Discussion

The aim of this investigation was to revisit the *Thalassia* study of the Wickstead Report (1975) with a view to comparing *Thalassia* blade length and density data from the 1974/75 survey and the comparable survey in 2001.

The results show that there is a significant difference between the average length of the *Thalassia* blades at each site from the surveys in 1974/75 and 2001 (see *table 6, Results*). See *table 7* (below) for result data. The 2001 survey shows that average blade length of *Thalassia* in the North Sound has decreased by 7cm, since the Wickstead survey.

	spring 1975 blade length cm	autumn 1974 blade length cm	average blade length 1974/ 1975	spring 2001 blade length cm	autumn 2001 blade length cm	average blade length 2001
Average for all sites	**11**	**26**	**19**	**12**	**14**	**12**

Table 7: Results for the average blade length for each survey.

The results also show that there is a significant difference between the number of *Thalassia* blades per 1/4m^2 quadrat from the surveys in 1974/75 and 2001 (see *table 5, Results*). The 2001 survey demonstrates that there is, on average, more that double the amount of *Thalassia* blades per ¼ m^2 quadrat than in the 1974/75 survey (see *table 8* below).

	spring 1975 # blades per 1/4m2	autumn 1974 # blades per 1/4m2	average # blades 1974/ 1975	spring 2001 # blades per 1/4m2	autumn 2001 # blades per 1/4m2	average # blades in 2001
Average for all sites	**100**	**134**	**113**	**257**	**241**	**249**

Table 8: Results for the number of blades per 1/4m^2 quadrat for each survey.

Decreased light availability due to eutrophication (persistent algal blooms) and re-suspended sediments have been implicated in seagrass decline, reduction in blade length and aerial biomass world-wide (Peres and Picard, 1997; Cambridge and McComb, 1984; Orth and Moore 1984; Giesen *et al*, 1990; Dennison *et al; 1993; Onuf*, 1994; Hall *et al*, 1999). However, this observation, coupled with increased number of blades has not been described before. Correspondence with Mark Fonseca (NOAA) and Mike Durako (University of North Carolina at Wilmington) (Appendix III) have called into question the methods of the original Wickstead survey and our subsequent methodology based upon theirs. We have been urged to confirm that Wickstead (1975) did indeed count the number of blades and not short-shoot densities.

Below is an excerpt from the original Wickstead Report (1975) describing the methods of the *Thalassia* study:

The density of Thalassia was measured in a 1/4 m^2. A diver counted the number of blades within a 1/4 m^2 quadrat, the blades were broken after counting to ensure that each leaf was only counted once. This procedure was effected three times at each station and the leaves were measured for average and maximum leaf lengths. (Wickstead Report, 1975, Part III)

Advice from Joseph Zeiman (University of Virginia, CARICOMP advisor and general seagrass God) has been sought but not yet received (Appendix III).

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Appendix I

The 'Biological' Terms of Reference:

Their brief as outlined by Exp.195/A of 24th August 1973 was:

Para 1.1 "to determine the nature and extent of the natural marine and swamp resources of the Cayman Islands, their current and potential importance to the islands, and the damage to which these resources might be or are being subjected."

Para. 1:2 "To recommend legislation and other measures for the preservation and utilisation of these resources."

Para. 2:2 "To survey the marine benthos (bottom life) with particular reference to North Sound and the mangroves of the Cayman Islands."

Para. 2:b "Jointly to survey the potentially important economic species with particular reference to conch, penaeid prawns, rock lobster and fish. Limited phytoplankton and zooplankton studies to be undertaken in North Sound in respect of

1) total abundance.
2) breeding seasons.

The oceanographic terms of reference:

P.1.1 To establish baseline oceanographic data in order that Cayman Islands Government has suitable points of reference to take note of environmental factors affecting future planning and development projects.

P.1 .2. To determine the physical parameters upon which the effects of dredging and resultant turbidity are dependent. These are currents, wave regime, meteorological conditions, and topography of the areas of marine sand.

