Chapter 10

Hypothesis Testing in Ecology

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Introduction

Ecology is often a difficult subject to deal with in general biology laboratories because of the time needed to follow ecological trends, the complexity of ecological systems, and the relative lack of biological background in beginning students. Furthermore, students often need practice in devising hypotheses, designing valid experiments, and interpreting data. This simulation exercise, involving changes in a marine intertidal system, is based on the commercially available "Ecology Game" developed by Tribe and Peacock (copyright 1976, Cambridge University Press). It attempts to lead students to think about ecological principles and how they operate in real systems as well as to give students experience in analyzing, proposing, and testing hypotheses.

Students are presented with a set of observations concerning the relative abundance of several key organisms in two years along a stretch of British shore at Angle Bay (See Fig. 10.2 in Appendix A.) In 1960, green algae were scarce and limpets and barnacles abundant, while in 1967 at the same site green algae were found to be dramatically more abundant and limpets and barnacles scarce. Although students are not told at this point, these observations (and the whole exercise) are based on real data stemming from the Torrey Canyon oil spill and subsequent clean-up with detergents. Students are then asked to divide into discussion groups to investigate the extent and nature of changes in this system and potential causes of these changes. To do this, groups devise hypotheses and experiments to test their ideas. The instructor has access to a large set of data cards (the "Ecology Game" data bank) detailing extensive material that might in one way or another relate to the problem; when a group addresses specific questions or proposes valid, controlled experiments to the instructor, the proper data card is given to the group so that results are obtained as if the work proposed had actually been done. Students then must interpret the data they've acquired and modify initial hypotheses in light of these results. Many students get quite involved in the process, are intrigued by the complexity and interconnectedness of the real world, and are excited by thinking about novel marine organisms.

This exercise is suitable for use in general introductory courses where students have minimal ecological and taxonomic background, as well as in marine natural history courses or in more advanced ecology courses. We commonly use this in our introductory sequence for majors; it requires no previous knowledge of marine organisms or systems and little theoretical ecology background. If used in upper division courses where students have more background, more sophisticated hypotheses and experiments can be expected, but the basic exercise should work in much the same way.

Tribe and Peacock (1976) recommend spending 4–6 hours, in one and one-half hour blocks of time on this exercise. We usually spread this over parts of three 3-hour lab sessions: all of the first lab is devoted to introducing and starting the process, about 1/2–1 hour of the next week is given to continuing questioning, and about 1–1 1/2 hours of the third session goes to a summary discussion.

Since the basic data have been compiled and are available from Cambridge University Press no advanced knowledge of marine ecosystems is required of the instructor. For our purposes, some reorganization and simplification of the data given in the "Ecology Game" has been useful; adaptation of the basic data bank to particular circumstances may be necessary but should be readily possible. Naturally the exercise is most successful if the instructor has spent some time going over the available data, to know what type of information is available and where within the data bank to locate specific items, but lack of familiarity with marine systems should not hinder anyone from using this exercise with success.

Student Materials

Tribe and Peacock (1976) recommend starting students with no more information than the initial observations; however, we generally provide some additional information. Before lab, students are given general background information: a list of commonly encountered terms with definitions, a map of the area of interest, and brief natural histories of the most abundant organisms. (See Appendix A). This saves some time and allows students to start thinking about the problem before coming to lab.

Instructors' Materials

Procedures

1. This exercise works best if students can be divided into 4–5 groups of 4–5 students each, with the instructor then circulating among groups. Five is about the maximum number of groups one instructor can comfortably handle, and even then groups will experience some delay while the instructor is occupied with other groups. Fewer, larger groups allow more instructor attention per group but inhibit active participation by all students. Each group should be given a separate section of the room so that they can work independently.

2. A short explanation of the game, outlining procedures, rules, time limits, written report expectations, etc. begins the exercise. We show a short series of slides briefly introducing marine ecosystems and ecology, some of the more abundant organisms encountered, and general background material. A filmstrip to accompany the "Ecology Game" is available from Cambridge University Press, although other slides could easily be substituted. If the "Ecology Game" filmstrip is used the last several frames, showing oil and detergent on the beaches, should *not* be shown at this time but should be saved for the end discussion.

3. Discussion groups must digest the initial observations and background material and then begin deciding what other information would be useful. There are three general types of information available in the instructor's data bank:

a. General information in the public domain, available at most libraries (weather records, population changes, etc.).
b. Descriptive (sampling) data about a particular organism or locale (per cent cover of *Enteromorpha* spp. in 1965 at Angle Bay, nitrate levels in seawater in Angle Bay in 1960, etc.).
c. Experimental information, obtained only by performing a field or laboratory manipulation (respiration rates of various invertebrates under different conditions, effects of increased phosphate availability on plant growth).

