1 April 2013

AMS 215

Office

BE 359A

NMFS LAB

OH Campus

M: 3-4   W: 4-5   (~30 beforehand)

Drop Box

Mangel and Clark 1988

Clark and Mangel 2000

Mangel 2006

Houston and McNamara 1999

Timing   105 × 19 = 1995 minutes

Miss April 24 (Steve Munch)

May 15, 13, 22

$\frac{1995}{120} = 16.62$ (17)

Field Notes on Science and Nature (MB Canfield)

G.B. Schaller (Veronica)

"The Scientist does not study nature because it is useful to do so. He does it because he takes pleasure in it; and he takes pleasure in it because it is beautiful"

Jules Henri Poincaré

(Juan)

"If you get the intuition right the details will take care of themselves"

Richard Courant (Braden)

Teaching Philosophy

"The only secret that I have got is damned hard work" - J MW Turner

(Everyone)

Kurt Friedrichs (Barry)

Patch Selection: A Game Against Nature

① Non-breeding interval

$t=0$ ——————————— $t=T$

② State of the organism ("reserves")

$X(t)$

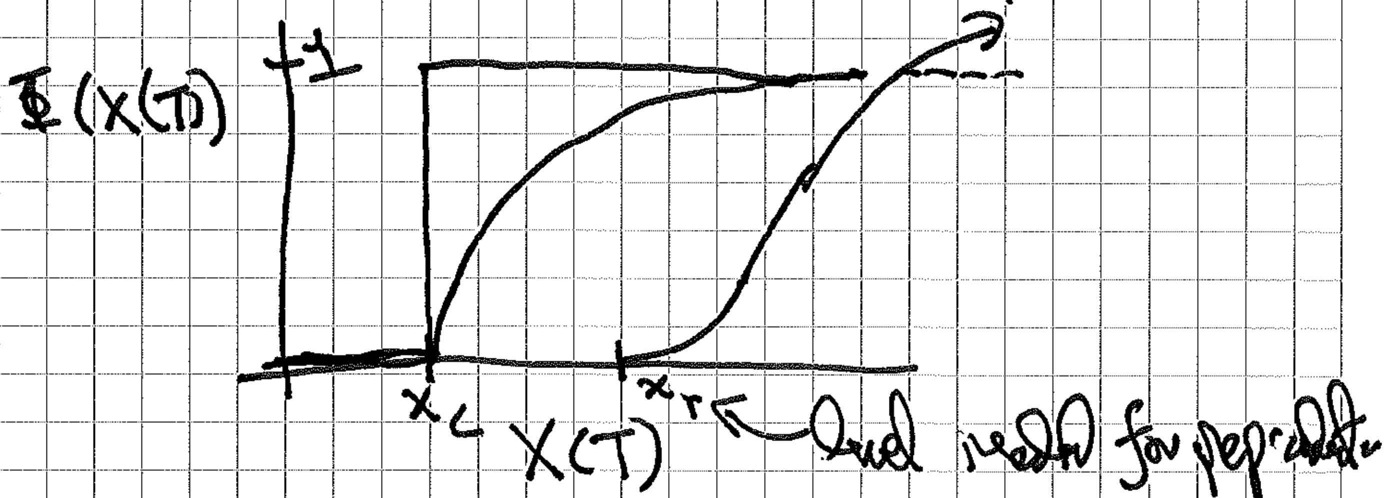
Small Bird In Winter (SBIW)

x_c ~ critical level [dead]

