Regression Analysis: Linear, Logistic and Mixed Models

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We are confronted by insurmountable opportunities: Novel statistics for entomologists

Regression analysis

- Predict outcome (dependent variable) from one or more independent variables
- Implies causality
- Used to explore relationships and assess contributions
- Models developed for explicit prediction

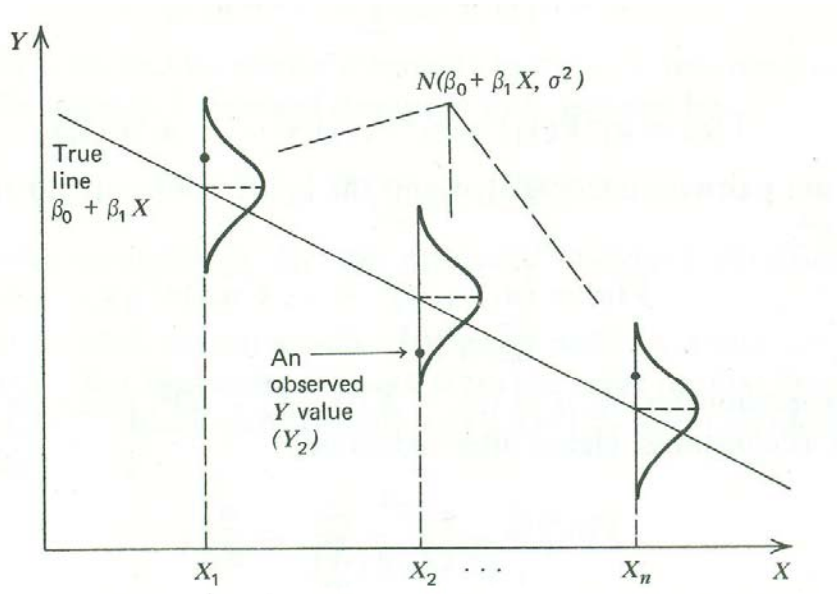
Familiar “types”

- Multiple regression
- Logistic regression
- Stepwise regression
- GLM: generalized linear models
- GLMM: generalized linear mixed models

"Traditional" Linear regression

- Dependent and independent variables
  - Numerical: continuous or ordinal
  - Fixed effects model
    - All levels /entire region of interest

    Included in x range
- Normal distribution for errors
- Single dependent variable
- Can be simple, single variable
  - $Y=b_0 + b_1x + \varepsilon$
- Or complex
  - $Y=b_0 + b_1x_1 + b_2x_2 +\ldots+ b_{ij}x_i*x_j + \varepsilon$
  - Multivariate, interactions



“Traditional”: Criteria for fitting model

- Hypothesis testing approach
  - F test, R^2
  - Are coefficients significantly different from 0?
  - Does variable make a significant contribution to the model?

Model Selection

- Main effects
- Interactions to specified level
  - Power issues
- Full model
- Stepwise selection

Only a single model is ultimately considered

GLM

- Generalized linear models
  - Extensions of fixed effects linear models
  - Used where standard assumptions are violated
    - Normal distributions
  - Use a link function to link a linear model to the mean of Y
    - Based on distribution of Y
  - Common distribution
    - Binomial: logit link

Logistic regression

- Form of dependent variable: Binary
  - Binomial distribution
  - 0 or 1, often coding for qualitative result
    - Infected or not
    - Present or not
- Probability that y=1
  - $p(y=1) = \pi$
- Logit link
  - $\text{Log}(\pi / 1 - \pi) = b_0 + b_1 x_1 + b_2 x_2 + \ldots$

Logistic - interpretation

- Probability of a "1" response given predictor variables
- Expressed as likelihood of an event
- Odds ratios (or log odds ratios)
  - Odds of a "1" response with one X over another
  - More common with levels of X rather than continuous

