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Writing Right: Enhancing Student Engagement and Performance in an Ecology Course

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This paper outlines the results of a collaborative effort between members of staff in the Departments of Life Sciences and Language, Linguistics and Philosophy, which involved the implementation of Writing Across the Curriculum strategies in an Ecology course. The lecturer for this course had expressed concerns regarding the poor quality of the laboratory reports presented and weak essays submitted by students. In order to enhance students' understanding of the content to be included in the report, and to improve expression of thought in writing, we agreed to 'treat' a sample of students selected from two laboratory groups by giving each group the other's lab report to read and to subsequently carry out the experiments described. Additionally a select group of students engaged in the planning, writing and revising of responses to past exam essay questions. Results showed that final exam grades for the 'treated' group and the writing group were significantly higher than their 'non treated' and 'non writing' counterparts. Feedback from students was generally positive. Implications and limitations are discussed.

Key Words: writing across the curriculum, ecology, undergraduates

Introduction

Enabling students to engage in scientific discourse in an effective and meaningful way is an essential component of science teaching. Additionally, the development of thought processes leading to the scholarly, sophisticated description of phenomena in their field is an important goal for all science students. We have found that undergraduate students pursuing science courses at our university have great difficulty in conveying scientific information in a clear, concise and logical manner. The inability to transfer knowledge and thought to written discourse is demonstrated by their confused/confusing, vague, ambiguous, and non coherent communication. This indicates a need for focus on writing to enhance writing /communication skills as well as to engage students in the learning process.

These observations are supported by the biology examiners of the regional assessment body (Caribbean Examinations Council, CXC) who have commented on the "generally vague" responses of the candidates coupled with their apparent inability to write in a logical sequence (Caribbean Examinations Council, 2007a, b). Consequently, these examiners recommend that

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students' examination preparations should be focused on "practicing how to interpret and answer questions clearly, concisely and to the point" (Caribbean Examinations Council, 2007a).

Such issues are not unique to the Caribbean, as researchers in the United States such as Jerde and Taper (2004), Moore (1994) and Samsa and Oddone (1994) have opined that generally, undergraduate students have not learnt to write effectively in scientific formats and that the majority of scientific writing problems observed are related to the documents' organization, tone, clarity and conciseness. In attempting to address this problem many have come to realise that writing tasks play an important role in facilitating students' thinking and domain-centred learning in the sciences (Tynjälä, Mason, & Lonka, 2001). In fact, Bocolo & Mason (2001) have determined that writing activities, particularly in the sciences, can be a useful aid in conceptual comprehension and retention as well as in promoting reflection on such information especially if there is a forum for feedback/discussion.

As a result, students are stimulated to view writing as enhancing the learning process through more appropriate assimilation of information and by communicating this information more effectively. Writing in the sciences is, therefore, elevated above the basic role of merely recording information to an appreciation of its role in the construction and transfer of knowledge in the mind of the learner.

It has thus been strongly suggested that science teachers assign writing activities which enable students to hone their skills in areas such as constructing arguments by using details from direct observations, explaining concepts, and reporting results so effectively that recipients will be able to adequately interpret and evaluate the information, and use it appropriately (Feldman, Anderson, & Mangurian, 2001). This position is entirely consistent with that of Gillen (2006) who has stressed the importance of honing the critical and analytical skills of science students through focus on the rhetoric of research articles and by engaging in the production of authentic laboratory reports.

Background

This focus on writing as a means of improving communication skills and engaging learners with course content is largely based on a two pronged approach which resides within the framework of the WAC (Writing Across the Curriculum) 'writing to learn' 'learning to write' pedagogy where writing is viewed as a way of teaching discipline specific content while facilitating the development of thinking and writing skills (Britton, Burgess, Martin McLeod, & Rosen, 1975; Bangert-Drowns, Hurley, & Wilkinson, 2004). It has further been suggested (Madigan, 1987) that in order to fully benefit from WAC theory and practice, faculty and administrators should view writing as a means to an end and not an end in itself.

