A Systematic Approach to the Design & Enhancement of Breeding Programmes

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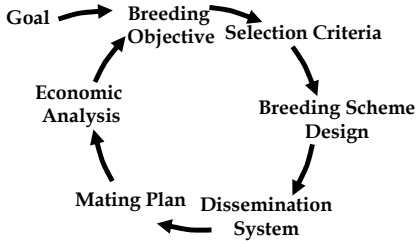
Animal Breeding



The First Step

- Define the high-level *goal* for the breeding programme
  - Improving *utility* or *satisfaction* from the "enterprise"

Dairy Industry Goal

If you're not farming for profit, we wish you well with your hobby

Livestock Improvement Corporation (LIC)
Profit per unit (4.5 t DM) of feed

Ultrafine Merino Goal

Maximize the total value of wool fibre leaving my farm over the cattle stop each year

- While being technologically innovative
- And improving my land & ecosystem

Refining the Goal

- What time frame?
  - Not Profit but Future Profit (5, 10, 50 yrs)
- Whose perspective?
  - Stud or seedstock breeder
  - Commercial producer
  - National Industry
- What limiting resource?
  - Animal Places, Feed, Output Quota, Effluent

What do you do with the Goal?

- Define the breeding or selection objective
  - List of traits that (directly) influence the goal
  - The relative emphasis of each trait in the list
- Leading to a selection index…

Classical Selection Index

- Selection Objective
  - $H = r_1g_1 + r_2g_2 + r_3g_3$
  - r_i are relative economic values
  - g_i are breeding values of goal traits
- Selection Index
  - $I = H\text{-hat} = b_1x_1 + b_2x_2 + b_4x_4 + b_5x_5$
  - b_i are selection index weights
  - x_i are selection criteria or clues as to merit

List of Traits

- Most producers can define this list much more easily than the goal
- Common errors are
  - Including both goal traits and selection criteria
    - Not helped by the classical selection index
  - Double-counting one or more traits
    - Input traits, output traits, efficiency (e.g., output/input)

Post-BLUP Selection Approach

- Selection Objective
  - $H = r_1g_1 + r_2g_2 + r_3g_3$
- Economic Index
  - $I = H\text{-hat} = r_1g\text{-hat}_1 + r_2g\text{-hat}_2 + r_3g\text{-hat}_3$
- Prediction problem
  - $g\text{-hat}_1$ = linear function of x_i
  - $g\text{-hat}_2$ = linear function of x_i, x_i'
  - $g\text{-hat}_3$ = linear function of x_i', x_i''

Relative Trait Emphasis

- Partial derivative of the profit "function"
  - Usually more amenable to numerical calculation (e.g., by difference) than by differentiation
- All other traits in the list held constant
  - Formal means of demonstrating double counting (e.g., input, output, efficiency such as feed requirements, sale weight, feed to gain ratio)

REV Issues

- An economic not a genetic question
  - Involves "value" of change
  - Does not involve heritabilities nor size/sign of genetic correlations
- Involves knowledge of managements reaction to genetic change
  - Pig industry – selection for leaness can alter the grading profile or allow producers to grow pigs faster to the same level of fatness

Management vs Selection

- No sense wasting selection to change attributes readily modified by management
  - Early selection for leaness in ad-lib pigs
    - often reduced voluntary feed intake
    - Feed intake can be restricted by management
    - Once selection had increased protein deposition potential, selection increased voluntary feed intake
  - Quality vs quantity (e.g., fleece wt vs MFD)

REV Issues

- What input costs & product prices ?
  - Economic or Financial
  - Problematic in very long term
    - Consider forestry examples say 30 years (pulping energy costs vs carbon credits)
- Not all traits are easily amenable to such analysis – some involve (unknown) risks
  - Resistance to (currently) exotic disease
  - Welfare issues (mulesing vs fly strike)

Economic or Financial ?

- Value of Fat Yield vs Protein Yield
  - Based on current payment formula
  - Extrapolation of recent financial trends
  - Based on modelling of product prices (demand) and production (supply)
    - Accounting for industry growth/shrinkage
    - Accounting for availability of technology
      - e.g., natural mating (say sheep) vs AI (say dairy)
    - Accounting for re-optimization of product mix

Equivalent Formulations

- Consider a pasture-based dairy system
- Goal traits are fat & protein yields & feed costs

$$H_1 = r_{fat}g_{fat} + r_{protein}g_{protein} - r_{feed}g_{feed}$$

- But if feed requirements can only be assessed from yields $g_{feed} = (\delta_{feed}/\delta_{fat})g_{fat} + (\delta_{feed}/\delta_{prot})g_{prot}$

$$H_2 = (r_{fat} - r_{feed}\,\delta_{feed}/\delta_{fat})\,g_{fat} + (r_{protein} - r_{feed}\,\delta_{feed}/\delta_{fat})\,g_{protein}$$

And $H_1 = H_2$ (and $\text{H-hat}_1 = \text{H-hat}_2$)

ERTs vs Indicators

- Economic Index should only include breeding values for (future) economically relevant traits
- Prediction problem uses all available (cost-effective) indicator traits

Selection by Simulation

- Index development requires a model to derive REVs (one-off), that are then used repeatedly to construct index values
- An alternative is to repeatedly use the model to directly rank sires/breeds on the outputs of the whole (non-linear) system

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What, Who and When to Measure

- Selection Criteria & Breeding Scheme Design
  - Each “goal trait” will be associated with a number of alternative “indicator traits” or “characters” that could be used as selection criteria
  - Typically these could be measured a variable number of times on a variable number of existing animals or animals could be “created” specifically for the purpose of evaluating other animals

Many Approaches

- Huge number of “scenarios”
  - Combinations of Selection Criteria and Breeding Scheme Design
  - One breeding scheme with one (average) objective or several schemes with customized objectives

Dissemination System

Often limited by:

- practical issues
  - Heat detection in extensive circumstances
- Political issues
  - Precludes certain approaches
    - (e.g., AI, cloning)

Mating Plan

- Nucleus level
  - Corrective mating
  - Avoidance of inbreeding
- Commercial level
  - Straightbreeding vs crossbreeding
  - Exploiting heterosis & breed complementarity
  - Mating strategy for F1s

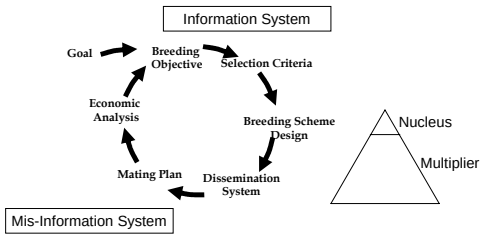
Economic Analysis

- Overarching Economic Analysis of Costs & Benefits of Breeding Programme
  - Production System Model of Enterprise(s)
  - Costs & Prices Model
  - Statistical Models for Goal Traits
  - Breeding Scheme Model (r_{ti} and L)
- Optimization - Evolutionary Algorithms

Other Economic Issues

- Time delay between costs & benefits requires account for time preferenc
- Time to breakeven can be important even when a scheme is profitable in the longrun
- The enterprise that pays the costs and the beneficiaries may be different
  - May be difficult to transfer the rewards

Entire Structural Context



Conclusion

- There is a logical, systematic approach to breeding scheme design and enhancement
- Components of the system are themselves complex, multidisciplinary and interact
  - but are amenable to modelling of alternative scenarios
- Step-wise improvement of an existing scheme is probably a more realistic endeavour than optimization

Conclusion

- Business and People issues (including education) are typically far more critical to success in improving a breeding programme than genetic issues
  - people control selection and mating as well as the monitoring and implementation of a breeding programme