmium concentration profiles for 13 Whiteshell Lakes	143
46.	Sediment lead concentration profiles for 13 Whiteshell Lakes	145
47.	Sediment mercury concentration profiles for 13 Whiteshell Lakes	146

List of Tables

1.	Inaccurate taxonomic classifications of <i>Lyngbya wollei</i> Farlow ex Gomont (Speziale and Dycke 1992)	4
2.	District vehicle entry between May and September 2003. Number of annual and casual Provincial Park Passes sold in each district	19
3.	Number of cottages, seasonal and transient campsites on 12 Whiteshell lakes	20
4.	Summary of public beach and boat launch facilities on 12 Whiteshell lakes. Maximum number of visitors, unknown visitor numbers (-) and lakes with no public beaches (n/a) were recorded	21
5.	Summary of historic waste disposal sites throughout the Whiteshell most of which are presently inactive (Karp 1987)	22
6.	Whiteshell Provincial Park land use zones and recreational activities permitted (Y) or prohibited (N) (The Whiteshell Master Plan: Summary Report August 1983) 41	
7.	Inventory of lakes sampled in 2002, monthly (M) or in July (J).	43
8.	A. Water sampling parameters for 2002	55
	B. Water sampling parameters for 2003	56
9.	A-C Summary information on sediment cores extracted from 13 Whiteshell lakes. Sediment cores dated (*) are indicated	59-61
10.	Sediment chemistry parameters measured in sediment cores collected in 2002 and 2003	65
11.	Number of campsites, washroom and sewage facilities at campgrounds located at 12 intensively studied lakes current to 2003. Some lakes without campground facilities (-)	69
12.	Morphological parameters and shoreline (D_L) and volume (D_V) development indexes for 12 intensively studied Whiteshell lakes	71
13.	Inventory of recreational activities for 12 intensively studied Whiteshell lakes	72

14.	Survey of origin, destination and type of watercraft brought to the Whiteshell by visitors camping at Betula, White and Brereton lakes	73
15.	Estimated number of motorized and non-motorized watercraft extrapolated from the Whiteshell resident survey. Percent of survey respondents with visitors who bring boats to the Whiteshell and there origin	75
16.	Number of boats launched or returned at public boat launches between 8 am and 6 pm on August 2, 2003	76
17.	Summary of lakes included in Group 12 and Group 13	78
18.	Photic depth of 12 Whiteshell lakes measured between July 15-22, 2003	80
19.	Filamentous algae genera collected from four Whiteshell lakes, which appear morphologically similar to <i>Lyngbya wollei</i>	82
20.	<i>L. wollei</i> dry weight harvested by SCUBA divers with 0.46 m ² quadrats along transects at 10 and 20 meters on July 30, 2003	83
21.	A: July Desiccation experiment ANOVA table. B: July 23, 2003 Desiccation Experiment treatment oxygen evolution	84
22.	A: August 18, 2003 Desiccation Experiment ANOVA table B: August 18, 2003 Desiccation Experiment treatment oxygen evolution	86
23.	Intensity of land-use parameters used to examine Group 12 using Correspondence Analysis. Variables were counted or calculated based on Whiteshell Resident 2002 Survey (*).....	90
24.	Summary of Loss on Ignition parameters for 13 Whiteshell sediment cores.....	103
25.	Sediment chronologies for Betula Lake calculated based on Constant Flux Model. Samples which were not dated are designated by n/a	122
26.	Sediment chronologies for White Lake calculated based on Constant Flux Model	123
27.	Sediment chronologies for Madge Lake calculated based on Constant Flux Model. Samples which were not dated are designated by n/a	124

28.	Sediment chronology summary for Betula, White and Madge Lakes	125
29.	A-B: Macronutrient mean (minimum and maximum) concentrations for 13 Whiteshell sediment cores	128
	C-D: Micronutrient mean (minimum and maximum) concentrations for 13 Whiteshell sediment cores	129
	E-F: Non-essential heavy metal mean (minimum and maximum) concentrations for 13 Whiteshell sediment cores.....	130
30.	Summary of the total number of mean macronutrients, micronutrient, heavy metal and element concentrations for 12 Whiteshell lakes which are significantly different from Betula Lake sediment.....	131