In a similar vein writing is seen as an effective tool for learning content instead of for merely reporting (Emig, 1977; Kelly & Chen, 1991; Paul & Elder, 2005) and also as an essential component in promoting thinking and engagement with information (Steglich, 2000). The principles of this methodology involve assigning activities which require students to explore ideas, discover relationships, observe contrasts, sequence ideas, and process information (Fulwiler & Young, 1982; Gage, 1986). Such activities also increase the quality of learning by helping students clarify ideas and the relationship between these ideas (Bean, 2001).

From the perspective of science, writing –to learn strategies are an important "resource for thinking and learning by which students clarify and consolidate knowledge" (Hand & Prain, 2002, p. 741) and not explicitly teaching students the principles of effective writing in the sciences will only handicap them in the future (Moore, 1993). In fact, Lerner (2007, p.

192) has highlighted the importance of using writing in science "to inculcate students into the research and communication practices of scientists" and others, (Chinn & Hilgers, 2000; Prain & Hand, 1999; Yore, 2000; Ellis, 2004; Robertson, 2004) have drawn attention to the value of writing in science to promote learning and technical science writing.

Although findings on the efficacy of writing in the learning process have been deemed for the most part questionable, given the inconsistent and contradictory nature of findings (Ochsner & Fowler, 2004), there is a much stronger case made for the effectiveness of the 'learning to write' component of WAC pedagogy. This case has been made by researchers, such as Harris & Schaible (1997) who, in commenting on the use of WAC intervention strategies among biology and economics students, have concluded that improvement in writing and learning only occurs when writing is guided and written work carefully and rigorously critiqued.

Our attempts to use writing to learn/learning to write strategies to enhance writing skills and learning in the sciences constituted the major part of an interdisciplinary project at our institution between the Faculty of Pure and Applied Sciences and the English Language Section of the Faculty of Humanities and Education. The project was implemented because of concerns on the part of both science and English language teachers that students who had completed English Language Foundation courses in their first year, were not applying the writing principles learned in these foundation courses to their other disciplines, the sciences in particular. This resulted in writing which, in most cases, failed to adequately demonstrate knowledge of concepts being taught and to effectively communicate scientific information.

The aims of this project were therefore to enhance science students' communication skills and to better enable the science teaching staff to assume responsibility for students' writing by ensuring that students learnt and practiced the discourse conventions appropriate for their discipline. A series of workshops was conducted in the Department of Life Sciences to introduce and familiarize ten interested staff at the departmental level to the Writing Across the Curriculum (WAC) "writing to learn" and "learning to write" theory and practice in order to guide them in the process of incorporating these strategies in their courses.

Interventions such as 'connections', voices, dialogue journals, double entry notebooks, lenses, admit and exits slips used in other WAC programmes were outlined and introduced to staff members using examples. Discussions suggesting how to promote critical thinking, sequencing and planning as well as the drafting of small and large assignments were facilitated by colleagues from the Department of Language, Linguistics and Philosophy. Resulting from this, seven lecturers were persuaded to utilize a variety of writing strategies in their courses. One of these courses was a 2nd year Ecology course whose aims are to introduce students to the scientific study of the interrelationships between and among organisms and between organisms and all aspects of the living and non-living environment. Related tasks include the design and execution of basic sampling techniques appropriate for any population or community of organisms and the description of concepts of community productivity, succession, nutrient and energy cycling and transformation.

The course is delivered via 24 hours of lectures, 6 hours of tutorials, 36 hours of field and laboratory work including a weekend field trip. Performance in this course is determined by course work which includes a 2 hour practical test (20%), a multiple choice test (10%) and laboratory and field reports (10%) and a Final Examination- a 2 hour theory paper (60%). This theory paper requires the writing of essays which measure the acquisition of knowledge as well as the ability to apply this knowledge to a variety of contexts, and as indicated by the weighting, constitutes the primary measure of student performance in the course.

The lecturer for this course had three main reasons for incorporating WAC related strategies into this course. These were the desire to a) improve the pass rate of the previous year which was 68%; b) improve the quality of students' writing skills so that they would be better able to function in the work environment when they graduated; and c) guide students' thought processes along a certain path so that they would better grasp course content and become more adept at conveying scientific information in a clear concise and factual manner.

