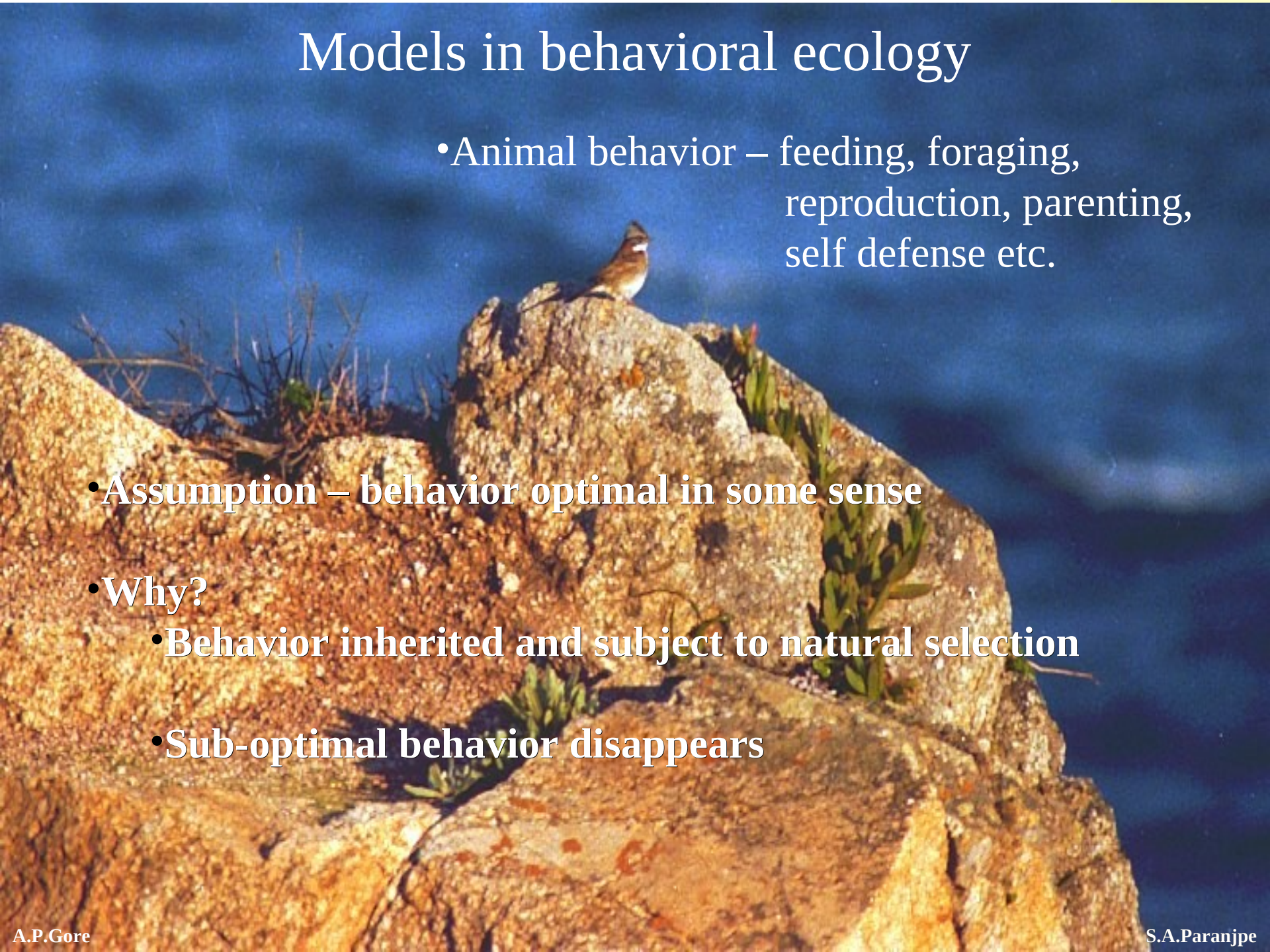
Models in behavioral ecology



- Animal behavior – feeding, foraging, reproduction, parenting, self defense etc.

