Biology 160 Pre-proposal format
(see example below - note that the example is more than you need to do).

Introduction - Introduce the reader to the question you want to address. Convince the reader that the question is ecologically interesting and important. For example, if the pattern has to do with zonation, start by explaining why ecologists are interested in studying what ecological processes create zonation and how that work has contributed to the field of ecology. The same thing holds for changes in abundance over time (i.e. dynamics). Ecologists are keen to understand what causes change in population size, why populations of some species are more dynamic than others, and how populations are able to avoid extinction. [The introduction section will be much more important in the full proposal - here we want a very brief section].

Pattern - Completely describe the pattern(s) and associated observations. Make sure that you graph the pattern. Remember the X axis is generally for the INDEPENDENT variable (or the one suspected as being independent) and the Y axis is for the dependent variable (or the one suspected as being dependent upon values of the independent variable).

Goal - Succinctly state the goal of the project.

Hypotheses section - You are required to have at least two general hypotheses and four specific hypotheses. These can come in many different arrangements (e.g., two specific for each of two general hypotheses, 3 specific for one general hypothesis and one specific for the other general hypothesis). Where appropriate, think about testing for generality of and mechanisms for the patterns (see below).
Introduction
In recent years there has been considerable controversy regarding both: (1) the evidence for global warming and, (2) what would count as evidence for global warming. The implications of this controversy are clear: changes in the distributional patterns of species will not be accepted by the scientific community as evidence for global warming as a process affecting the organization of populations and communities until alternative hypotheses for such shifts are tested.

Theory suggests that species at the limits of their ranges or those in harsh environments should be among the first to show the effects of a warming (or cooling) trend. The intertidal community in the northern Gulf of California combines both of those features and therefore should be a model system for testing predictions about shifts in species distributions caused by global warming. It is the northern limit of the range for most of the intertidal species in the community and it is one of the harshest places on earth. In the summer, daytime air temperatures routinely are above 40° C and rock surface temperatures often are greater than 50° C. In the winter temperatures can drop below 0° C. Such extremes in temperatures combined with the large tidal amplitude (>7 meters) suggest that individual organisms are at the limits of their physiological tolerances and species boundaries reflect these limits.

Pattern
Over the period 1985 - 1988 I sampled the cover of the barnacle species, Chthamalus anisopoma, at least quarterly in replicate plots throughout the intertidal zone at Pelican Point (Punto Pelicano), in the northern Gulf of California. During that period the vertical distribution of Chthamalus, was between 0 and 2.5 meters above mean low water (MLW - see figure). At no time during that period did cover in any plot between 0 and 2.5 m (MLW) drop below 50 %. In June of 1995 I sampled the same plots and found that the upper limit of the distribution of Chthamalus had dropped by over 1 meter (see figure). Replacing Chthamalus in the upper intertidal (above 1.3 m) was the blue green bacteria, Calothrix crustacea, a species that in 1985-1988 occurred much higher in the tidal zone. Average temperatures during the interval 1988 - 1994, a period when Chthamalus was not sampled, were the highest recorded in the northern Gulf of California.
Goal
The goal of this project is to determine if the processes determining the current upper limit of the
distribution of *Chthamalus anisopoma* are the same as in 1985-1988. During that period the upper limit
was determined by a complex interaction between settlement behavior, competition (exploitative) with
*Calothrix*, and severe post-settlement mortality from desiccation/thermal stress. Specifically: (1)
*Chthamalus* did not ever settle on *Calothrix* (which dominates the zone above *Chthamalus*), (2) would not
settle above the adult distribution unless *Calothrix* was removed and a settlement inducer was applied
(causing larval settlement behavior in the cyprid larvae) and, (3) could not survive to adulthood above the
normal adult upper limit unless there was relief from desiccation/thermal stress. Hence the settlement
behavior (don’t settle above the upper limit) was reinforced by post-settlement mortality.

There would be support for the idea that regional changes in environmental conditions (e.g., global
warming) is occurring if the processes determining the upper limit of *Chthamalus* were the same
now as in 1985-1988. This would indicate that the ecology is the same but that the stress imposed
by the environment has increased - resulting in a shift, down, in zonation.

HYPOTHESES

Generality of Patterns

General hypothesis - The pattern seen at Pelican Point is representative of other sites in the northern Gulf
of California.

This hypothesis is here to test the generality of the pattern. If this pattern only occurred at one site -
Pelican Point - then hypotheses about mechanisms based on the assumption of regional effects - say
distributional shifts caused by global warming - would probably not be reasonable. Other, more
site specific, hypotheses - say local geological uplifting - would then be proposed.

Specific hypothesis - For other sites in the northern Gulf of California, the upper limit of the distribution
of *Chthamalus* is lower now than when originally surveyed (all surveyed between 1980 and 1989), and the
shift in distribution at these sites is similar to that seen at Pelican Point.