Since writing skills were a major concern we decided that students should engage in writing and rewriting drafts of essays and laboratory reports with guidance and feedback on each draft provided by the lecturer and his support team. Further engagement with course content and improvement in communication skills would be achieved by activities which involved evaluation, interpretation and the use of the information related to an experimental procedure.

From the outset, the lecturer gave students information about the writing strategies that he would be integrating into the course. There was initial resistance to additional writing activities, but this abated somewhat when the lecturer highlighted the potential benefits of these activities which included the possibility of higher grades. The lecturer made two modifications to course assessment before implementing strategies. For the practical exam, students would now be asked to conduct an experiment not previously undertaken and to report it in such a way that another ecologist could conduct it and gain similar results. Prior to this, they had been required to design an experiment which would demonstrate some ecological principles.

Another modification was made in the area of the administration of the supplemental examinations. A supplemental examination is awarded to a candidate who has marginally failed to obtain a passing grade (5% below a pass) but has mastered the coursework and practical examination components. Students awarded a supplemental examination would now be required to respond to questions in writing as opposed to responding orally as was previously the case.

We decided that outcomes of the use of WAC related strategies in this course, would be measured quantitatively by:

a) determining whether there were significant differences in exam/test performance between control and experimental groups as well as between writing and non writing groups and,
b) comparing previous and current performance.

Furthermore, in keeping with Becker's (1993) position that qualitative as well as quantitative measures need to be applied in assessing WAC outcomes, we decided to hold interviews with the lecturer as well as five students at the end of the course to obtain feedback on their perceptions of the use of the writing strategies. Questions were open ended and generally sought responses from students on issues such as the perceived benefits/challenges of WAC for students, thoughts as to whether WAC strategies should be used in all Life Science courses, and changes in approach/ attitude to writing. We sought responses from the lecturer regarding his willingness to continue applying WAC strategies in other courses, the challenges which he encountered, what he saw as the most impressive outcome of WAC intervention strategies, and which strategy he viewed as being the most instrumental in improving students' writing and performance outcomes.

Method

All students were required throughout the course to produce drafts of laboratory reports on experiments carried out and to revise these reports based on feedback given by the lecturer, a teaching assistant and laboratory demonstrators who were provided with guidelines by the lecturer. No grades were assigned to these reports and the feedback given was to be viewed as constructive criticism. .

In addition to this, a group of 41 students (referred to as the experimental group from hereon) from the cohort of 121 students was randomly selected to engage in the strategy of 'mirroring'/peer review on their weekend field trip to marine and forest areas. They were randomly divided into two groups: Group A -the forest group- would sample, identify, and evaluate specified communities in forests and Group B–the marine group -- would participate in the same activity in coastal areas. Members of each group were required to immediately write the methodology component of a lab report and submit them to the instructors. These were then randomly exchanged with members of the other group (ie. Group A to give reports to Group B group and vice versa). Each group would then attempt to replicate the experiment of the first group. Important to note is the fact that neither group of students was told that they would be writing instructions/ methodologies for the other group nor were they told they would be replicating the experiment from the reports of their colleagues.

According to the lecturer, many students on reading the reports of the members of the other group, claimed at first to understand the content. However when they were told that they should now carry out the experiment described in the report, they were forced to admit that the writer had omitted crucial details and information which would hinder the undertaking of the task. Questions such as "How far?"; "How high?"; "How wide"?; "How long?" "At what point exactly?"; "Do you really mean…..?" were asked and so the original writers were forced to review their work , and based on comments, revise what they had written (three examples of original and reviewed reports are provided in Appendix A1 and A2).

This revision exercise on the part of students led to lab reports with more detailed descriptions, clearer communication of the sequencing of activities as well as more appropriate word choice. Evaluation of lab reports was undertaken with the assistance of demonstrators and a teaching assistant who the lecturer provided with clear guidelines.

Another type of strategy involved responding to essay exam questions. The procedure undertaken by the lecturer was as follows:

- discussion of strategies for answering essay exam questions in tutorials
- highlighting the need for preparing outlines in preparation for writing.
- engagement in essay planning exercises during tutorials.
- incorporation of the draft/redraft strategy by (a) handing out essay questions (b) suggesting to students that they attempt some of these, submit them to him for feedback (c) using this feedback to attempt another draft which would also be assessed by him.