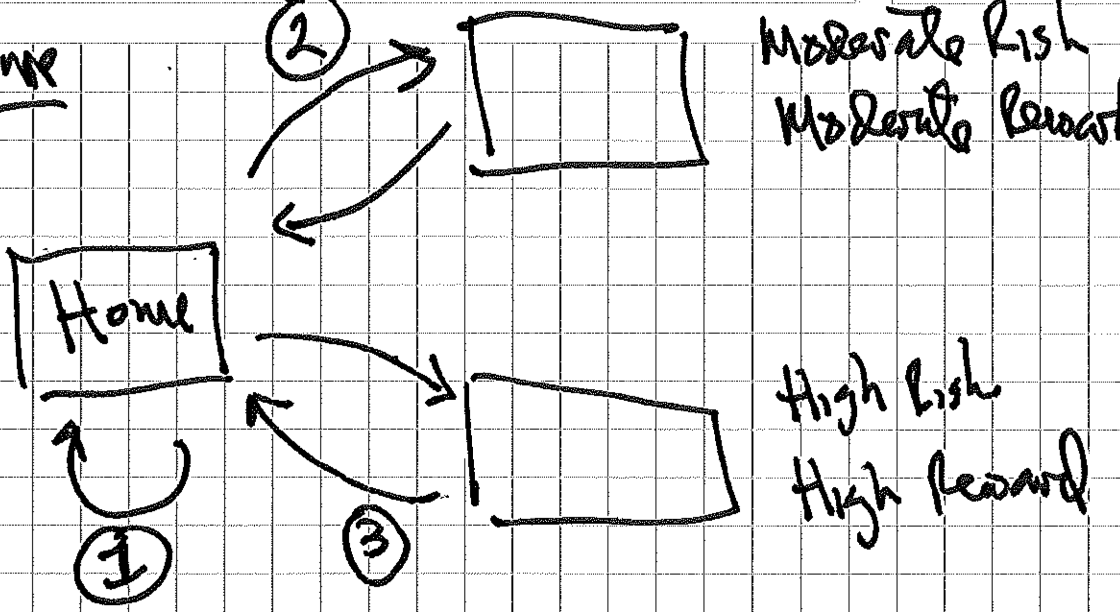
Krebs (Ellen)

③ Lifetime Reproductive Success (LRS) after time T depends on $X(T)$, $\Phi(X(T))$

phi



Nature



Risk : $\beta_i = \Pr\{\text{killed one visit to patch } i\}$

$$\beta_1 = 0$$

$$\beta_2 < \beta_3$$

Reward $\quad \alpha_i$ = cost of visiting patch i

$\lambda_i = \Pr\{\text{finding food on a single visit to patch } i\}$

Y_i = Value of the food if found

$$E\{\text{Reward}\} = 0 \cdot (1-\lambda_i) + \lambda_i Y_i = \lambda_i Y_i$$

$$\text{Var}\{\text{Reward}\} = \lambda_i Y_i^2 - (\lambda_i Y_i)^2$$

$$= Y_i^2 \lambda_i (1-\lambda_i)$$

What about units

$[X] \sim gm$ $\qquad$ $[\lambda_i] \sim$ unitless

$[\alpha_i] \sim gm$

"Crisis of the common currency"

$[Y_i] \sim gm$

$[\beta_i] \sim$ no units

If patch i is visited ($i=2,3$)

with probability

$$X(t+1) = \begin{cases} X(t) - \alpha_i + Y_i & \text{w.p. } (1-\beta_i)\cdot\lambda_i \\ X(t) - \alpha_i & \text{wp } (1-\beta_i)(1-\lambda_i) \\ x_c & \text{wp } \beta_i \end{cases}$$

If patch 1 is visited

$$X(t+1) = X(t) - \alpha_1 \quad \text{wp } 1$$

Back to the game against nature. Define a fitness function

$t \leq T$

$$F(x,t,T) = \max E\left\{ \Phi(X(T)) \mid X(t)=x \right\}$$

"for historical reasons" [20^{th}]