Abstract

Nuisance growth of a filamentous cyanobacterium, *Lyngbya wollei*, was studied in lakes of Whiteshell Provincial Park in eastern Manitoba. Its increasing abundance in two lakes, White and Betula, over the last half dozen years has heightened awareness and concern by cottagers and recreational users that nearby lakes may become infested. *L. wollei* is typically found in the southeastern United States, and this is the only known occurrence in Canada. Desiccation experiments used to assess the ability of *L. wollei* to survive inter-lake transfer on recreational watercraft showed it can remain viable after short-term drying and stagnant conditions. Comparisons of lake basin morphology, land use, water and sediment chemistry of the infested lakes to those of other Whiteshell lakes showed that all lakes with shallow littoral areas and a photic depth greater than two and a half meters possess potential *L. wollei* habitat. Intensively used lakes such as Falcon, Caddy, Brereton, and Big Whiteshell are most susceptible to *L. wollei* inoculation. Principle Component Analysis based on water and sediment chemistry identified Jessica, Red Rock, Florence, and Madge Lakes as having the most similar conditions to the infested lakes. Consequently, these lakes may develop the greatest biomass and adverse effects of *L. wollei* growth. It is imperative that all clothing, footwear and recreational watercraft be cleaned thoroughly after being removed from infested lakes to prevent the further spread of *L. wollei* in the lakes of Whiteshell Provincial Park.

Chapter 1: Introduction

As humans become more mobile, moving efficiently around the globe, so do flora and fauna. Exotic species invade habitats where they do not naturally occur and often decrease both the abundance and diversity of native species in the invaded community (Buchan and Padilla 2000). This alters the system's natural biodiversity and community structure. Currently, exotic species constitute 10-30 % of the flora in most regions and, once established, are often impossible to eradicate (Buchan and Padilla 2000). As a result, inoculation must be minimized through the identification and protection of areas vulnerable to invasion.

L. wollei is a large, filamentous, mat forming cyanobacterium that has become common in lentic ecosystems in the Southeastern United States. At the time of this writing Lake Itasca in Minnesota is the most northerly known location of *L. wollei* in the United States. In Canada, *L. wollei* has been identified in two Whiteshell lakes, Betula and White. Presently, these infestations represent the only known occurrence of *L. wollei* in Canada. Recent *L. wollei* growth observed in the infested lakes and its occurrence around developed areas with cottages, resorts, campgrounds and public boat launches, suggest this is an exotic species introduced to the Whiteshell.

Like other exotic species, *L. wollei* is an opportunistic species out-competing most interspecific competitors once established in an aquatic system. Thick, dense mats proliferate on the bottom of littoral areas impeding swimming, boating and other recreational activities. Additionally the production of geosmin and neurotoxins analogous to those which cause paralytic shellfish poisoning may pose a health concern for all users (Carmichael *et al.* 1997). As a result, *L. wollei* infestations result in recreational, ecological and economic loss of affected lakes (Speziale *et al.* 1991).

Whiteshell Provincial Park encompasses 131 lakes (Schneider 2002). The Whiteshell has historically been an important recreational area facilitating activities such as swimming, boating and fishing. Betula and White Lakes have active water skiing clubs which were

established in 1950 and 1963 respectively. These are the only two Whiteshell lakes with ski clubs. Historically boats used in water skiing competitions were moved around the continent for competitions. If *L. wollei* is transported between lakes by recreational watercrafts it is imperative that other Whiteshell lakes are protected from *L. wollei* inoculation.

This thesis marks the beginning of the investigation, identification and monitoring of *L. wollei* infestations in Whiteshell Provincial Park. The research presented here may be used to aid future research endeavors so that Whiteshell lakes may continue to provide recreational opportunities for future generations.

1.1 Objectives

1) The primary objective of this study was to examine the distribution and inoculation source of *L. wollei* in Whiteshell Provincial Park.

2) The second objective of this study was to investigate why Betula and White Lakes are the only known Whiteshell lakes with *L. wollei* infestations. The infested lakes were compared to other Whiteshell lakes based on land-use parameters, lake morphology, water and sediment chemistry.

1.2 Hypotheses

1) I hypothesize that recreational watercraft moved between infested water bodies in the United States and the Whiteshell resulted in the infestation of Betula and White Lakes. Current boat movement between these infested lakes and other Whiteshell lakes may put other waterbodies in the Whiteshell and throughout North America at high risk for infestation.