However, only 16 students complied in a consistent manner in the draft/redraft component of this exercise. These students for purposes of analysis are referred to as the writing group (WrGr) and those who did not participate in this exercise are referred to as the non writing group (NWrGr). Additionally 13 students, as previously stated, were given a written examination for their supplemental examination instead of an oral examination.

Results

Quantitative

Regarding the results from the practical exam which involved the writing up of a report on a laboratory experiment, the lecturer reported a 100% pass rate for the first time in his 20 years of delivering the course. Additionally the pass rate for the final examination was 83% compared to 68% the previous year. We undertook a comparison between the mean percentage grade of the experimental group (the 41 students who had participated in the coastal/forest writing exercise) and the control group (those who had not participated in this exercise) on the:

a) practical exam component of the course work
b) total course work(practical exam, multiple choice test and field reports) and
c) the final (theory paper) examination (see Appendix B)

Independent Samples-*t* tests were carried out to determine whether there were any significant differences in mean scores between the control and experimental groups on the aforementioned evaluation components. Performance as a score between 1 and 100 marks in each evaluation component was the quantified measure used in the *t test procedures.*

Results from these analyses yielded no significant differences ($p<.05$) between the control and experimental groups in performance on the practical exam. These results are illustrated in Table1. There were also no significant differences between the two groups for total coursework as is illustrated in Table 2. Notwithstanding, the experimental group attained a slightly higher mean score on both the practical exam and total coursework (Tables 1 and 2). However, in the case of the final examination, the experimental group gained a significantly higher percentage mean than their counterparts in the control group. These results are displayed in Table 3.

Comparisons between the mean exam grade for the 16 students who participated in the practice essay exam writing exercise (WrGr) and those who did not (NWrGr) revealed a statistically significant difference in the final examination results in favor of the writing group. These results are illustrated in Table 4.

Table 1. T-test on practical exam performance for control and experimental groups

Group	N	df	Mean	Std Deviation	Std Error	t	*p*
Control	75		55.08	8.986	1.038		
Experimental	41	114	56.05	8.854	1.838		
Equal variances assumed						-.558	.578

p>.05

Table 2. T-test on total course work for control and experimental groups

Group	N	df	Mean	Std Deviation	Std Error	t	*p*
Control	75		71.44	10.073	1.163		
Experimental	41	114	71.54	6.569	1.026		
Equal variances assumed						-.055	.956

p>.05

Table 3. T-test on exam grade for control and experimental groups

Group	N	df	Mean	Std Deviation	Std Error	t	p
Control	78		42.24	13.131	1.487		
Experimental	41	117	47.38	10.869	1.667		
Equal variances assumed						-2.166	.032*

*p<.05

Figure 1 graphically illustrates the differences in mean exam grade between writing and non writing groups as well as between the experimental and control groups. We also noted that the 13 students who engaged in writing for their supplemental exam had a pass rate of 93%-- an increase of over 80% on the previous year's 50% pass rate.

Qualitative

Tables 5a and 5b display the students' and their lecturer's perceptions, respectively, of the benefits and challenges of the WAC strategies. Students report benefits in the areas of confidence in writing ability, preparation techniques and approach/ attitude to writing but view the time and effort required by more writing activities to be a challenge. Students did however suggest that time management gained in the course would make their next attempt at WAC strategies more successful.

Table 4. T-test on exam grade for writing group and non writing group

Group	N	df	Mean	Std Deviation	Std Error	t	*p*
WrGr	16		51.06	9.623	3.458		
NonWrGr	105	119	42.55	13.290	2.733		
Equal variances zassumed						-2.461	.015*

$^*p<.05$

At the same time, the lecturer has expressed his commitment to continuing implementing WAC strategies, and has attributed the increased pass rate in the practical and final examination to the feedback on writing tasks as well as guidance on essay planning strategies. He however views students' resistance to writing as well as the volume of marking generated by additional writing activities to be a challenge. These he recommended could be overcome with the services of a committed Teaching Assistant, experienced laboratory demonstrators and a clear marking scheme.

