S396 Ecosystems

The Open University

Are you ready for S396?

Contents

1 Introduction

If you are intending to study S396, you will want to make sure that you have the necessary background knowledge and skills to be able to enjoy the course fully and give yourself the best possible chance of completing it successfully.

Please read through this booklet carefully and work through the examples. This is a useful exercise, even if you have already studied other Open University science courses and completed the prior courses recommended for S396 *Ecosystems* (see Section 2). Working through the booklet will serve as a reminder of some of the facts, skills and conceptual knowledge which it is assumed you will have from those earlier courses or from other prior study.

If you are coming to S396 without having studied at least one of the recommended prior courses at The Open University (OU), then it is essential that you establish whether or not your background and experience give you a sound platform from which to tackle the course.

We advise you to seek further help and advice from the OU's Student Registration and Enquiry Service on 0845 300 60 90, especially if, after working through this booklet, you are not quite sure whether S396 is the right course for you.

In Section 8, we have suggested sources of further reading that will help you to fill any gaps in your knowledge or revise any areas of weakness.

2 Suggested prior study

You will need a background in science, such as you would get from the OU's Level 1 science courses S103 *Discovering science* or S104 *Exploring science*. The preferred route would be to take at least one of the following Level 2 Science courses before embarking on S396 *Ecosystems*: S216 *Environmental science* or S204 *Biology: uniformity and diversity* (or its predecessor, S203). Other routes are possible, however, if you have developed your scientific literacy either through University-wide courses such as U316 *The environmental web* or via technology courses such as T172 *Exploring your environment* or T308 *Environmental monitoring, modelling and control*. These are by no means your only options. You will also be able to start S396 if you have successfully studied recent science-based courses equivalent to HND or second-year undergraduate level.

3 Course content

This course strives for a holistic approach and is composed of four sections or 'blocks', which will take you gradually from simple local systems and processes up to the complexity of the global scale. Block 1, which is the introductory block, defines what is meant by the term 'ecosystem' and presents a range of examples describing their biotic (living) and abiotic (non-living) components. The second block then addresses the cycling of water, carbon and inorganic nutrients through these systems, reflecting on how these flows control the type and number of organisms inhabiting the system and how the presence of living organisms in turn affects the cycling of energy and matter. The resilience of the ecosystems to the perturbations of human activity is explored in the third block, using a range of case studies from across the globe. Ecosystems can range in size from a simple microbial community in a lump of soil to an expanse of tropical forest; even the Earth may be considered as a single ecosystem. The final block, therefore, looks at our planet as a whole to investigate the interdependence of the sub-systems within it.

The majority of this course is delivered online using a variety of media: specially written texts, a DVD, web resources (including electronic books and journal papers) and an interactive website. Throughout these materials, the four core concepts of definition, cycling, resilience and interdependence will be illustrated by examples from around the world, using the full range of media. The course emphasises the nature of data obtained in environmental studies with its inherent variability. To understand our environment scientifically, manipulation and statistical interpretation of data are essential and some key skills in this area will be taught. One particularly interactive element will be the use of some basic equipment, supplied in a home kit, to record your own observations. These observations will be made first on an individual basis and then in small groups and will involve an element of experimental design. Results will be compiled into a database, which you will analyse to investigate some ecosystem properties. The statistics required for this investigation will be taught on a need-to-know basis. The outputs from these activities will be assessed in tutor-marked assignments.

Another theme running through the course is the use of modelling. Predictive modelling of ecosystem response is now a frequent issue in the media. This course aims to illustrate the different types of models that are used, exploring their inputs, components and assumptions in order that the outputs can be correctly interpreted. There will be a number of spreadsheet-based or stand-alone models that you can engage with to explore how a particular system responds to external influences.

4 Mathematical skills

Being comfortable with mathematical and graphical skills is the single most important way you can be prepared for S396. Please be certain that you can:

- use a scientific calculator
- understand scientific notation using powers of ten (e.g. 10^3, 10^{-5}, 6.2×10^{-1}) and perform calculations using scientific notation

- perform unit conversions (e.g. m^3 to mm^3, N m^{-2} to MPa)
- manipulate equations to find an unknown
- plot data on **graphs** choosing appropriate scales and axes, and interpret graphical data correctly including interpolation and extrapolation
- **retrieve data** from the internet and paste it into a spreadsheet.
- calculate statistical parameters (**mean**, **median**, **mode**, **standard deviation** and **variance**) for a set of data
- perform **statistical tests** (Spearman Rank Correlation test and a *t*-test).