choice of patch between t and T-1

over the distribution of possible outcomes

assuming maximizing behavior

What is

$$F(x,T,T)?$$

$$= \max E\{\Phi(X(T)) \mid X(t)=x\}$$

$$F(x,T,T) = \Phi(x)$$

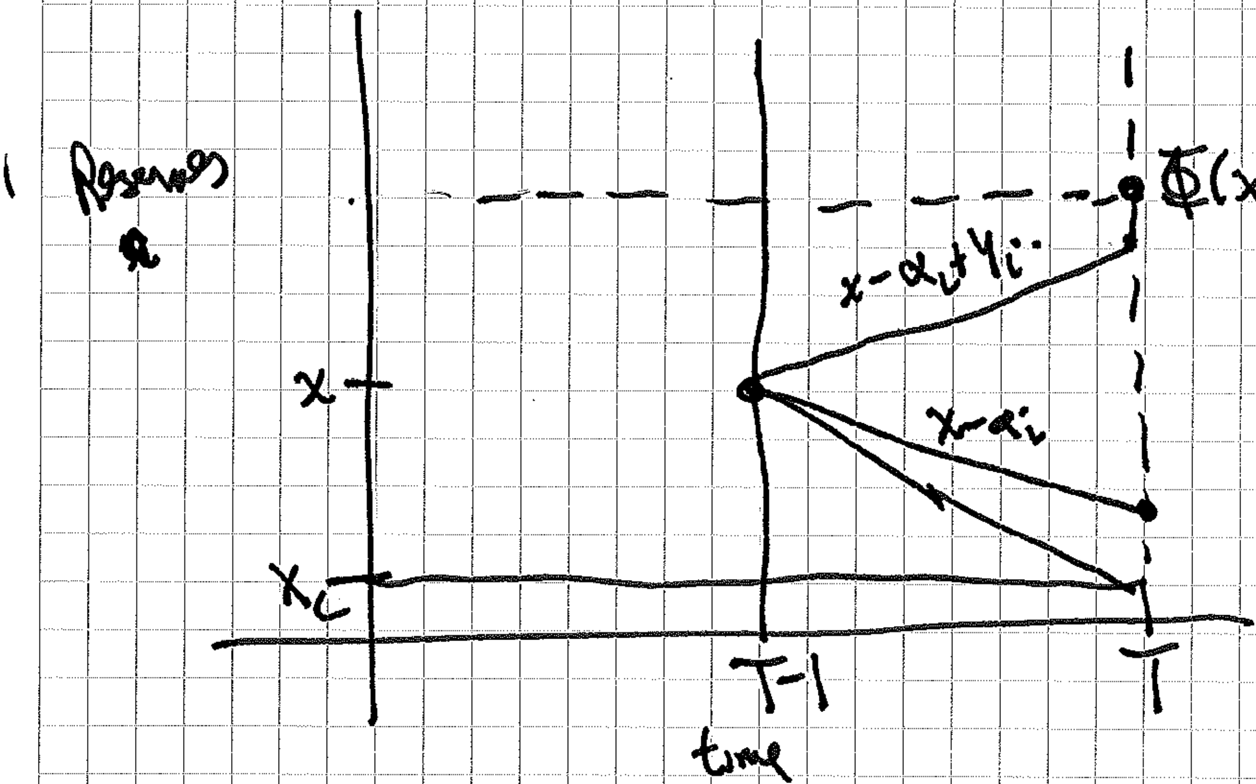
e.g. for prob of survival

$$F(x,T,T) = \begin{cases} 1 & \text{if } x > x_c \\ 0 & \text{if } x \le x_c \end{cases}$$

We know $F(x,t,T)$ at the end of the nonbreeding interval

so we call $\Phi(x)$ the end condition

Let's go backwards 1 time unit ("Backward induction" R Bellman)



$V_i(x, T-1, T)$ = Fitness value of visiting patch i at time $T-1$ when $X(T-1)=x$

$$= E\left\{ \Phi(X(T)) \mid X(T-1)=x, \text{ patch } i \text{ is visited} \right\}$$

$$= (1-\beta_i)\lambda_i \Phi(x-\alpha_i+Y_i) + (1-\beta_i)(1-\lambda_i)\Phi(x-\alpha_i) + \beta_i \cdot 0$$