2) I hypothesize that Betula and White Lakes are unique from other Whiteshell lakes, with certain parameters which enable *L. wollei* to proliferate. Unique parameters may include high concentrations of calcium and phosphorus, which are known to be growth limiting nutrients. If Betula and White Lakes do not prove to be unique from other Whiteshell lakes based on land-use, lake morphology, water or sediment chemistry then we may use the data to predict other similar Whiteshell lakes which may be susceptible to *L. wollei* inoculation and infestation.

Chapter 2: Literature Review

2.1 *Lyngbya wollei*

2.11 Introduction

In the southeastern United States, a nuisance mat-forming cyanobacterium impedes the recreational, economic and aesthetic value of infested aquatic systems (Speziale *et al.* 1991). Recent taxonomic investigation by Speziale and Dyck (1992) classified the nuisance species as *Lyngbya wollei* Farlow ex Gomont comb. nov. Classification has enabled consistent communication and biological understanding of *L. wollei*. Investigation of its ecological and biochemical characteristic has resulted in a better understanding of this opportunistic species. *L. wollei* possesses both morphological and physiological characteristics, that give it a competitive advantage over other species. Consequently, aquatic systems can become dominated by *L. wollei* with associated biomass reaching as high as 1.0 – 1.5 kg dry weight m⁻² (Beer *et al.* 1986). The nuisance potential of *L. wollei* makes it crucial to focus on management techniques so that this species no longer limits the use of the reservoirs, lakes and ponds which it currently infests.

2.12 Taxonomy

In the last three decades infestations of a recently described and exceptionally large filamentous cyanobacterium have become increasingly common in the Southeastern United States. Although there have been consistent descriptions of this organism it has been identified as six different species within three genera (Table 1) (Speziale and Dyck 1992). Proper identification of this nuisance organism is crucial for consistent communication and biological understanding. Traditionally cyanobacteria have been taxonomically classified by the International Code of Botanical Nomenclature (ICBN₁). This system is primarily used for eukaryotic organisms. Some researchers believe that cyanobacteria, with their prokaryotic habit, would be more accurately classified by the rules of the International Code of Bacteriological Nomenclature (ICBN₂) (Rippka *et al.* 1979). The discrepancies in the

Table 1: Inaccurate taxonomic classifications of *Lyngbya wollei* Farlow *ex* Gomont (Speziale and Dyck 1992).

Proposed Taxonomic Classification	Author(s) cited
<i>Microcoleus lyngyaceus</i>	(Kutzing) Crouan <i>sensu</i> Drouet
<i>Plectonema wollei</i>	Farlow <i>et</i> Gomont
<i>Lyngbya magnifica</i>	Gardner
<i>Lyngbya majuscula</i>	Harvey <i>ex</i> Gomont
<i>Lyngbya birgei</i>	Smith
<i>Lyngbya latissima</i>	Prescott

identification of this cyanobacterium appear to be the result of concurrent use of the two classification systems by different groups of researchers. Use of the ICBN₂ with cyanobacteria is based on a limited number of strains, and therefore receives limited support (Speziale and Dyck 1992).

The use of the ICBN₁ is also problematic. Grietler sub-divided the family Homogoneae into two sub-families using this system. Sub-division was based on the occurrence of heterocysts and presence of false branching (Speziale and Dyck 1992). The family Oscillatoriaceae is composed of taxa, that lack heterocysts and have simple filaments. *Lyngbya*, although occasionally having false branches, was placed in this family. *Plectonema* was placed in the sub-family Scytonemataceae due to characteristic false branching, even though it lacked heterocysts. Since both genera lack heterocysts the division was ultimately based on the occurrence of false branching. Speziale and Dyck (1992) proposed that false branching is a taxonomically invalid method of classification because it can result from environmental modification.

In contrast to *Plectonema*, *Lyngbya* does not put undo emphasis on the environmentally variable false branching characteristic. Therefore Speziale and Dyck (1992) has proposed that *Lyngbya* is the most accurate genus classification of the nuisance organism. Designation of the specific epithet was based on the elimination of previously applied taxonomic classifications. *Lyngbya birgei* is a planktonic species, which does not form floating masses. The nuisance organism differs from the marine species *Lyngbya majuscula* both in size and it has a limited halotolerance. *Lyngbya latissima* and *Lyngbya magnifica* are acknowledged synonyms for *Plectonema wollei*. *Plectonema wollei* is accurate in the description of the nuisance organism yet it puts strong emphasis on false branching. As a result, the nuisance organism has been classified as *Lyngbya wollei* Farlow ex Gomont comb. nov (Speziale and Dyck 1992).