- **Assumption – behavior optimal in some sense**

- **Why?**
  - **Behavior inherited and subject to natural selection**

  - **Sub-optimal behavior disappears**

- Diet choice: two prey types- large and small
  - Small prey easy to find, less reward
  - Large prey rare, more reward
  - Optimal choice – maximize average energy gain / effort

- Central place foraging:
  - Constraint – total time
    - Divided into travel time (fixed)+
    - food gathering time (decision variable)

  - Food collection efficiency decreases as
    - gathering time increases

  - Maximize the ratio :food gathered / total time
  - Optimal gathering time less if patch is closer

- Clutch size model
  - Vulture –1-2, Eagle – 2-3, Myna – 4-5
  - (Contrast Fish – thousands)

- Aim : maximize # viable offsprings

- Too many offspring- feeding inadequate (parental capacity)

- Vigilance
  - Squirrel – looks up frequently, fear of predation
- Vigilance reduces feeding rate

Decision variable- frequency of such acts

- Will the solution change if animal moves in a herd
  - Yes. Less vigilance expected.
- Will the solution change with state of hunger?
  - Yes. Less vigilance expected when hungry.

Behavioral caste

- **Honey bees: two castes**
  - **Only one bee lays eggs-Queen, all others-workers**
  - **Morphological differences**
  - **Castes predetermined, no choice**

- **Paper wasp:**
  - **Egg laying ability common**
  - **Only some lay eggs even when all are given opportunity**
  - **What makes a wasp prone to laying eggs?**
  - **Morphological characters? No.**
  - **Parental nest properties? Yes.**
    - **More empty cells in parent colony, higher chance of egg laying**

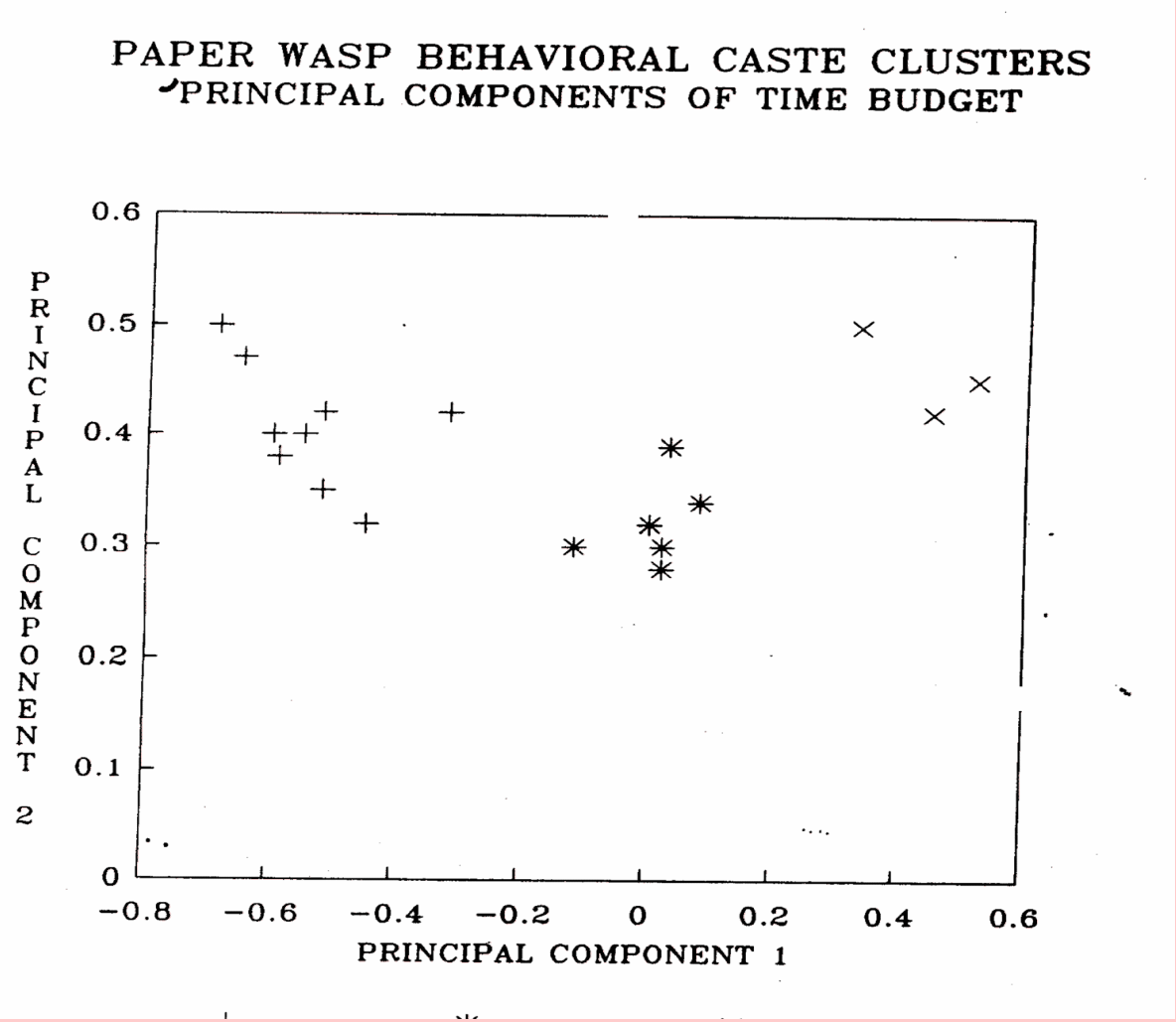
Only two castes in paper wasps?