If you are uncertain about any of these concepts, you can review them in *The Sciences Good Study Guide* or *The OU Project Guide.* (Details of these publications are given in Section 8 of this booklet.)

Self-assessed test for numeracy

Try the following questions to test your mathematical skills. (The answers are given in Section 9.) It is essential that you are comfortable with the skills tested in these questions before you start S396. It should take you no more than 2 hours to complete.

Question 1

Rearrange the following equation in terms of r :

$$A = \pi r^2$$

Question 2

The diameter of the common freshwater diatom, *Gomphonema minutum*, is 0.00012 m. Express this number in scientific notation. Assuming the diatom has a circular cross-section, calculate its area in mm^2.

Question 3

Convert 426 milligrams of carbon per square metre into tonnes of carbon per square kilometre. Express your answer to 2 significant figures using scientific notation.

Question 4

The global cycle of water or important biological elements like carbon and nitrogen comprises two main parts: reservoirs where the molecules or atoms are stored for various lengths of time, and transfers between the reservoirs. Dividing the mass of a substance in a reservoir by its rate of transfer through that reservoir gives us its residence time:

$$\text{residence time} = \frac{\text{mass of substance in reservoir}}{\text{rate at which substance enters (and/or leaves) reservoir}}$$

or the *average* time that a substance spends in a reservoir.

The atmosphere contains 1.5×10^{16} kg of water, mostly as water vapour, and precipitation and evaporation are balanced, transferring 5.05×10^{17} kg of water per year between the atmosphere and the oceans/land.

What is the residence time of water in the atmosphere? Express your answer in days to 2 significant figures.

Question 5

Open a blank spreadsheet, paste the daily rainfall figures for May 2006 as recorded at Toolik Lake, Alaska from the following website into it:

http://ecosystems.mbl.edu/ARC/meta_template.asp?FileName=./weather/tl/2006dltld.html

then plot a bar chart to display the data.

Hint: On the website, select either of the links named 'Comma Delimited' or 'Excel file with Metadata and data'. If you are asked to register, select 'Register later'.

Question 6

(a) Infer from Figure 1 the expected species richness of a meadow with a productivity of 5 tonnes per hectare.

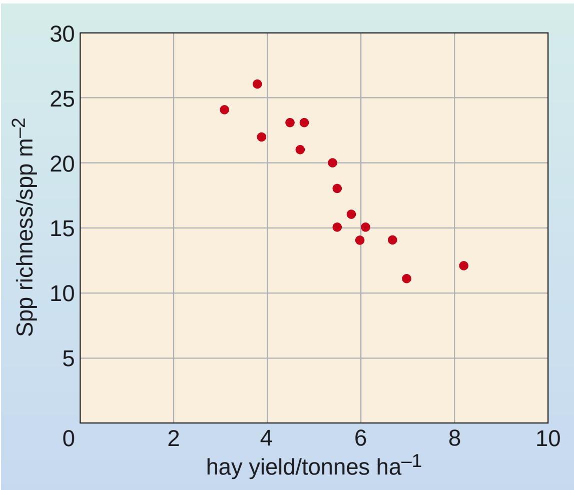


Figure 1 The relationship between plant species richness and the productivity of meadows.

(b) Describe the relationship between the two variables in Figure 1 and name a statistical test that could be used to determine the significance of the relationship.

Question 7

Which of the two distributions in Figure 2 has the greater variance?