P.1 .3. To assess the type of sand to be found in the marine environment and its suitability for building purposes.

P.1.4. To recommend, in conjunction with the other members of the survey, areas suitable for sand extraction which will cause the least environmental damage.

P.1.5. To advise on safeguards to be used in conjunction with the extraction of sand and fill.

These primary terms of reference were subsequently supplemented in 1974:

Although these studies (Natural Resources Study: Phase I - Marine and Swamp Investigations) are planned to cover all basic marine parameters, emphasis should be placed on those primarily concerned with, or affected by, the practical needs of development in the Cayman Islands; e.g. fill and sand by dredging, or other means.

1) Therefore it is expedient at this early date for the Executive Council to consider and enumerate the future development needs affecting the sea bottom, coast line and littoral swamps in order that the marine study can solve or minimise the detrimental side affects of such development activity, or advise where an area can only be protected by leaving it in its virgin state. Some major examples follow:

2) a) Sand There is an urgent need for sand for building purpose. This can be obtained from the beach ridges or from the Sounds. Investigations should be made with the object of answering the following questions:

   (i) Which is the most expedient ecologically?

   (ii) If the Sounds are, and in particular North Sound, the study should predict on the basis of the current, turbidity, wave slope and depth of sediment which area would be exploited with the least environmental damage?"

   b) Marl fill by hydraulic dredging Fill is essential to development in the Cayman Islands. It can be obtained by dredging and or draglining in the open sea or by encapsulation thus:

   (i) Which method is the most expedient for the least environmental damage?

   (ii) Which localities in the Sounds could be worked to create the least damage through turbidity and/or sedimentation?

   c) Coral Reefs. Skin diving, glass bottom boating, etc. are an important attraction for the tourism. It is believed that the Cayman Islands are fortunate enough to have flourishing reef ecosystems and these should be protected. Therefore:

   (i) Which areas are the worthiest of total protection by the creation of underwater parks?

   (ii) Are these other areas where licensed removal of the flora and fauna could be allowed?

(iii) What would be the quantitative index needed to control this?

d) Removal of mangrove and reclamation. Mangrove can be divided into littoral mangrove and deep swamps removed from the sea.

(i) How much of this could safely be removed?

(ii) Would large reclamation of the deep swamps be more desirable than fringe filling along the North Sound?

It is recommended that the Natural Resource Study Team be requested to give special attention during the studies to the subjects mentioned in paragraph 3 of this submission, and where possible to provide this Government with answers to the questions posed therein.

<u>The Government brief was interpreted by the NRS team as indicating the following lines of study:</u> -

(1) Examination, description and semi-quantification of the main elements of the inshore (i.e. within the outer perimeter of the Grand Cayman land mass, as demarcated by the reef drop off) fauna and flora in order to provide an overall baseline of the existing situation against which the results of future surveys may be compared to assess the effects of development projects.

(2) Assessment of the potential of animal and plant species of current or possible future commercial value.

(3) Assessment of the practicality of increasing the fish stock density in lagoons by provision of additional shelter in the form of artificial reefs and of cultivating black coral by means of cuttings.

Determination of sources of sand and fill, whose exploitation, if conducted with adequate precautions, should produce more limited deleterious biological consequences than would occur if stocks were to be taken. Previous surveys conducted in Cayman waters have been limited to either rather general consideration of the main ecological zones (Roberts, 1971) or to collection of specific animal groups, e.g. molluscs (Abbott 1948) corals (Rigby 1969). The marine flora seems to have been entirely neglected. Detailed analyses such as those compiled for the terrestrial flora (of Brunt, in preparation) or animal groups such as the birds (Johnston, Make, Buden, 1971), gastropods (Pilsby, 1947) are lacking for marine waters.