Table 5a. Students' perceptions of WAC benefits and challenges

Benefits	
Preparation	"My preparation strategies for essay exam questions have definitely improved" "I have improved my preparation for labs and writing lab reports"
Confidence	"I am better able to understand the requirements of questions and I am more at ease in responding to these" "I am more confident in my ability to deal with writing tasks"
Approach/ Attitude to writing	"I now think more logically and this has led to more coherence in my writing" "I am applying writing strategies which I leant in this course to my other courses". " My time management skills have improved" "I am better able to identify weaknesses in my own writing "WAC strategies should be implemented in all courses"
Challenges	
	"The strategies are tedious and require effort and more writing than what I am accustomed to"

Table 5b. Lecturer's perception of WAC benefits and challenges

Commitment to WAC	"I am willing to continue using WAC strategies. I am also committed to encouraging colleagues in other disciplines to apply WAC strategies in their courses".
Challenges	"Students' resistance to writing, due in part to the fact that very little writing is required in Year 1 Biology courses".
	"The volume of marking was also a challenge although I had assistance".
Reaction to Outcomes	"I am pleased with the improvement in the exam pass rate and I am particularly impressed with the 100% pass rate for practical exam".
	"I believe essay planning and guidelines for responses to exam questions as well as feedback from myself and my support team were the most effective strategy in improving students' writing.

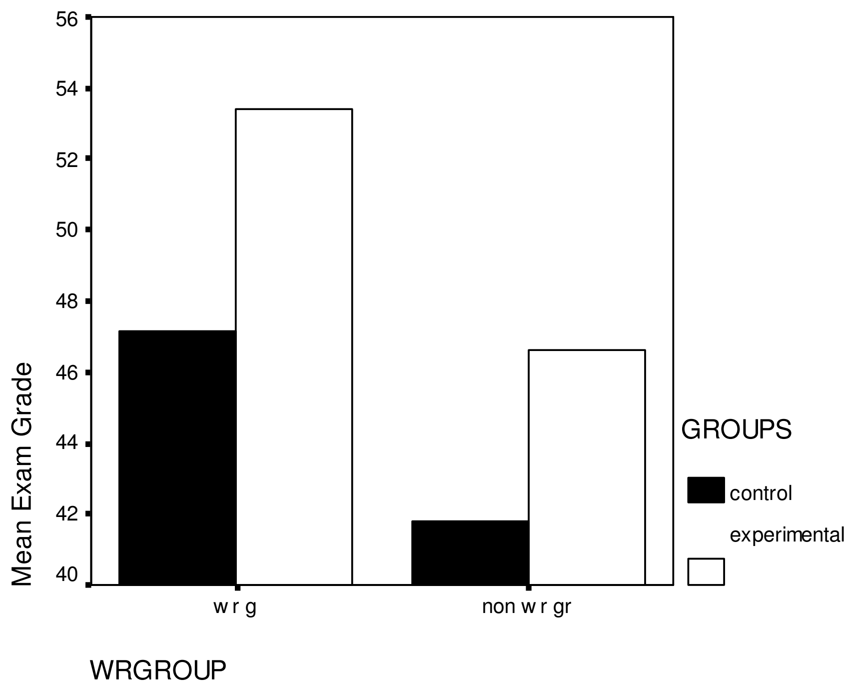

Figure 1. Illustration of differences in mean exam grade between writing and non writing groups and experimental and control groups

Discussion

The results from this investigation suggest the positive impact that additional engagement in writing and rewriting activities have had on students' performance. This is in fact consistent with the findings of Light (1992) and Lonoff (1994) who both demonstrated a connection between writing and learning . Furthermore, the effectiveness of these strategies is supported by students' post WAC reports of increased confidence in writing ability, improved essay preparation techniques and enhanced attitude/approach to writing as well as the lecturer's view regarding the effectiveness of the guidance and feedback offered to students by himself and his team. Indeed Day (1989) in reporting on the findings of her research on social sciences students has also indicated that it was the thoroughness and quantity of instructor feed back rather than the writing activities themselves that correlated with improvement in student writing. Moore (1993) has also contended that teacher guidance is necessary for improving writing, and more recently, Ochsner & Fowler (2004, p.125) in their critique of WAC/ WID literature have posited that, "No evidence confirms that having students write-without instruction-augments their ability to write.