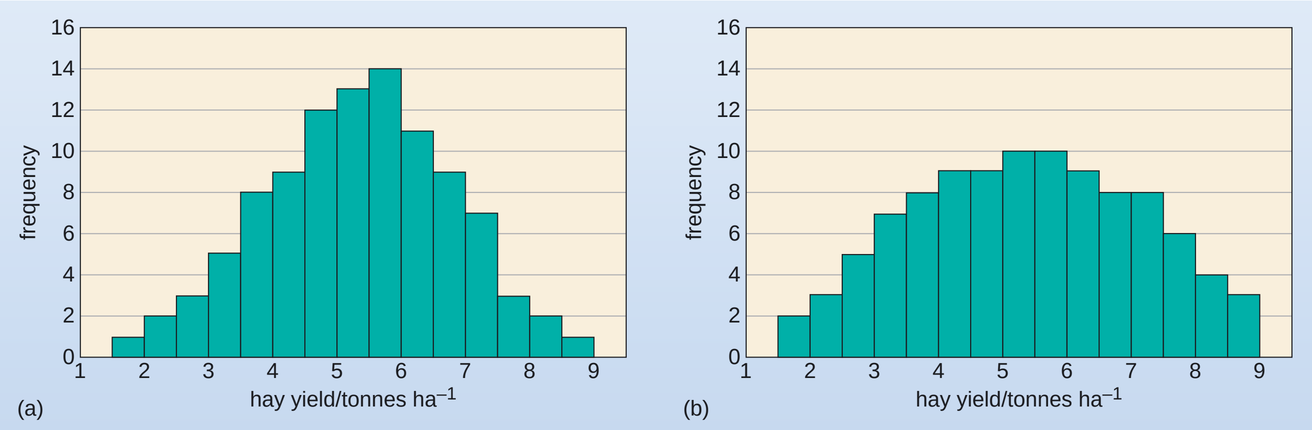


Figure 2 Variability in hay yield during the 20th century for (a) a floodplain meadow in Brabant, Belgium, and (b) a hillside meadow in Vermont, USA.

Question 8

Calculate the mean ($\bar{x}_1$), median (M), mode and standard deviation (σ_1) of the following set of data:

1.2, 1.8, 2.1, 2.2, 2.4, 2.4, 2.7, 3.3, 4.1, 4.8

Question 9

Calculate the mean ($\bar{x}_2$) and standard deviation (σ_2) of this second set:

0.8, 1.3, 1.6, 1.8, 1.8, 1.9, 2.0, 2.1, 2.5, 3.2

Apply the *t*-test (often referred to as Student's *t*-test) to determine whether the means of the two sets are significantly different. The formula you need to use is:

$$t = \frac{\bar{x}_1 - \bar{x}_2}{\sqrt{\frac{\sigma_1^2}{n_1} + \frac{\sigma_2^2}{n_2}}}$$

where $\bar{x}_1$ and $\bar{x}_2$ are the means of the two samples; σ_1 and σ_2 are the standard deviations of the two samples. If your value of t exceeds the critical value of 1.96, then you can conclude the two means are significantly different. If the value of t is smaller then you cannot.

5 Key concepts and self-assessed test for key concepts

This section outlines concepts that are developed in S396 and in which prior knowledge is either essential or helpful. Your knowledge of each of the concepts is tested in one or more of the questions in the self-assessed test that follows the list.

1. **Classification of organisms**: familiarity with the binomial system of labelling organisms. Awareness of the hierarchy of classification (kingdom, phylum, class, order, family, genus, species). (Question 10)
2. **Chemical formulae and notation**: familiarity with the symbols for common elements and with the conventions for chemical equations. (Question 11)
3. **Gas laws**: the relationships between mass, density, pressure and temperature. (Questions 11 and 12)
4. **Energy**: conservation of energy and its various forms and its transfer within biotic and abiotic systems. Familiarity with terms concerned with energy transfer through food webs, such as autotroph, heterotroph, assimilation, producer and consumer. (Questions 14, 15 and 19)
5. **Environmental conditions controlling species distributions**: species are restricted to areas where they can compete effectively for the resources they require (e.g. water, nutrients and light). (Questions 16, 17 and 18)

Self-assessed test for key concepts

Try the following questions. (The answers are in Section 9.) **You should spend no more than 1 hour on this part.**

Question 10

Name one difference between a prokaryotic and a eukaryotic cell and list the four main kingdoms into which eukaryotes are classified.

Question 11

Give the chemical formula of the gas consumed during photosynthesis. Describe the changes in the flux of this gas between a sunflower leaf and the surrounding atmosphere over a 24-hour diurnal cycle.

Question 12

Why does atmospheric pressure decrease with height? If you knew the pressure at a given altitude, how would you calculate the mass of air per unit area above that point?

Question 13

How does temperature typically change with altitude in the troposphere and the stratosphere?

Question 14

Describe how excess solar energy absorbed by tropical regions is transferred toward the polar regions.

Question 15

Define the terms transpiration and evapotranspiration. Why are these processes relevant to the energy budget of the ground surface?

Question 16

What is meant by the term limiting nutrient?