Appendix II

Two Sample T-Test and Confidence Interval

Two sample T for average blades in 1974/75 vs average blades in 2001

	N	Mean	StDev	SE Mean
average	45	146.0	61.1	9.1
average	25	249	116	23

95% CI for mu average - mu average: (-154.0, -53)
T-Test mu average = mu average (vs not =): T = -4.16 **P = 0.0002** DF = 31

Two Sample T-Test and Confidence Interval

Two sample T for average blade length 1974/75 vs average blade length 2001

	N	Mean	StDev	SE Mean
average	44	24.7	12.8	1.9
average	25	12.08	5.92	1.2

95% CI for mu average - mu average: (8.1, 17.1)
T-Test mu average = mu average (vs not =): T = 5.58 **P = 0.0000** DF = 64

Two Sample T-Test and Confidence Interval

Two sample T for spring 1975 blades per 1/4m2 vs spring 2001 blades per 1/4m2

	N	Mean	StDev	SE Mean
spring 1	26	142.7	85.3	17
spring 2	25	257	124	25

95% CI for mu spring 1 - mu spring 2: (-174, -53)
T-Test mu spring 1 = mu spring 2 (vs not =): T = -3.80 **P = 0.0005** DF = 42

Two Sample T-Test and Confidence Interval

Two sample T for spring 1975 blade length vs spring 2001 blade length

	N	Mean	StDev	SE Mean
spring 1	22	16.27	8.79	1.9
spring 2	25	11.72	5.46	1.1

95% CI for mu spring 1 - mu spring 2: (0.1, 9.0)
T-Test mu spring 1 = mu spring 2 (vs not =): T = 2.10 **P = 0.043** DF = 34

Two Sample T-Test and Confidence Interval

Two sample T for autunm 2001 blade length vs autumn 1974 blade length

	N	Mean	StDev	SE Mean
autunm 2	14	14.57	7.68	2.1
autumn 1	45	26.2	15.1	2.3

95% CI for mu autunm 2 - mu autumn 1: (-17.8, -5.5)
T-Test mu autunm 2 = mu autumn 1 (vs not =): T = -3.81 **P = 0.0004** DF = 44

Two Sample T-Test and Confidence Interval

Two sample T for autumn 2001 blades per 1/4m2 vs autumn 1974 blades per 1/4m2

	N	Mean	StDev	SE Mean
autumn 2	14	241.3	94.7	25
autumn 1	47	134.5	65.2	9.5

95% CI for mu autumn 2 - mu autumn 1: (50, 164.1)
T-Test mu autumn 2 = mu autumn 1 (vs not =): T = 3.95 **P = 0.0011** DF = 16

average blade length

Mann-Whitney Confidence Interval and Test

average N = 44 Median = 23.000
average N = 25 Median = 10.000
Point estimate for ETA1-ETA2 is 11.000
95.1 Percent CI for ETA1-ETA2 is (5.999,17.000)
W = 1892.0
Test of ETA1 = ETA2 vs ETA1 not = ETA2 is significant at 0.0000
The test is significant at **0.0000** (adjusted for ties)

spring blade length

Mann-Whitney Confidence Interval and Test

spring 1 N = 22 Median = 15.500
spring 2 N = 25 Median = 10.000
Point estimate for ETA1-ETA2 is 4.000
95.1 Percent CI for ETA1-ETA2 is (0.000,8.002)
W = 623.5
Test of ETA1 = ETA2 vs ETA1 not = ETA2 is significant at 0.0428
The test is significant at **0.0426** (adjusted for ties)

autumn blade length

Mann-Whitney Confidence Interval and Test

autunm 2 N = 14 Median = 11.00
autumn 1 N = 45 Median = 23.00
Point estimate for ETA1-ETA2 is -9.50
95.1 Percent CI for ETA1-ETA2 is (-19.00,-3.00)
W = 254.0
Test of ETA1 = ETA2 vs ETA1 not = ETA2 is significant at 0.0032
The test is significant at **0.0029** (adjusted for ties)

APENDIX III

Email to JC Zeiman sent 19 July 2002

Dear Sir,

I am writing to you from the Cayman Islands Department of Environment, in search of advice. 25 years ago a Natural Resource study on Grand Cayman Island investigated, amongst other things, the blade length and number of blades of *Thalassia testudinum* using 1/4m quadrats at 60 sites in our North Sound (a 90km2 semi enclosed lagoon).