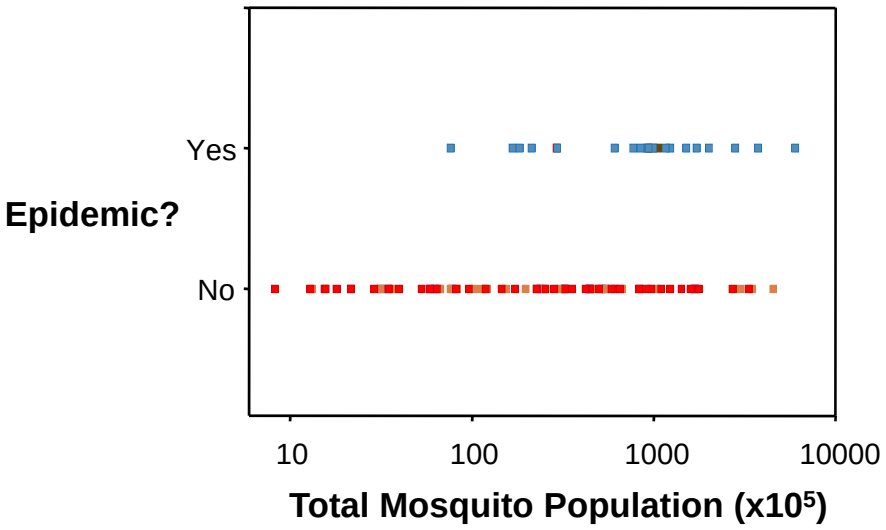
Example: logistic stepwise regression

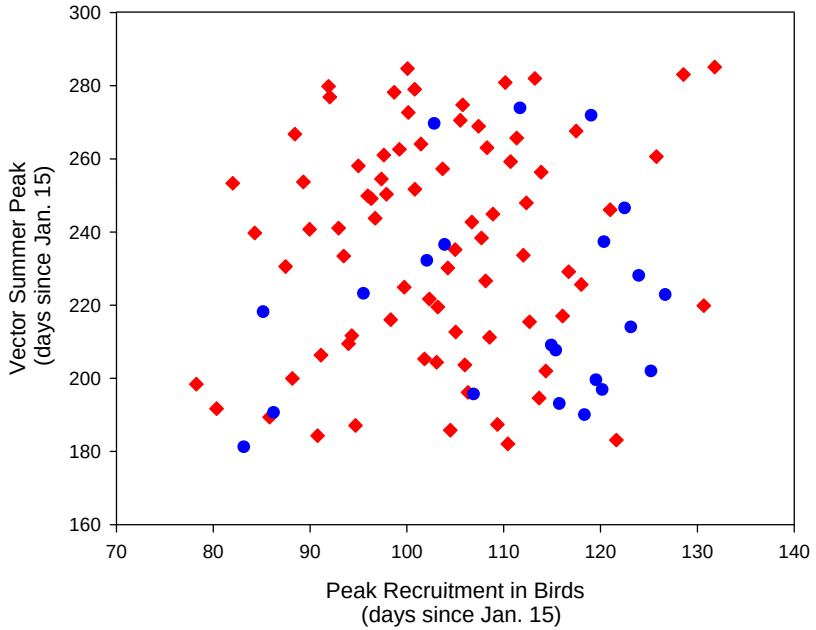
- Data from simulation model: St. Louis Encephalitis virus
- Outcome (dependent variable): epidemic or not
  - Epidemic = 1
  - Not epidemic = 0
- 14 input parameters as independent variables
- Sampled from defined parameter space
  - Fixed effects
- Main effects only, no interactions
  - Power of data with n=100 and many independent variables

Example: Stepwise logistic regression

Logistic Model $R^2 = 0.34$

Mosquito population
Mosquito mortality (baseline)