2.13 Morphology

Speziale and Dyck (1992) identified a specimen type based on morphological variation found in *L. wollei* specimens. *L. wollei* cells are defined as discoid in shape having a diameter of 24-65 μm . Cells vary in length from 2-12 μm . The cells are arranged into uniseriate filaments, which are encased by a hyaline, lamellate sheath up to 12 μm thick. The filaments are indeterminate in length and can exceed 40 cm in length. False branching may result from protrusion through lateral breaks in the sheath. These filaments produce an entangled mat of sparsely branched filaments. Mats are vertically stratified occurring throughout the water column in the summer (Speziale *et al.* 1991). The subsurface filaments are photosynthetically active, rich in phycobilin and as a result are blue black in color. Surface filaments are photosynthetically inactive and they are yellow – orange in colour, as a result of the high carotenoid content and bleached chlorophyll and phycobilin (Speziale and Dyck 1992). *L. wollei* is a perennial species, which overwinters as a benthic mat. *L. wollei* has no specialized reproductive or overwintering structures such as akinetes. All biomass produced throughout the water column accumulates as a benthic mat which functions as a base stock for re-infestation in the following growth season. Heterotrophic *L. wollei* filaments buried in the benthos are living and viable (Speziale *et al.* 1991). As a result these filaments may function as inoculum for subsequent growth (Head *et al.* 1999).

2.14 Ecological Adaptation

In any ecological system species assemblage is determined by the chemical and physical characteristics of the environment (Kohler and Hoeg 2000). In *L. wollei* dominated habitats these characteristics have been investigated to identify optimal growth conditions. Water conductivity and alkalinity were found to account for 55% of the variability in *L. wollei* biomass (Cowell and Botts 1994). Limited halotolerance suggests that *L. wollei* is a freshwater species. *L. wollei* is a stenohaline species with a strong preference for freshwater, showing negative growth at all salinities between 0 and 35 ppt by the loss of cells. At salinities of 17.5ppt and above, rapid death of the organism occurs (Cowell and Botts 1994). Optimal

growth of *L. wollei* occurs in water of pH 8 (Cowell and Botts 1994). It may be concluded that *L. wollei* is sensitive to acidity and grows optimally in an alkaline environment. In contrast, at pH 4 there was negligible growth (Tubea *et al.* 1981). *L. wollei* has been identified most commonly in the southwestern United States in freshwater lentic ecosystems with these characteristics. Lakes, ponds and reservoirs may all be affected.

Alkalinity reflects the predominant form of inorganic carbon present in the water body and thus is an essential component in understanding the niche of *L. wollei*. Photosynthetic activity of *L. wollei* results in diel fluctuations in dissolved inorganic carbon (DIC) (Beer *et al.* 1990). In initial hours of photosynthesis, CO₂ concentrations are depleted to negligible levels. The water pH increases and consequently increases the bicarbonate concentration (Beer *et al.* 1986). At pH 8 bicarbonate is the predominant form of DIC. Beer *et al.* (1992) report that CO₂ concentrations within *L. wollei* mats are less than 1mM suggesting bicarbonate is the main source of DIC available to *L. wollei* for photosynthesis and growth. Bicarbonate concentrations are as low as 0.15mM at midday as a result of increasing pH and yet photosynthesis still functions at 60% of its maximum productivity (Beer *et al.* 1986). Beer *et al.* (1986) results conclude efficient inorganic carbon uptake at low DIC levels maintains photosynthetic productivity.

L. wollei is able to efficiently utilize bicarbonate to supply cellular demands for inorganic carbon. This provides a competitive advantage to the species (Beer *et al.* 1986). Bicarbonate use results in an increase in carbon dioxide levels at the ribulose – 1,5-bisphosphate carboxylase oxygenase (RUBISCO) site. This is the same result achieved by plants employing the C4 mechanism (Beer *et al.* 1990). Beer *et al.* (1992) conclude that there is no evidence supporting bicarbonate dehydration at the cell wall. Instead, *L. wollei* achieves saturating inorganic carbon concentrations through cellular uptake of bicarbonate. This conclusion is based on the absence of the enzyme carbonic anhydrase (CA) which intraconverts bicarbonate and carbon dioxide. In addition there is no evidence of a highly active carbon dioxide transport system and oxygen released originates internally. It is further