Using their methodology, in 2001 we revisited all their original sites and counted the number and measured every *Thalassia* blade in four (4) 1/4m2 quadrats, They surveyed in the Autumn of 1974 and Spring 1975 and we survey in the Spring and Autumn of 2001.

The aim of this investigation was to revisit the *Thalassia* study of the Wickstead Report (1975) with a view to comparing *Thalassia* blade length and density data from the 1974/75 survey and the comparable survey in 2001.

The results show that there is a significant difference between the number of *Thalassia* blades per 1/4m^2 quadrat from the surveys in 1974/75 and 2001. The 2001 survey demonstrates that there is, on average, more that double the amount of *Thalassia* blades per ¼ m^2 quadrat than in the 1974/75 survey.

The results also show that there is a significant difference between the average length of the *Thalassia* blades at each site from the surveys in 1974/75 and 2001. The 2001 survey shows that average blade length of *Thalassia* in the North Sound has decreased by 7cm, since the Wickstead survey.

So it seems that blades have become shorter, but more dense (number of blades per 1/4m2 has increased). Anecdotal evidence suggests that the visibility of the North Sound has reduced over the years due to dredging, boat traffic, runoff etc, therefore we can assume that light through the water column has been attenuated.

I have been in touch with Mark Fonseca and Mike Durako and attach their comments and suggestions. I can confirm that neither the 1974/75 nor the 2001 study counted short-shoots. Blade length and number of blades are only reported.

I am confident in the results and the duplication of the methods by which they were obtained however, to the best of my literature search capabilities I am unable to interpret the results. These morphological changes we presume are a factor of environmental change. Can you suggest some papers or other research (preferably digital as our library capabilities are impractical !) that may support our findings and perhaps give us your opinion?

I sincerely thank you and appreciate any time you give to this matter.

Kirsten Luke

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Dear Kirsten:

I have placed in the mail some reprints of our Florida Bay work that may help you with your interpretation of your results. You should also review the literature on shading studies.

In my experience and what has been observed in many shading studies, is that as light becomes reduced short-shoot density declines (stand thinning), leaves/short-shoot declines, but maximum leaf length may increase (initially, then it may also decrease). If you are truly observing an increase in short-shoot density with a decrease in max leaf length, I would suspect an increase in light availability at the sites. In clear, shallow bank-edge Thalassia beds we usually observe high densities, blades/shoot, but short leaves. The observation of die-off survivor short-shoots producing very high numbers (>10 leaves/shoot) of shorter blades was due to abundant light (no shading from neighboring shoots) and very short Plastochron Intervals (as short as 4 days, compared with the usual 18-26 days) as the ramet became the genet.

I agree with Mark in urging you to be careful about the distinctions among shoot-specific, areal-specific, and standing crop characteristics.

Hope this helps.

mjd

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-----Original Message-----
From: Mark Fonseca [mailto:Mark.Fonseca@noaa.gov]
Sent: Tuesday, March 12, 2002 10:39 AM
To: Luke Kirsten
Cc: Dr. Mike Durako
Subject: Re: Thalassia confusion
Importance: High

ok - some observations and information.

First, the number of quadrats that you are using (4) is very small. While a good start, such a small number of quadrats yields data that is really susceptible to being biased by one or two unusual samples. I strongly recommend that you increase the sample size to at least 30 and maybe more.

Second - you need to be sure that the previous workers were counting short shoots and not actual blades. This is an inconsistency in terminology that has caused problems before. The best method is to count the number of shoots where they emerge from the sediment. This cluster of leaves arise from a single meristem and may number between 2-5 (or rarely more) blades per shoot. So - need to be sure you are counting SHOOTs and not BLADES of all the shoots combined. You must also be certain of the methods in 1975.

Third - I had heard that with the big seagrass dieoff in Florida Bay, that some shoots started to produce very high numbers of leaves (>10) but essentially shut down any branching or population growth. Mike Durako (no longer at Florida, but Univ. of North Carolina at Wilmington) may know more about this (I am copying him).