Question 17

What do you understand by the term biogeochemical cycling? Why is it important for life on Earth?

Question 18

Describe the soil profile in Figure 3, using standard terminology for its horizons.

Figure 3 A soil profile with a 1.5 m auger for scale.

Question 19

On Macquarrie Island in the south-west Pacific Ocean, the natural ecosystem was disturbed by humans through the introduction of rabbits and cats. These two species became major players in the energy flow of the island's terrestrial ecosystem. In its simplest form, the energy flow through the terrestrial food chain can be represented as:

Grass → Rabbit → Cat

(a) Identify the primary producer, the primary consumer and the secondary consumer.

(b) What eventually happens to all the energy assimilated by the cats?

When the rabbit population declined due to disease, the cats started eating ground-nesting sea birds instead, prompting conservationists to remove cats from the island. The population of rabbits then exploded and the grass cover on the island was severely reduced. Sea bird populations have recently declined as a result of soil erosion.

(c) Why was the biomass of grass affected by the removal of cats?

(d) Where do the sea birds fit into the food chain? Why do you think the huge rabbit population only affected them via soil erosion?

(e) In the absence of cats, will the rabbit population continue to expand?

6 Computing skills

A significant majority of S396, including the course text will be delivered online, so you will need access to a PC and the internet. You should therefore be familiar with some basic computer skills before starting. You will also need a PC to use the multimedia components of S396 and the course website, to read information on a range of websites (including searching for appropriate sites), to locate and download data and to participate in electronic forums with your tutor and other students.

There will be IT guidance within S396, especially in the more advanced uses of spreadsheets. In particular, you will need to be able to use spreadsheets to manipulate, analyse and present data.

You are also advised to be aware of **health and safety**. To get more advice on this, read *Advice for Using your Computer*, available from http://www.open.ac.uk/our-student-policies/ (see the Health and Safety section).

You should be able to do the tasks listed below.

Spreadsheet skills

- enter formulae into cells to conduct calculations
- plot a line or pie graph from a column of data
- plot a bar chart with error bars from a column of data
- plot a scatter (XY) chart from two sets of data and then add a trend line to the resultant scatterplot
- manipulate the sheet itself by adding or deleting rows and columns
- use functions to find the sum, mean and standard deviation of a column of figures
- cut and paste data from one spreadsheet to another
- paste numbers as values only or as underlying formulae.

Internet skills

- type or paste a url into Internet Explorer (or comparable internet browser)
- use a search engine to find websites containing keywords
- select and copy data from an external website into a spreadsheet on your PC.

If you are unsure whether you have the necessary skills, have a look at SAFARI, an online tutorial that will help you develop your information skills. This is available through the OU Library website, or directly from http://www.open.ac.uk/safari/index.php. All the IT skills you learn will be useful in other areas of your life, not just for your OU course, so it's worth spending the time.

If you're unsure about just one or two of the items above, you could try using the Help facility on your computer. Alternatively, experiment to work out how to do the task.

7 Other skills

Basic study skills – You will need to set aside on average about 12–13 hours per week to study this course. If you have not studied for some time, you should consider how you are going to manage your time whilst studying. Chapter 1 of *The Sciences Good Study Guide* (see Section 8 of this booklet) gives helpful suggestions on how to approach your return to study.

Writing skills – Although we do not ask you to write long essays on this course, we do expect you to produce short, well-structured and carefully argued answers. We usually ask you to write to a word limit, which means carefully selecting and extracting relevant information and presenting it clearly in your own words. If you have not been involved in writing activities for a while and feel out of practice, Chapters 2, 3 and 9 in *The Sciences Good Study Guide* are particularly helpful. Chapters 2 and 3 provide strategies for effective reading and note-taking, whilst Chapter 9 gives guidance on writing and assignments.

Data interpretation skills – Throughout the course we do expect you to produce well-structured and carefully argued answers, often based on a range of sources, including published papers, websites, tables, diagrams, photographs and maps. You will be presented with a large amount of data and statistics. You must therefore be selective and be able to recognise the critical information that you will need.

Getting back into reading – Most broadsheet newspapers contain articles from time to time that provide useful commentary on current issues in ecosystems, as do occasional issues of *New Scientist* and *Scientific American*, which should be freely available via the OU Library website. There are also an increasing number of good internet sites providing helpful information on a wide variety of ecosystems-related topics.