Also, the improved pass rate in the case of the supplemental examination can be attributed to the fact that students were evaluated in a way which was congruent with their learning activities within the course. That is, they were required to provide written responses to questions rather than delivering their responses orally which were in keeping with the medium used to demonstrate knowledge of content during the course. This also holds true in the case of the practical examination where a one hundred percent pass rate was reported subsequent to a change in requirements for laboratory examinations. The change in requirements involved students being asked to conduct experiments and write reports which were more in keeping with the type of class activities in which they had engaged.

The importance and efficacy of congruence between teaching, learning activities and assessment measures as evidenced here, has been promoted by Biggs (1999) and Robertson (2004). In fact Keys, Hand, Prain and Collins (1999) have deemed a match between the types of writing required, the conceptual structure of a topic and broader curricular goals as critical to student success.

Limitations

As WAC practitioners, we are strongly inclined to proclaim the unequivocal effectiveness of our strategies in improving individual as well as overall performance in the Ecology course. However, as researchers, we have tempered this inclination in order to critically examine the strength and meaning of our findings in the face of other possible intervening factors. For instance, we are cognizant that these results may have been due, at least in part, to external conditions such as students' innate ability, prior writing experience, motivation and other variables (Condon, 2001; Penrose, 1992). Indeed, statistical differences which pointed to superior performance on the part of the experimental and the writing groups could be partially attributed to differences in the sample population as these were not measured nor controlled for in the design of the study.

In addition to this, the increased pass rate in final examinations (83%) compared to that of the previous year (68%) may also be attributed to intervening factors in the circumstances surrounding the delivery of the course the previous year. Such factors included an increased class size, change in lecturer and a generally poor performing group. Therefore, the current increased pass rate may be partially related to the absence of these negative circumstances.

Implications and Recommendations

Clearly, we need to undertake further research which takes factors such as sampling differences and analyses of actual student writing into account. Studies which adopt a longitudinal approach (Ochsner & Fowler, 2004) would also serve to further support the efficacy of the WAC 'writing to learn' and 'learning to write' pedagogy. However, in spite of the limitations, we consider our 'WAC experience' to be a positive one, based not only on our findings, but also on the opportunities afforded for interdisciplinary collaboration as this has promoted meaningful interaction with faculty in disciplines other than the Language Arts. We firmly believe that the discussions and interactions surrounding the implementation of WAC in Ecology have had and will continue to have numerous beneficial effects. First, as this is a core course for all majors in Life Sciences, the implementation of WAC strategies has introduced all Life Science students to these modalities. Second, once impacted and convinced, the students will continue to use some WAC strategies in their future courses and in so doing, improve their learning and performance.

Generally speaking, the opportunity to exchange ideas within an interdisciplinary context introduces new concepts and methods which as best practice will provide all staff involved with another skill or tool to enhance the teaching-learning exchange. This is evidenced, in our case, by the fact that examples from the field of science are often used in English language courses to reinforce approaches to analytical and process writing. Conversely, language/writing related pedagogy is increasingly being employed in the teaching of science.

Finally those staff who had been employing WAC strategies without even being aware that they were doing so have been reassured and have experienced self affirmation through their exposure to WAC theory and pedagogy. We recommend that science teachers utilize writing strategies similar to the ones described here in order to engage their students with course content and to improve their communication skills. Interdisciplinary collaboration is also strongly encouraged.

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Appendix A1. Original Reports from Students in Experimental Group

Description of Method

Student A:

10 Random Qudrats were taken by randomly tossing quatrats on sea floor. All observations of sea communities were then noted.

Student B

- Each student was outfitted in full snorkel gear.
- An imaginary transect line was chosen from the dockside to the reef or vice versa.
- A $1m^2$ quadrat was placed at every 10m interval along the transect line for 10 random throws. Each member of the group ensured that they did not disturb the sample area.
- At each area the species plant and animals were noted.
- The water depth temperature was also recorded as well as the number of animals and th percentage cover of plant species in each quadrat.