I attached the abstracts of a couple of papers, as well as the pdf file of a report you may find interesting. Mike might have more lucid comments but this is all I could come up with, without knowing more about the site.

Title
Decadal Changes in Seagrass Distribution and Abundance in Florida Bay
AU:
Author
Hall, MO; Durako, MJ; Fourqurean, JW; Zieman, JC
AF:
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Source

Estuaries, vol. 22, no. 2B, pp. 445-459, Jun 1999
IS:
ISSN
0160-8347
AB:
Abstract
The Florida Bay ecosystem has changed substantially in the past decade, and alterations in the seagrass communities have been particularly conspicuous. In 1987 large areas of Thalassia testudinum (turtlegrass) began dying rapidly in western Florida Bay. Although the rate has slowed considerably, die-off continues in many parts of the bay. Since 1991, seagrasses in Florida Bay have been subjected to decreased light availability due to widespread, persistent microalgal blooms and resuspended sediments. In light of these recent impacts, we determined the current status of Florida Bay seagrass communities. During the summer of 1994, seagrass species composition, shoot density, shoot morphometrics, and standing crop were measured at 107 stations. Seagrasses had been quantified at these same stations 10 yr earlier by Zieman et al. (1989). T. testudinum was the most widespread and abundant seagrass species in Florida Bay in both 1984 and 1994, and turtlegrass distribution changed little over the decade. On a baywide basis, T. testudinum density and biomass declined significantly between surveys; mean short-shoot density of T. testudinum dropped by 22% and standing crop by 28% over the decade. T. testudinum decline was not homogeneous throughout Florida Bay; largest reductions in shoot density and biomass were located principally in the central and western bay.
Percent loss of T. testudinum standing crop in western Florida Bay in 1994 was considerably greater at the stations with the highest levels of standing crop in 1984 (126-215 g dry wt m super(-2)) than at the stations with lower levels of biomass.
While turtlegrass distribution remained consistent over time, both the distribution and abundance of two other seagrasses, Halodule wrightii and Syringodium filiforme, declined substantially between 1984 and 1994. Baywide, H. wrightii shoot

density
and standing crop declined by 92%, and S. filiforme density and standing crop
declined by 93% and 88%, respectively, between surveys. Patterns of
seagrass
loss in Florida Bay between 1984 and 1994 suggest die-off and chronic light
reductions were the most likely causes for decline. If die-off and persistent
water-column turbidity continue in Florida Bay, the long-term future of
seagrasses in
the bay is uncertain

Seagrass die-off in Florida Bay (USA): Changes in shoot demographic
characteristics and population dynamics in Thalassia testudinum
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Florida Mar. Res. Inst., 100 Eighth Ave. S.E., St. Petersburg, FL 33701, USA
SO:
Source
Marine ecology progress series. Oldendorf [MAR. ECOL. PROG. SER.], vol.
110,
no. 1, pp. 59-66, 1994
IS:
ISSN
0171-8630
AB:
Abstract
Population dynamics, including demographic characteristics, of short-shoots of
Thalassia testudinum were evaluated within 3 Florida Bay (USA) basins
experiencing
differing severities of sea-grass die-off. Annual mean plastochrone intervals
(PI)
ranged from 14.1 to 20.6 d, and they increased from the basin experiencing
the most
prolonged and extensive die-off to the basin least affected by die-off. PIs
calculated
by leaf punching were always shorter than those estimated by cohort
analyses. In all
3 basins, overall population age structure changed significantly between April
1989
and April 1990; population half-life, mean shoot age, the age of the oldest
shoot, and
shoot density declined, whereas rhizome apical density increased. An
examination of
the population dynamics of the 3 T. testudinum populations revealed that both

recruitment and mortality of short-shoots increased between April 1989 and April 1990, but the increase in mortality was proportionately greater. These changes indicated that the T. testudinum populations in Florida Bay were continuing to decline and that the declines corresponded to the increased extent and severity of short-shoot die-off.