8 Further reading/revision

The basic chemical and biological concepts are covered in any good GCSE-level chemistry or biology textbook.

Chalmers, N. and Parker, P. (1986) *OU Project Guide: Fieldwork and statistics for ecological projects*, Field Studies Council. This book includes a large section on statistical tests.

Northedge, A., Thomas, J., Lane A. and Peasgood, A. (1997) *The Sciences Good Study Guide*, Milton Keynes, The Open University. This book includes a large 'maths help' section.

The Open University (2002) S216 *Environmental Science*, Blocks 2–4, Milton Keynes, The Open University.

The Open University (2003) SXR216 *Environmental Science in the Field*, Milton Keynes, The Open University.

Chapin, F. S., Matson, P. A. and Mooney, H. A. (2004) *Principles of Terrestrial Ecosystem Ecology,* Springer, Berlin.

The last book is used as a reader in the course itself. The book will be made freely available to students as an 'ebook' for reading online; however, you may prefer to purchase your own copy before the course starts, especially if you have difficulty reading online.

Your regional centre can provide details of where to find copies of the books listed, or you can buy some of them from: OU Worldwide, The Open University, Milton Keynes, MK7 6AA. Tel: 01908 658785; Fax: 01908 858787: email: ouwenq@open.ac.uk.

9 Answers to self-assessment questions

Question 1

$$A = \pi r^2$$

$$r^2 = \frac{A}{\pi}$$

$$r = \sqrt{\frac{A}{\pi}}$$

Question 2

0.00012 m is written as 1.2×10^{-4} m in scientific notation.

Cross-sectional area $\pi r^2 = 1.13 \times 10^{-8}\ \text{m}^2 = 1.13 \times 10^{-8} \times 10^6\ \text{mm}^2$

$= 1.13 \times 10^{-2}\ \text{mm}^2$

Question 3

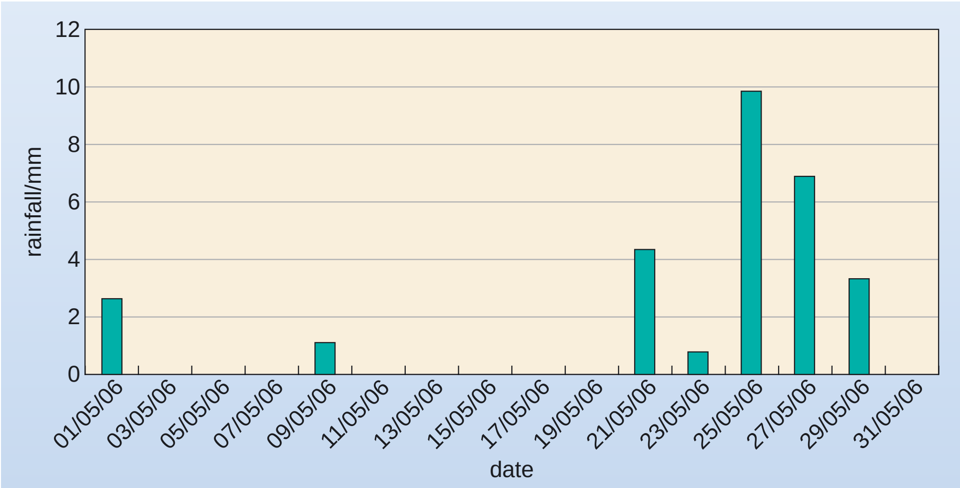
$426\ \text{mg m}^{-2} = 426 \times 10^{-9}\ \text{t m}^{-2} = 426 \times 10^{-9} \times 10^6\ \text{t km}^{-2}$

or $4.3 \times 10^{-1}\ \text{t km}^{-2}$ (to 2 significant figures in scientific notation).

Question 4

$$\frac{1.5 \times 10^{16}\ \text{kg}}{5.05 \times 10^{17}\ \text{kg y}^{-1}} = 0.0297\ \text{y} = 11\ \text{days (to 2 significant figures)}$$

Question 5



Question 6

(a) 20 species m^{-2}

(b) The relationship is an example of a negative correlation (as one variable increases, the other decreases.) A suitable method to test the statistical significance of this relationship is to calculate the Spearman Rank Correlation Coefficient.

Question 7

Distribution (b) has the greater variance as more values lie in the ranges further from the mean.