Student C

After line transect of 100m was set up along the floor of the dry limestone the $1m^2$ quadrat was used to demark study area for each 1m length for 10 meters for each group of students. Within the quadrats, the following data for each species of fauna was collected:

(1) Name of species (2) height (3) distance from datum point (4) percent cover (5) diameter at breast height

Also noted was the light intensity pH and temperature of soil along with wind at 0m (datum point), 5m and a 10m distance from datum point. The fauna seen in each quadrant was also noted and any adaptations seen documented.

Appendix A2. Revised Reports of Students in Experimental Group

Description of method after revision based on views of class mates and instructors

Student A

Each student was outfitted in full snorkel gear and transported (by boat) to the reef. The marine community was sampled along an imaginary transect line at 10m intervals using a $1m^2$ quadrat. The plant and animal species were identified and counted, and the percentage cover of each plant species was recorded. The water depth, temperature and appearance of the area being sampled was also noted, along with how the marine organisms located there are adapted for survival. The information was tabulated based on results collected within each group.

Student B

Each student was outfitted in full snorkel gear. Members of the group snorkeled along an imaginary transect line from the dockside to the reef. A $1m^2$ quadrat was placed at every 10m interval along the transect line for 10 random throws. Each member of the group floated above the quadrat to avoid disturbing the study area. The water depth, temperature, the plant and animal species in the quadrat and the number of individuals of each animal species were recorded. The percentage cover of each plant species and average length of the seagrass blades were determined. The changes of the appearance of the water and changes in the marine community between quadrats and the adaptations of the marine community were also noted. The transect data were used to construct a depth profile.

Student C

A line transect 100 m long was extended along the dry limestone forest floor. The transect was tagged every one (1) meter. A 0.25 m^2 quadrat was used to measure a 2 m^2 area (2m x 2m) starting from the daum point (origin of the line transect). The 2 m^2 area can be measured and marked – (to identify the area instead of using the 0.25 m^2 quadrat 8 times). 2 m along the line (every 2 m) the quadrat area (2 m^2) was measured alternately on each side. This means that from the datum point (0 m) to 2 m on the line only one side of the line was measured. Then for 2m to 4m the opposite site of the transect line was sampled. 2 m^2 quadrats were placed alternately every 2 m on the line. In each quadrat abiotic factors was measured such as light, soil temperature and wind speed every 5 m. In each quadrat all plant species were identified (name specimen 1, 2 etc. If actual name is unknown) Its height measured, DBH measured (Diameter at Breast Height), its distance from datum point and percentage cover. Samples of unknown plants were taken for identification at herbarium. The actual number of each species found was recorded as above. (ie measured as above) number of animal species in quadrat was recorded as well as the abundance of each species

Appendix B. BL 20N: Ecology Theory - 2 HRS 1 page and 6 questions

Answer THREE questions, one from each of the two sections and one other. Where ever appropriate, use labelled drawings to illustrate your answer.

Section A

1) List the important ecological characteristics of soils (25 marks).
Analyse the significance of these soil characteristics in the establishment, distribution and success of plant communities (75 marks).

2) Explain the concept of a biome and list the world's seven major biomes (20 marks). Construct a biome triangle and use it to demonstrate how the world's seven major biomes are created (50 marks). Using two contrasting biomes comment on the range of organisms found in each (30 marks).

3) Discuss the importance of resource allocation in explaining population ecology and growth models of plants and animals.

Section B

4) Write notes on the following ecological terms:

    a) Mimicry and Camouflage in animals (55 marks),
    b) Secondary metabolites in plants as a defense mechanism (45 marks).

5) Define the term 'ecological diversity' and show how diversity indices are calculated (30 marks). Critically evaluate two commonly used diversity indices (20 marks). Describe how the concept of diversity indices is used in the analysis of communities (50 marks).

6) Compare the Carbon and Nitrogen biogeochemical cycles and evaluate the ecological importance of microorganisms in each cycle.