The Logical Structure of Hypothesis Testing in Ecological Research

Observation (p. 366): who, what, when, where
Detection of / departure from pattern
Experimental result
Observation

Models (p. 367): how, why
A legitimate possible explanation for the observations
Deal with processes, mechanisms
Usually several models can be formulated, each consistent with observations
(these are the multiple working hypotheses of Chamberlin, Platt)

Logical Hypotheses (predictions, deductions) (p. 367)
Predictions must meet the following criteria:
1. If the model is correct, then under some new set of circumstances, specific predicted observations will occur.
   The deducibility criteria of Giere: If H then P
   If the prediction is logically deduced from the model:
   It is impossible for the prediction to be false and the model true;
   If the prediction is false the model is false (Not P thus not H).
   If history subsequently shows the model to be true even though the prediction was false then the prediction was not logically deduced from the model.

2. Predictions most different from those deduced from possible alternative models should be the ones chosen for further examination
"The most profitable method of research is to devise as many models as possible, and then to deduce from each the most different hypotheses (predictions), because this provides the maximum possibility of contrasting the various models." (p. 367)

The improbability criteria of Giere: If not H, then (very probably) not P
If the prediction is improbable, then:
   The prediction will not be consistent with any other model;
   If the predictions is true, then very probably the model is true P thus (very probably) H
If history subsequently shows the model to be false even though the prediction was true, then the prediction was consistent with another model and not improbable.

Proof and Disproof (p. 368)
Proof only possible for the most trivial hypotheses.
Huge imbalance between the onerous burden of proof and the relative simplicity of disproof which requires only one contradiction.
modus tollendo tollens = logical basis of disproof (= refuting argument of Giere)

    from Underwood:       from Giere:
    If Ho then data.       If H then P.
    Other data.            Not P.
    Thus not Ho.           Thus, not H.
Logical Null Hypotheses (p. 369)
A tool for justification.
Logical hypotheses cannot be proven true, but they can be inverted to form logical null hypotheses.
Logical Null Hypothesis: comprises all alternative possibilities to those predicted by logical hypothesis.
Thus, logical null hypothesis excludes only the stated hypothesis.

Example:
Logical Hypothesis: population size will increase when predators are removed.
Logical Null Hypothesis: populations size will not change, or will decrease

Disproving the Logical Null Hypothesis leaves the Logical Hypothesis (prediction) as the only possibility without having to prove it.

The hypothesis (prediction) is not proven, rather all other alternatives are disproved.

Logical Null Hypothesis vs Statistical Null Hypothesis (p. 370)
In many cases, sampling and statistical analyses are required to determine the correctness of the prediction.

When the Statistical Null Hypothesis is derived from (equals) the Logical Null Hypothesis:
Refutation of the Statistical Null Hypothesis supports the Theoretical Model because its prediction (hypothesis) has been found true.

This support requires the use of the Justifying Argument, a point not adequately addressed by Underwood.

Tests (experiments, critical evaluations) (p. 370)
Objective of experiment: provide critical test of the model
Critical (Galilean) Tests: contrast predictions with observations made during the experiment (p. 371)

Conclusions (interpretations or inference) (p. 371)
1. reject null hypothesis = support model (result consistent with prediction)
   "Rejection of a null hypothesis is support for the hypothesis, because the logic of rejection is sound and a refutationists (falsification) test has eliminated the alternatives..." (p. 371)
   Why? because prediction is inconsistent with other models, i.e. improbable
   This allows support via the justifying argument of Giere
   Key Point:
   Rejection of the statistical null hypothesis supports the Model because it uses the refuting argument to eliminate all alternatives to the prediction, thereby leaving the prediction as the only possibility. Confirmation of the prediction supports the model using the justifying argument of Giere (assuming no experimental artefacts are responsible for the outcome; i.e., experiment is properly designed and controlled (the verifiability criteria of Giere)
   Next step: refine model adding more precision or generality

2. do not reject null hypothesis = reject model (result inconsistent with prediction)
   via the refuting argument of Giere (modus tollendo tollens)
   Key Point:
   Failure to reject the statistical null hypothesis falsifies the Model because it fails to disprove the alternatives to the prediction, and thus disproves the prediction. Failure to support the prediction falsifies the Model using the Refuting Argument of Giere (assuming no experimental artifacts are responsible for the outcome; i.e., experiment is properly designed and controlled (the verifiability criteria of Giere)
   next step: add new observations to previous and construct new model, accounting for entire set of observations
Problems for Interpretation (p. 372)
Experiments often require statistics to determine whether or not null hypotheses should be retained

Two possible statistical errors
Type I: correct null hypothesis is rejected (difference found when none exists) probability is known; determined \textit{a priori}
Type II: false null hypothesis is not rejected (no difference found when one exists) probability (power of test) is generally unknown

Interactions of Logical and Statistical Problems (modification of Underwood Table 3, p. 374)

<table>
<thead>
<tr>
<th>TRUTH</th>
<th>EXPERIMENTAL RESULT</th>
<th>CONCLUSION</th>
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<tbody>
<tr>
<td><strong>Correct Logical Inferences</strong></td>
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<tr>
<td>Case 1</td>
<td>Model True</td>
<td>Null Hypothesis Rejected</td>
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<td></td>
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<td>Prediction is found correctly to be true.</td>
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<tr>
<td>Case 8</td>
<td>Model False</td>
<td>Null Hypothesis Retained</td>
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<td>Prediction is found correctly to be false.</td>
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<tr>
<td><strong>Statistical Errors Lead to Incorrect Conclusions</strong></td>
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<tr>
<td>Case 2</td>
<td>Model True</td>
<td>Null Hypothesis Retained</td>
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<tr>
<td></td>
<td></td>
<td>Prediction is found incorrectly to be false (Type II Statistical Error)</td>
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<tr>
<td>Case 7</td>
<td>Model False</td>
<td>Null Hypothesis Rejected</td>
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<tr>
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<td>Prediction is found incorrectly to be true (Type I Statistical Error)</td>
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<tr>
<td><strong>Logical Errors Lead to Incorrect Conclusions</strong></td>
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<tr>
<td>Case 4</td>
<td>Model True</td>
<td>Null Hypothesis Retained</td>
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<td></td>
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<td>Prediction is found correctly to be false: Fails “deducibility” standard of Giere</td>
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<tr>
<td>Case 5</td>
<td>Model False</td>
<td>Null Hypothesis Rejected</td>
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<tr>
<td></td>
<td></td>
<td>Prediction is found correctly to be true but fails “improbability” standard of Giere (other models share prediction)</td>
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<tr>
<td><strong>Logical and Statistical Errors in Combination: Two Wrongs Make a Right</strong></td>
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<tr>
<td>Case 3</td>
<td>Model True</td>
<td>Null Hypothesis Rejected</td>
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<tr>
<td></td>
<td></td>
<td>Prediction is found incorrectly to be true: Logical error cancelled by Type I Statistical Error</td>
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<td>Case 6</td>
<td>Model False</td>
<td>Null Hypothesis Retained</td>
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<tr>
<td></td>
<td></td>
<td>Prediction is found incorrectly to be false: Logical error cancelled by Type II Statistical Error</td>
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Note: Typographical errors in Underwood paper
Caption Fig. 3 (p. 374) should read ".... when the logical null hypothesis is the same as the statistical null hypothesis." (delete "not")

Caption Fig. 4 (p. 381) should read ".... when the logical null hypothesis is \textbf{not} the same as the statistical null hypothesis." (insert "not")