- List of behavior types: sitting with or without raised antennae
  Giving/ receiving food, attacking, absent from nest, cleaning etc.

- Time budget

- Vector valued random variable – time spent by one individual in various activities

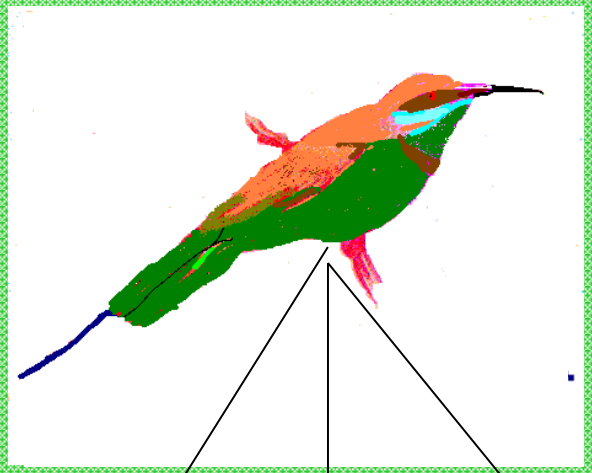
- Principal component analysis
  - Three clusters identified
  - Treated as behavioral castes
  - Caste names selected post facto


PAPER WASP BEHAVIORAL CASTE CLUSTERS
PRINCIPAL COMPONENTS OF TIME BUDGET
PRINCIPAL COMPONENT 2
0.6
0.5
0.4
0.3
0.2
0.1
0
−0.8
−0.6
−0.4
−0.2
0
0.2
0.4
0.6
PRINCIPAL COMPONENT 1

Can bee eaters read predator's mind?

- Do animals have mind?
- Can they think?
- Can this be verified experimentally?

- Bee eater in breeding season
- Busy foraging, feeding nestling
- Waiting at a perch near nest, on return trip
- Notices predator
- Predator may be
  - Watching nest
  - Not watching nest
  - Unable to watch nest



P -I

P-II

Visual barrier

NEST

Observations

- Average time taken to enter the nest

- Case I : predator watching nest –11.7 min, n=35

- Case II: Predator cannot see nest – 8.5min, n=35

- Case III: predator far away,
  bird cannot see predator- 1.7min, n=35

- Case III value lower than others

- Bird responds to what predator sees

Modeling seed weight

- Plant reproductive traits
  - Flower number
  - Ovule number
  - Seed number /weight

- All vary enormously across species
  - Sesame - very small seed, many in a pod
  - Mango – large seed, only one
  - Groundnut – intermediate number and weight