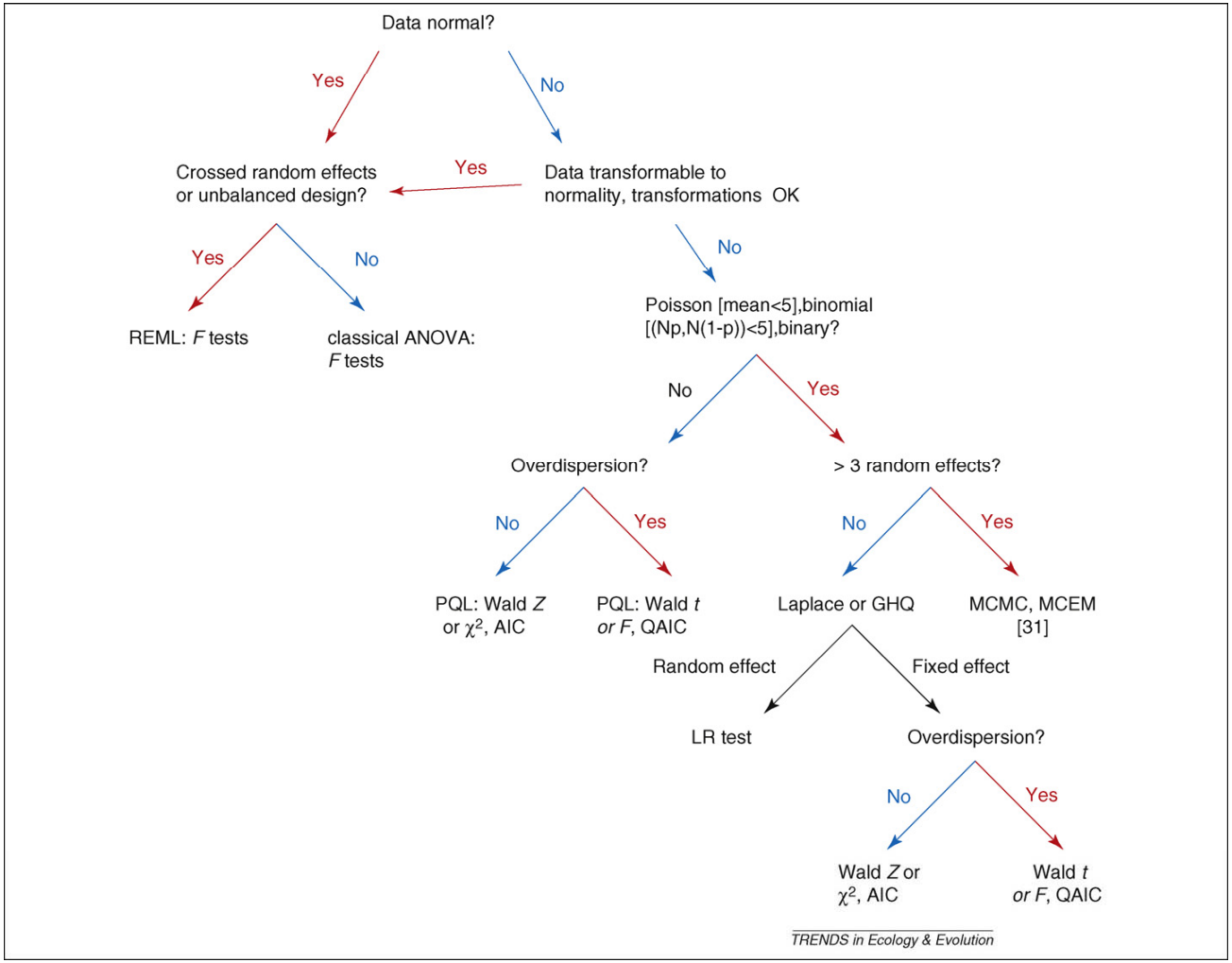
Time of peak bird recruitment
Time of summer peak in mosquitoes

Generalized Linear Mixed Models

- GLM
  - Fixed effects
- Random effects
  - Independent variable is considered random if its levels plausibly represent a larger population with a probability distribution