General and descriptive data can simply be given to students who ask questions specific enough to allow selection of the relevant data card. However, experimental data should not be released until detailed hypotheses and valid controlled experiments have been proposed (either verbally or in writing). Instructors should refrain from directing or channeling groups since the primary challenge of the exercise is to stimulate critical, analytical thought; only when students are hopelessly lost should the instructor intervene. Students need to figure out for themselves what information is relevant and what not, what other factors might be involved, etc; therefore, any information that is available should be released without comment if it is requested in an unambiguous way.

If information is requested that is not available, the instructor can either tell the group that the information is not available and some other approach must be taken (after all, this often happens to investigators) or the information (or a biologically reasonable estimate) can be supplied from the instructor's own knowledge. We use both approaches depending on the question asked.

The major problem with the exercise is to prevent uncomfortable delays, as groups need more information and wait for access to the instructor. This can be minimized by supplying more initial information to all groups (although it is possible to supply too much), by encouraging groups to consider more than one hypothesis at once, and by requiring written experimental protocols before releasing experimental data.

Groups should be given a manila folder or envelope to keep their data together over the course of the exercise and should be advised not to write on the data cards so that they can be collected at the end and reused.

4. At the end of the exercise we set aside about one hour for a group summary discussion. Groups are asked to give short (5 minute or less) reports on what they've explored and conclusions reached. Typically, by the end of

the exercise most groups will have hit on oil pollution and the attendant detergent application as the primary cause of the decrease in the herbivorous invertebrates, which in turn led to the buildup in algal populations. Groups will have considered other physical factors, biological interactions such as competition and predation, and will be impressed with the far-reaching effects changes in one variable may have on the whole system. Groups will generally point out other contributing factors as well (such as effects of weather and season). The discussion can then broaden into a consideration of theoretical ecological principles and how they might apply, or to thoughts about oil pollution and its effects (lethal and sublethal), alternative clean-up methods, chronic vs. episodic pollution, etc.

5. There are several variations of the rules that might be applied:

a. "Grants". In the method outlined above, information is released as requested with no limits on the number of questions or on the complexity of the proposed experiments. Another approach would be to set a time or dollar cost on each piece of information and then give each group a time or monetary budget within which to operate. This makes students discriminate a bit more and set priorities on various lines of investigation; it also relates the exercise in a practical way to the real world. We have done this by assigning each data sheet an estimated cost (based on a guess as to how long it would take to find out the information and how skilled the experimenter would need to be) and by giving each group a fixed budget (but one large enough so that, in practice, no one is really inhibited from asking questions). Tribe & Peacock (1976) suggest a more elaborate exercise in which each group gets variable "grants" based partly on past performance (see b, below).
b. Written reports. We require a written summary report at the end of the exercise, and, sometimes, written experimental protocols before information is released. Tribe & Peacock (1976) suggest written reports at the end of each session, with these being used at least partly to determine how much of a "grant" in time or money to allot each group for the next session. They also encourage groups to "publish" short reports in an "Ecological Journal" so that groups can share results. Once a paper is "published" no other group can subsequently re-publish the same piece of work; groups also gain increases in their "grants" or "publication" efforts. This sounds like an interesting variation but is more complicated than we've attempted; it could be especially appropriate if used in an upper division course.

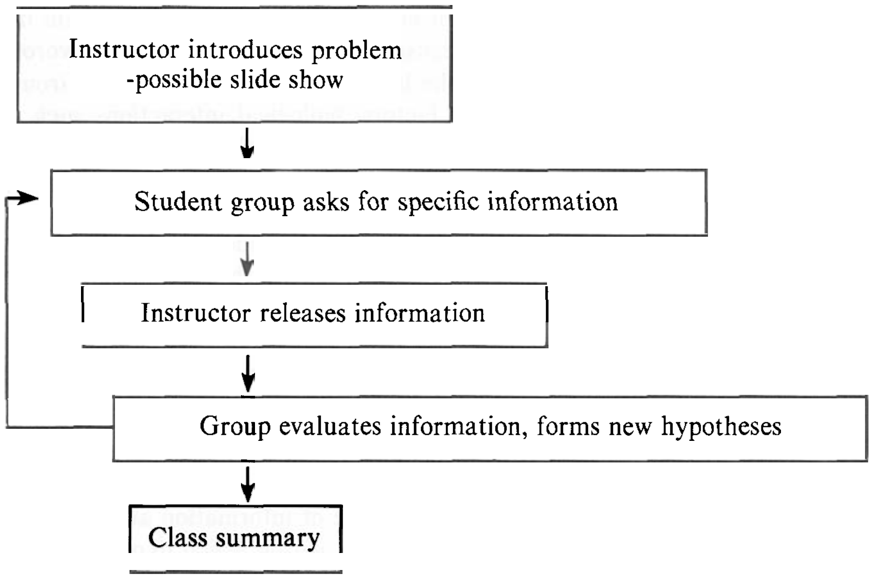

Figure 10.1. Flow diagram.