Note that this is a testable hypothesis

Mechanisms for Patterns

These hypotheses will test for specific mechanisms causing the observed pattern

General hypothesis (1) - Settlement determines the current upper limit of the adult distribution of
*Chthamalus*.

General hypothesis (2) - Desiccation (or thermal stress or UV etc.), leading to mortality, determines the
current upper limit of the adult distribution of *Chthamalus*.

General hypothesis (3) - *Calothrix* outcompetes and excludes *Chthamalus* above 1.3 m (MLW) and hence
determines its current upper limit.

General hypothesis (4) - The current upper limit of the adult distribution of *Chthamalus* is determined by
an interaction between desiccation, competition (with *Calothrix*) and settlement.

As examples

1) Assume I find (as I did in 1988) that larvae don’t settle above the adult upper limits (they will
settle just above the fringe but no more than 1 - 2 cm above the established upper limit) - indicating
that the upper limit is generally set by settlement. The question still must be asked - how did the
upper limit become lower. One possible explanation is that increasing environmental harshness caused post-settlement mortality (say from desiccation) and reduced the limit dramatically and that it can’t go back up because of the gregarious settlement response (settling next to conspecifics) coupled with continued increased desiccation stress in areas above the current and within the former distribution of Chthamalus (this is sort of the global warming hypothesis).

2) Assume I find (as I did in 1988) that Chthamalus can’t settle on Calothrix. The current upper limit of Chthamalus could be caused by the combination of exploitation of space by Calothrix (still to be answered is how Calothrix moved down in the zone) coupled with inability to settle on occupied space by Chthamalus and requirement for conspecific settlement cues. If this is the case then the upper limit could experimentally be moved back up by removing Calothrix and inducing Chthamalus settlement to the cleared areas.

3) Following on from (2). If the processes are all the same as in 1985-1988 (see Goal) then the current upper limit of Chthamalus could be caused by a combination of settlement behavior, exploitation of space by Calothrix and post-settlement mortality from desiccation/thermal stress.

**Specific hypothesis (1)** - Settlement only occurs at sites within the current adult distribution of Chthamalus.

**Specific hypothesis (2)** - Mortality of newly settled or juvenile Chthamalus is greater in sites above the current adult distribution of Chthamalus compared to that within the current adult distribution. (This assumes that individuals settle above the current adult distribution).

**Specific hypothesis (3)** - In areas above the current distribution of Chthamalus but within its past distribution, Chthamalus will settle and survive to maturity in sites cleared of Calothrix and not in control sites (areas where Calothrix is left unmanipulated).

**Specific hypothesis (4)** - Specific hypotheses could be posed for a number of things (see table below). For example 1 (see above), the hypothesis is that Chthamalus density will be greatest in treatments e and f (settlement inducer, no desiccation) than in the rest because in all the former treatments a settlement inducer will be used in conjunction with relief from desiccation in areas above the current and within the former distribution of Chthamalus. For example 2, we would compare b and f (settlement inducer, no competition) to the rest. A series of other specific hypotheses could be tested using this design. For example 3 (same processes now and in 1985-1988) we would compare survivorship to maturity in treatment f to all other treatments (induced settlement behavior, no competition, relief from desiccation). The prediction is that there would be survivorship to maturity only in treatment f.

*Note that:*

1) specific hypothesis (1) could be tested as part of the design shown below (a,b,e,f) vs (c,d,g,h): treatments with inducer vs treatments without inducer.

2) specific hypothesis (2) could be tested as part of the design shown below (a,b,c,d) vs (e,f,g,h): treatments with desiccation vs treatments without desiccation.

3) specific hypothesis (3) could be tested as part of the design shown below (b,f,d,h) vs (a,e,c,g): treatments with no competitor vs treatments with the competitor.
Table 1: Design of experiments to test a series of specific hypotheses. In the table above all treatments (a-h) are done in areas above the current and within the former distribution of *Chthamalus*. Plus’s and minus’s enter in the following order: First, presence or absence (+,-) of settlement inducer. Second: competition (*Calothrix* removed = -, *Calothrix* left alone = +). Third, desiccation (desiccation diminished = -, desiccation not diminished = +). For example, treatment b has settlement inducer present at an area without *Calothrix* and with desiccation.

**Extension of the pattern in time**

**General hypothesis** - If the shift in the distribution reflects a response to changing environmental conditions then the upper limit of the distribution of *Chthamalus* should continue to decrease.

*The expectation here is that the shift will continue over an ecological time frame - years - because the observed shift was detectable over such a period.*

**Specific hypothesis** - Density of *Chthamalus* in plots currently at its upper limit will decrease relative to plots lower in its distribution.