Question 8

$\bar{x} = 2.7$; $M = 2.4$; mode = 2.4; $\sigma = 1.08$

Question 9

$\bar{x}_2 = 1.9$

$\sigma_2 = 0.65$

$$t = \frac{2.7 - 1.9}{\sqrt{\frac{1.08^2}{10} + \frac{0.65^2}{10}}} = \frac{0.8}{0.4} = 2.0$$

As t exceeds the critical value of 1.96, you may conclude that the means of the two data sets are significantly different.

Question 10

The eukaryotic cell has genetic material organised into chromosomes OR it has membrane-bound organelles, such as mitochondria.

The four kingdoms into which eukaryotes are organised are *Plantae* (plants), *Animalia* (animals), *Fungi* and *Protoctista* (protists and algae).

Question 11

CO_2. During hours of daylight, CO_2 will enter the sunflower leaf down a concentration gradient because the gas is being consumed inside the leaf by photosynthetic reactions. During hours of darkness, CO_2 will leave the leaf down a concentration gradient (albeit more slowly as stomata are closed) because the gas is being produced inside the leaf by respiratory reactions.

Question 12

Pressure is force per unit area. In the atmosphere this force is almost entirely the gravitational force of the mass of air above, thus you would calculate the mass m of air from the relation $F = mg$, where F is the force and g is the acceleration due to gravity. Since pressure P is force *per unit area*, then the mass of atmosphere above a given point *per unit area* is:

$$m = \frac{P}{g}$$

Question 13

Temperature typically falls off with height in the troposphere and increases with height in the stratosphere.

Question 14

The excess of solar energy near the Equator is what drives atmospheric and oceanic motions, so atmospheric eddies (e.g. mid-latitude cyclones) and ocean current systems, such as the Gulf Stream, North Atlantic Drift and the global thermohaline circulation are responsible for the heat transport.

Question 15

Transpiration is the movement of water through plants from the soil to the atmosphere. Evapotranspiration is a combination of transpiration from vegetation with evaporation from other wet surfaces, such as the soil or bodies of open water. These processes are relevant to the energy status of the surface because evaporation requires energy, which it draws from the wet surface, thereby cooling it.

Question 16

A limiting nutrient is one whose availability is so low that an organism is forced to reduce or stop its growth as a result of being unable to access sufficient supplies. Growth will be restricted despite the abundance of other nutrients. In extreme cases, the organism may fail to reproduce, or it may even die. Increasing the supply of the nutrient will increase the growth rate of the organism.

Question 17

Biogeochemical cycling is the transformation of elements from one chemical compound to another as they pass through the biosphere and geosphere. It is important that these elements are recycled because there is a fixed supply – if they weren't recycled, the supply would become exhausted and life would cease.

Question 18

The soil profile is showing at least two clear horizons. The upper A horizon is more darkly coloured than the lower B horizon. This is probably as a result of a higher content of organic matter. There may be a shallow O horizon of organic matter overlying the A horizon, but this is not visible in the photograph. The B horizon is rather variable in colour, but appears deep with no evidence of the underlying C horizon of untransformed parental material beneath.

Question 19

(a) Grass is the primary producer; rabbit the primary consumer and cat the secondary consumer.

(b) The energy assimilated by cats is either respired by the cats, or goes into the detritivore food chain via either excretion/defecation or, when the cats die, their biomass being consumed by detritivores (e.g. carrion beetles). The corpses and waste products of all the organisms are eventually consumed by decomposers (e.g. fungi and bacteria). Virtually all the energy in the system is thereby eventually released as heat through respiration.

(c) Cats were consuming rabbits and thereby controlling their numbers by predation. The removal of cats allowed the rabbit population to expand until it was only limited by the availability of food (grass). As a result, the amount of grass on the island decreased due to rabbits consuming everything available.

(d) Sea birds (as their name suggests) feed from the ocean (e.g. on fish) and are therefore part of a separate food chain; a marine one rather than a terrestrial one. They do not eat grass and are therefore not in competition with the rabbits or the cats for food. The huge rabbit population did not affect them in terms of energy availability, but eventually it led to a significant abiotic effect (soil erosion) because the island's soil was largely held together by grass roots. This loss of soil caused sea bird populations to decline through a decrease in the availability of nesting sites.

(e) The size of the rabbit population will become limited by its food supply and may in fact decline over time if soil erosion causes a decrease in grass productivity.