Supplies and Materials

"The Ecology Game" by Michael Tribe and Derek Peacock, copyright 1976 by Cambridge University Press, New York; includes instructor's guide and suggested student guide.
—1 copy per group

(Optional) "The Ecology Game Filmstrip" or other slide series introducing common marine organisms, zonation, intertidal ecology, etc.; projector and screen.

Folders—1 per group—for student data collections.

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Appendix A
Student Introduction to the Problem

The Observations

Visits to Angle Bay in July 1960 and July 1967 revealed the following very obvious changes in the abundance of several conspicuous organisms:

	1960	*1967*
% cover *Enteromorpha* spp.	< 5%	80%
% cover *Ulva* spp.	< 5%	40%
number of limpets (*Patella* spp.)/m^2	180	12
number of barnacles (*Balanus* sp.)/m^2	1600	1000

Your assignment is to investigate this change and to uncover as much information as possible about its cause(s). The following background information should prove helpful in thinking about the problem:

General Background Information

We are primarily concerned about the intertidal (= littoral) ecosystem. This is the area that is alternately exposed to air and covered by seawater, as the tidal level fluctuates.

The intertidal area is commonly divided into 3 zones: the high zone (which is exposed to air for long periods of time), the mid zone (which is exposed to air and is underwater about equal amounts of time), and the low zone (which is exposed to air only on quite low tides for a short period of time).

Some other terminology may be helpful:

Subtidal Zone—that area always underwater, never exposed to air
Benthic—attached to, or sitting on, the bottom
Plankton—plants and animals that are free-floating in the water column
Phytoplankton—plant component of the plankton
Zooplankton—animal component of the plankton

A map of the general Angle Bay area may be useful:

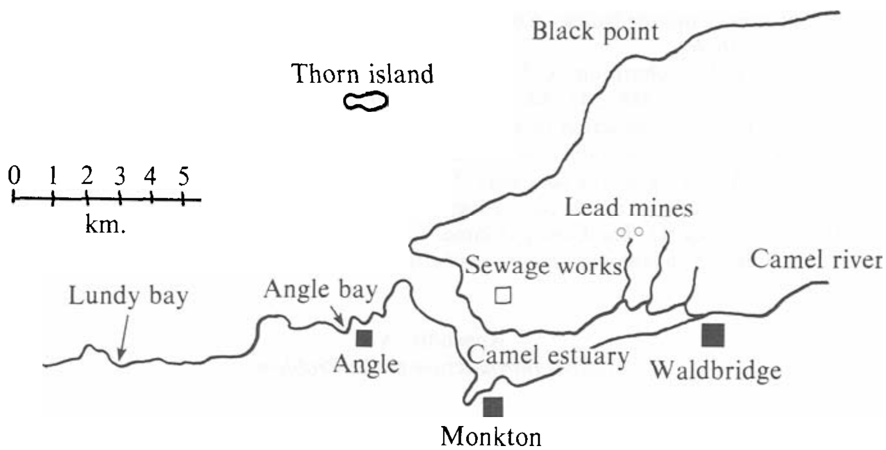

Figure 10.2. A map of the general Angle Bay area. (From "The Ecology Game," M. Tribe and D. Peacock, copyright 1976 by Cambridge University Press. Reprinted with permission.)

Biological Background

Algae

Algae are divided into 5 main groups; two of these (the blue-green algae and the diatoms) are microscopic and are important members of the phytoplankton, although many species are benthic as well.

Large algae (seaweeds) belong to the remaining 3 groups: the green algae, the brown algae, and the red algae. The groups are divided on the basis of the photosynthetic pigments present in each, the kind of storage products produced, and other biochemical and structural differences.

Algae are zoned within the subtidal-intertidal area; that is, different species are characteristically found at different tidal levels. This zonation is related to the physiological tolerances of various species as well as biological interaction between algal species (competition) and between algae and marine invertebrates (competition for space, grazing).

There are two types of life cycles common among algae. Many species are annuals; they live less than one year. Many annuals die off in the autumn, and new plants are generated from spores that germinate in the spring. Growth is fast but restricted to one season, generally spring or summer.

Other seaweeds are perennials (they live more than one year). Growth is generally slower but continuous throughout the year. Some perennials may partially die back in autumn and wither, but basal portions regenerate in the spring.