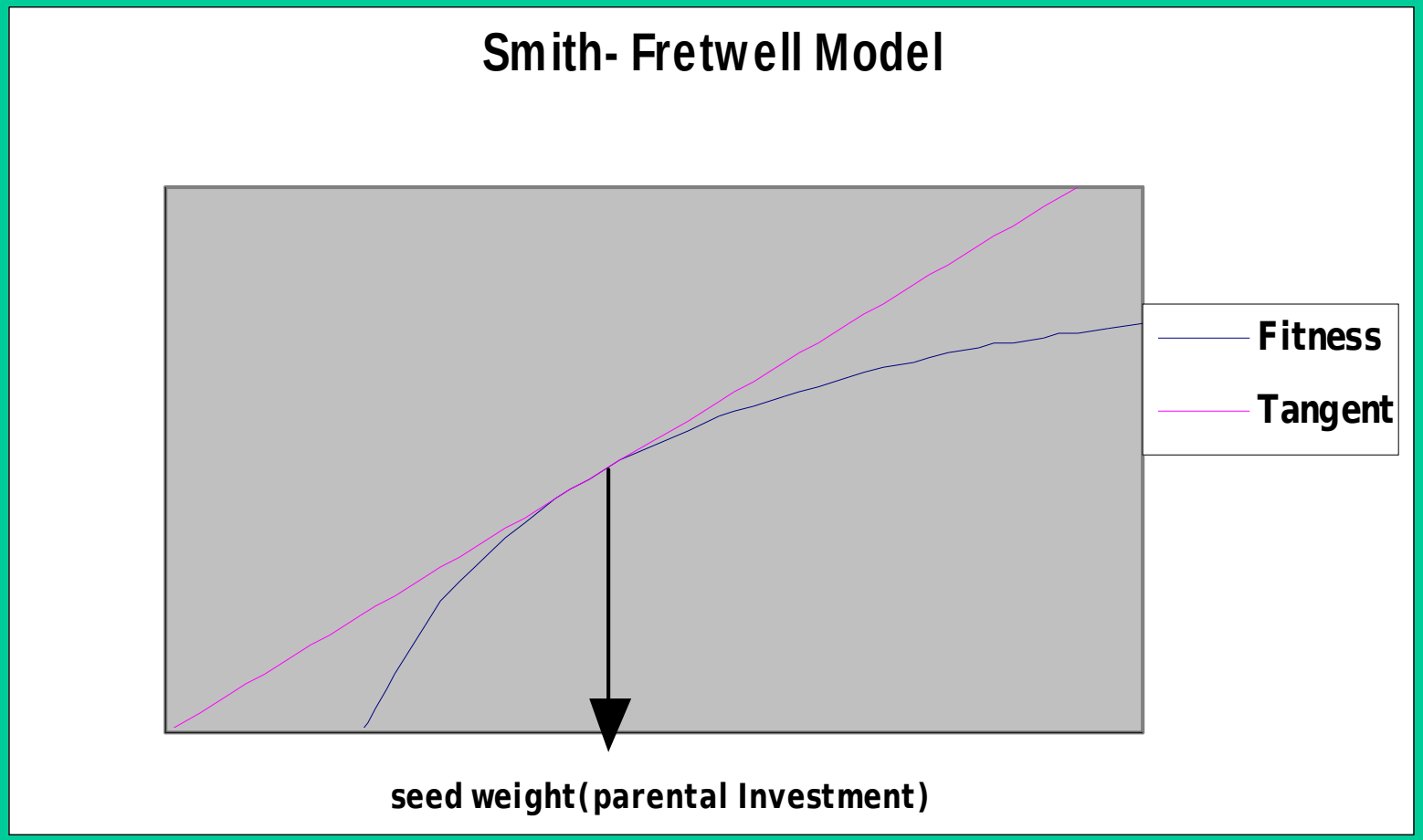
- Groundnut –seed number per pod : 1-4
- Seed weight varies from pod to pod
- Why?

Single seed story: Smith -Fretwell Model

- Fruits with a single seed
- What determines the optimal weight of the seed?
- Two opposing considerations
  - Investment by and benefit to parent
  - Investment – seed weight
  - Benefit – fitness of the offspring
- Aim: maximize fitness / Investment

- Assumption
  - No benefit unless Investment > threshold
  - Benefit increases with Investment
    - at a decreasing rate

- Model : saturating hyperbola (shifted)



- **Arrow : optimum seed weight**

Limitations of Smith-Fretwell model

- Assumes :
  - Constant reproductive resource level
    no allowance for change in resource status
  - Identical fitness function for all seed genotypes
  - Fitness independent of population density
  - Fitness unaffected by environmental variation