GLMM models

Depends on:
Distribution of variables
Design of study
Variance structure



Bolker et al. 2008.
TREE 24: 127-135

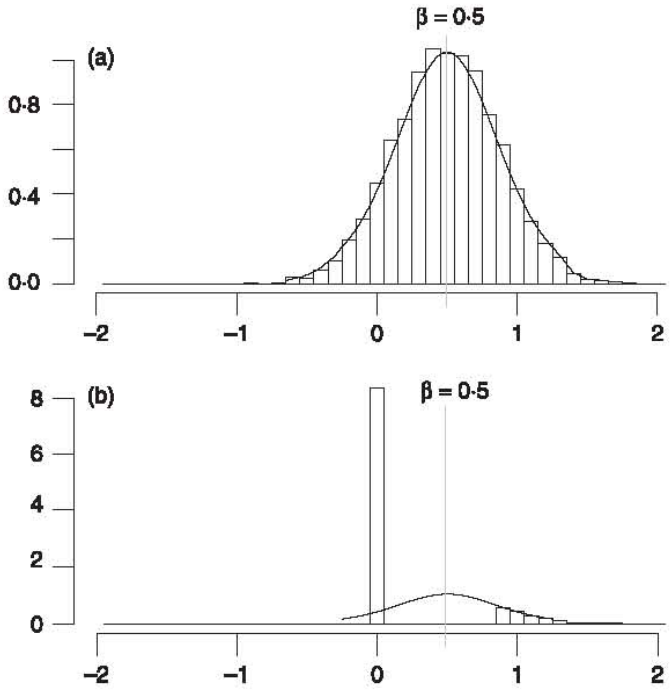
Bias in parameter estimation

Hypothesis testing: If coefficient is not significant, it is treated as 0

Simulation study:
Y=1 + 0.5*x +e
e~N(0,1)
n = 10
Regression model fit

Slope tested using hypothesis testing

Slope = 0 accepted if p<0.05



Distribution of slopes from models fit

Distribution of slopes from hypothesis testing model selection

Whittingham et al. 2006. J. Anim. Ecol. 75: 1182-1189

Stepwise regression

- Entry of independent variables sequentially
- Test for exit of entered variables
- Can be done using hypothesis testing or model selection methods
  - Choice of criteria used
- Penalty for increased complexity
- In hypothesis testing, modified by stringency for entry & exit

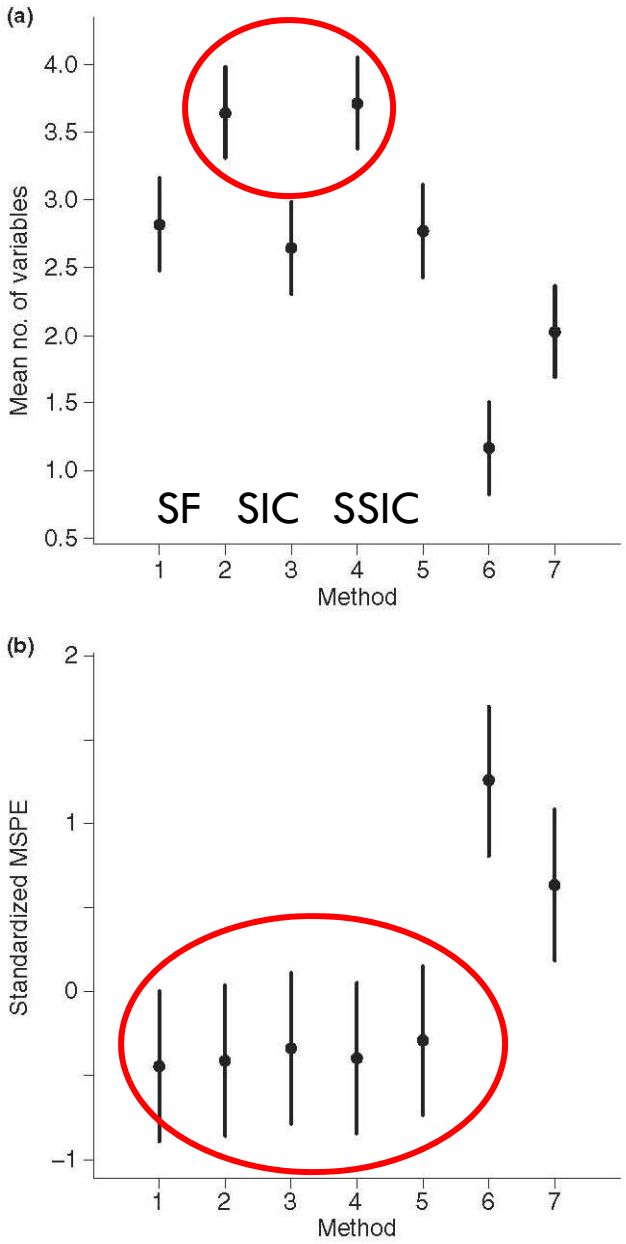
Issues in stepwise regression

- Hypothesis testing
  - Involves many sequential tests
  - Type I (false positive) errors inflated
  - Also affects distribution of F-statistic
  - Overall significance of the final model affected
- Fits single model with no assessment of whether others would have similar predictive ability

Variable selection methods

- Stepwise selection with hypothesis testing
- Stepwise selection with information criteria
  - AIC
  - BIC
- All subsets and examine for fit
- All penalize model for increased complexity
- Do methods bias towards increased complexity?

12 data sets
Reanalyzed using
1: Stepwise F test
2: Stepwise AIC
3: Stepwise BIC
4: All subset AIC
5: All subset BIC
6: Regression tree A
7: Regression tree B



Models produced by IC methods included more variables

Models produced by IC and stepwise methods had similar predictive value

Murtaugh. 2009. Ecology Letters 12:1061-1068

Issues with regression

- Model selection
  - How many models should be considered?
- Hypothesis testing or IC methods
- Multiple dependent variables?
- Biological realism and hypothesis generation

Statistics are a tool

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ESA Symposium References – Lord presentation

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