but $\Phi(x-\alpha_i+Y_i) = F(x-\alpha_i+Y_i,T,T)$

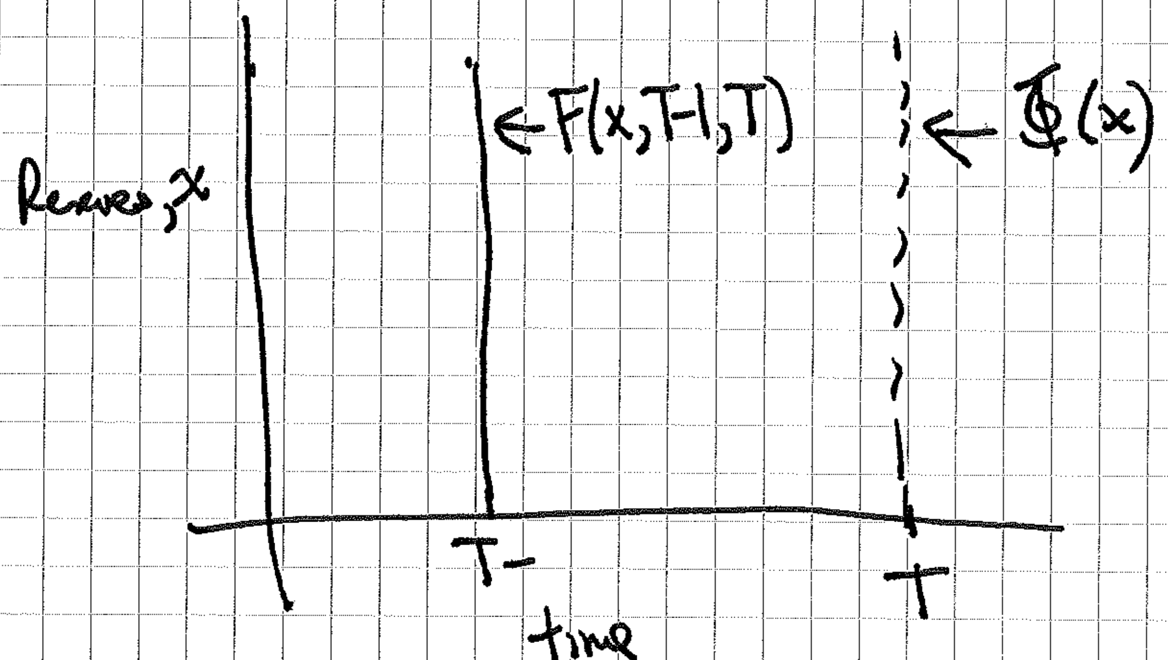
$\Phi(x-\alpha_i) = F(x-\alpha_i,T,T)$

$$V_i(x,T-1,T) = (1-\beta_i)\lambda_i F(x-\alpha_i+Y_i,T,T) + (1-\beta_i)(1-\lambda_i)F(x-\alpha_i,T,T)$$

$$F(x,T-1,T) = \max_i V_i(x,T-1,T)$$

$$\boxed{F(x,T-1,T) = \max_i (1-\beta_i)\left[\lambda_i F(x-\alpha_i+Y_i,T,T) + (1-\lambda_i)F(x-\alpha_i,T,T)\right]}$$

An equation of Stochastic Dynamic Programming



<u>Do this ad nauseam</u>

$(1-\beta_i)$

$$F(x,t,T) = \max_i \Big[\lambda_i F(x-\alpha_i+Y_i, t+1, T) + (1-\lambda_i) F(x-\alpha_i, t+1, T) \Big]$$

$$F(x,T,T) = \Phi(x)$$

end condition
or
terminal fitness

$i^*(x,t)$

G.O.D.