A few of the more common algal species follow:

Green Algae

1. *Enteromorpha* spp.—This is a fast growing annual, very common on intertidal rocks at all tidal levels; it frequently grows on other plants as well. It is shaped like soft, papery tubes, 5–15 cm long and 3–6 mm in diameter. Reproduction (and settlement) can take place at any time of year.
2. *Ulva* sp. (sea lettuce)—This is very similar to *Enteromorpha* but is a flat sheet instead of a tube.

Brown Algae

1. *Pelvetia* sp.—This is a robust, leathery plant, 15–20 cm long, found in the high intertidal zone. Gametes are released in late summer; plants are perennial.
2. *Fucus* spp.—Very similar to *Pelvetia;* found in the high-mid intertidal zone.
3. *Laminaria* sp.—Another large, leathery perennial that reproduces in summer; found only in the low intertidal (and subtidal) zones.

Red Algae

1. *Porphyra* spp.—A papery sheet, found primarily at high to mid tidal levels; this is an annual and is often found growing on other algae as well as directly on the rock surface. Some species are common only in winter and others only in the spring.
2. *Chondrus* sp.—A short, tough species that forms a carpet at low tidal levels. It is perennial and reproduces in late summer.

Invertebrates

Most intertidal animals are invertebrates (animals without backbones). There are many phyla that may be encountered on intertidal rocks; a few of the more common animals are discussed below:

Barnacles (Arthropod crustaceans)

These are stationary once they settle on a rock surface. They are small (< 1.3 cm in diameter) and covered by calcareous plates. These can be opened when the animal is underwater and feathery appendages filter plankton (primarily diatoms) from the water. Barnacles reproduce in early spring, and produce planktonic larvae. These float in the water column for a while but soon select a spot on the rock surface and attach. Their main predators are drills and starfish. Barnacles rarely live more than 1–2 years.

Two species are common in Angle Bay: *Chthamalus* sp., which occupies the high intertidal zone, and *Balanus* sp., which occupies the mid zone.

Limpets (Molluscan gastropods)

Limpets are intertidal snails having a flat shield-like shell. They are capable of moving up to a meter/day but rarely do so; generally, they return to the same place on the rock ("home"). Their shape and their strong muscular foot (which enables them to cling tightly to the rocks) allow limpets to withstand violent wave action. Limpets are herbivorous, scraping the rock surface for diatoms and newly-germinated sporelings (very small plants); they rarely eat macroscopic (large) algae. Limpets spawn (shed gametes) primarily in winter. The larvae are planktonic for a short time (1–2 weeks) and then metamorphose into a crawling stage that settles on the rock. They rarely live more than 1–2 years, although a few large individuals may be 10–15 years old. Their main predators are starfish and birds (especially oystercatchers).

There are several species of the genus *Patella* that range from high to low intertidal zones; we will not differentiate between these species.

Periwinkles (Molluscan gastropods)

Periwinkles, or littorines, are small, very abundant snails found primarily at high to mid intertidal levels; there are several species in this group, but these will not be differentiated here. Littorines are highly mobile and do not home. They are herbivorous, primarily on microscopic diatoms and young sporelings, but may graze larger algae as well (although they inflict little damage on large plants). They reproduce in early spring; some species have planktonic larvae (which spend only a short time in the plankton before settling out), and others have non-planktonic (benthic) larvae. Periwinkles generally live 1–2 years; their main predators are starfish, drills, and birds (especially rock pipits and gulls).

Top-Shells (Molluscan gastropods)

Two genera of top-shells (snails) are common in Angle Bay: *Gibbula* spp. (which is found in the high-mid zone) and *Monodonta* sp. (at mid-low levels). These are mobile, non-homing snails. They are herbivorous, feeding primarily on brown algae *(Fucus, Laminaria);* since a large part of their diet consists of drift algae (macroscopic algae that has been ripped off the rock surface by wave action and is beginning to decay) they also qualify as scavengers. They reproduce in the spring; larvae spend some time (1–2 months) in the plankton. Top-shells may live to be quite old (15–20 years is not uncommon). Their main predators are birds (oystercatchers, rock pipits, and gulls) and starfish.

Drills (Molluscan gastropods)

Drills (*Thais* sp.) are snails that inhabit mid to low tidal levels. They do not "home" but rarely move more than one m/day. They tend to return to the same spot year-after-year to reproduce. They lay benthic egg capsules in late winter and early spring. The young hatch from these in several months (there is no planktonic larva); average life span is 4–5 years. Drills are carnivorous and feed on barnacles, mussels (clams) and, occasionally, top-shells; they bore through the shell with a highly modified boring organ and suck out the soft body contents inside (hence the common name "drills"). In turn, they are eaten by birds (gulls and oystercatchers).