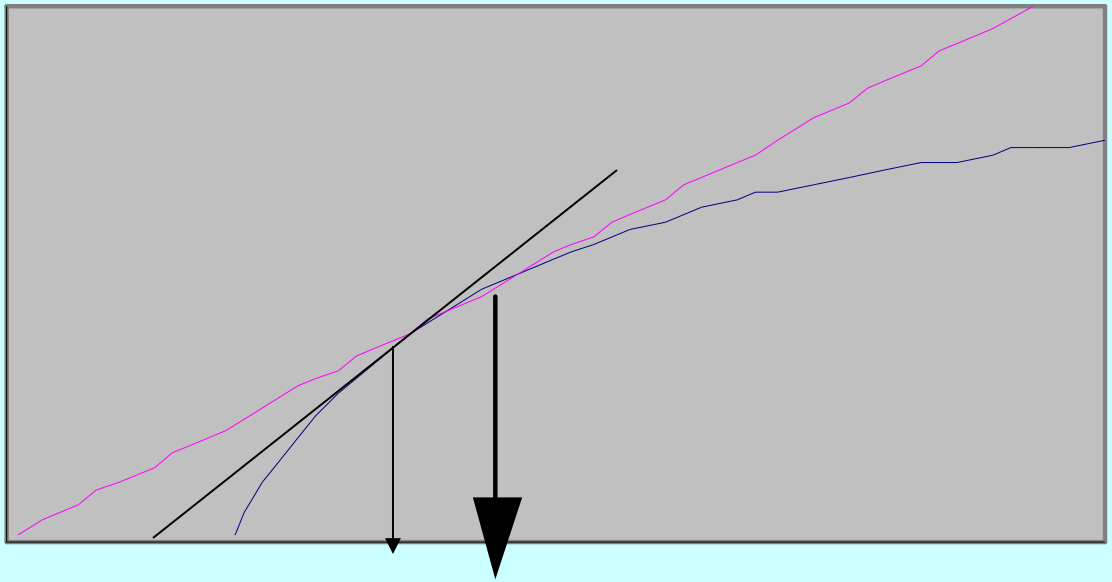
- Overlooks:
  - Fruits with multiple seeds
  - Overhead cost (flower/peduncle/seed cover-pod)

- Modification needed

Extended Smith-Fretwell Model

- Overhead cost : **C**
- Number of seeds : **i**
- Investment in each seed : **x + C/i , x –seed weight**
- How to find optimum x?
- Draw tangent to fitness curve from (-C/i , 0)
- Can vary with i

Smith- Fretwell Model



x_1 : optimum seed weight for single seed pod

x_2 : optimum for 2 seed pod

- Fitness function:
  - $Y = \{k*(x-a)\}/\{b+x-a\}; \quad x>a$
  - k : fitness at high level of investment
  - a : limit below which seed is unviable
  - a + b : seed weight giving fitness k/2

- Aim : maximize $f = Y/\{x+C/i\}$

- Optimum seed weight given by
  - $x = a + [\, b(a + C/\, i\,)]^{1/2}$

- Relates optimum seed weight to # seeds in a pod

- Implies x ↓ as i ↑

Alternative models

- If ‘a’ is small compared to ‘b’ and ‘C’, earlier model reduces to
  - X * √i = constant or in general X * i^q = constant (d)
  - This may be called ‘**Generalized Smith-Fretwell model’**

- **Competition model:**
  - Investment per fruit same regardless of # seeds in it
  - Leads to competition for resource within fruit
  - x*i = constant (e)

- Data : seed number and average seed weight /pod

- Three species : Raphanus, Sesamum, Enterolobium

- Three models fitted by least squares

Comparison of models

Model and estimates	Species		
	Raphanus	Sesamum	Enterolobium
Extended S-F			
a	0.425	0.0001	311.4
b	6.63	0.75	663.4
c	8.0	1500	828.0
% RSS	3	52.5	32
Generalized S-F			
q	0.35	0.6	.07
d	7.3	47.0	977
% RSS	4	52.2	36
Competition			
e	21.6	197.4	8302
% RSS	-	98.5	-

Results

- Extended S-F model : uniformly good
- Generalized S-F model : reasonable
- Competition model poorest

- **Implications of extended Smith- Fretwell model**
- Optimal seed weight an upper limit
- Uneconomical (for parent) to invest more
- Constraint due to other factors (if any)
  may lower realized weight
- Optimization process- a flexible strategy
  - Optimum can vary from fruit to fruit
- Offers explanation for observed negative correlation
  between seed number and seed weight
- Competition as an explanation is invalid