HW #1 What piece of biology would you like added?

e.g. multiple seasons ||

COMPUTER IMPLEMENTATION

DIMENSIONALIZE

- SCALARS

$x, t \sim$ integer variables

XC $[x_c]$ critical level
T $[T]$ final time
XMAX maximum level for the state

- VECTORS

ALPHA [3]
LAMBDA [3]
BETA [3]
Y [3]
PHI [XMAX]

MATRICES

F[XMAX][T]

V[3][XMAX][T]

ISTAR[XMAX][T]

INITIALIZE

3 April 2013

webcast.ucsc.edu

$$F(x,t) = \max E\left\{\Phi(X(T)) \,\middle|\, X(t) = x\right\}$$

$$F(x,T) = \Phi(x) \qquad \text{end condition}$$

SDPE

$$F(x,t) = \max_i (1-\beta_i)\Big[\lambda_i F(x-\alpha_i+Y_i, t+1)$$

$$+ (1-\lambda_i) F(\underbrace{x-\alpha_i}_{}, t+1)\Big]$$

$$< x_c \Rightarrow F \equiv 0$$

What Biology Would You Like To Add

- A game against conspecifics @ 11
- α, β, Y ~ time dependent
- Patch depletion
- Disease
  - $\beta_i > 0$
  - Disease $\Rightarrow$ $\alpha\uparrow$ or $\beta\uparrow$ or $\lambda\downarrow$

3.0

HISTORY OF SCIENCE

What Poincaré Knew

Peter Pesic

Henri Poincaré (1854–1912) was one of the most distinguished and influential scientists of his time, active in an astonishing variety of fields spanning pure mathematics, physics, astronomy, geodesy, telegraphy, and the philosophy of science. The centenary of his death is an appropriate occasion to look back at him, as Jeremy Gray (a historian of mathematics at the Open University and the University of Warwick) does in this biography.

Henri Poincaré: A Scientific Biography
by Jeremy Gray
Princeton University Press, Princeton, NJ, 2013. 608 pp. $35, £24.95. ISBN 9780691152714.

Gray is a versatile and prolific writer, whose previous books include treatments of non-Euclidean geometry, the Hilbert problems, and (most recently) a wide-ranging treatment of mathematical modernism (*1*–*3*). Even so, Poincaré's vast and diverse scope of activities presents a formidable challenge, which Gray addresses with remarkable skill. His book is the first full-length attempt to deal with all the main aspects of Poincaré's work.

Gray's subtitle alerts us that this will be a scientific biography, a detailed account of Poincaré's work rather than of his life in a more private sense. Gray thus emphasizes "the mind which creates" rather than "the man who suffers," as T. S. Eliot phrased it. In so doing, Gray chooses to foreground the internal interplay of influences within science itself, rather than the external social influences that have been the main interest of many historians of science in recent decades. To be sure, Gray presents an overview of the historical situation in which Poincaré worked. We learn about Poincaré's involvement with political issues (such as the Dreyfus affair) and some details of his personal life and mannerisms that help fill out the sense of him as a human being. But the bulk of this hefty book unapologetically presents us with an account of Poincaré's multifarious works, mainly within the context of the various research fields in question.

Gray structures his book topically, rather than chronologically. He begins with Poincaré the essayist, whose lucid and trenchant writings became best-sellers and yet had such depth and substance that the young Albert Einstein remembered being "breathless with excitement for weeks" as he read them. These accessible, popular works were the most visible signs of Poincaré as a public intellectual. Gray's skillful treatment of them gives a nice point of entry for general readers, who then are poised to read his overview of Poincaré's career. This includes Poincaré's practical activities in geodetic mapping and wireless telegraphy as well as his involvement in a few debacles (such as the discredited "N-rays," an elusive phenomenon that he endorsed for a time).

After devoting the first 200 pages to these eminently accessible topics, Gray then turns to more difficult and technical matters. He structures his account around certain pivotal episodes, such as the 1880 prize competition that crowned Poincaré's mathematical work or the problem of the celestial mechanics of three bodies, to which Poincaré contributed signally. Gray shows his mettle by the care and depth with which he has read a vast range of technical writings by Poincaré and others. As he deals with this difficult material, Gray demonstrates a notable ability to give detailed and yet clear, succinct accounts, synthesizing and summarizing formidably technical issues.

Still, given the range of topics across mathematics and physics, many general readers will find the rest of the book quite challenging. Gray presents this technical material frankly, rather than avoiding its difficulties. He offers brief explanations to help the reader grab a foothold, along with useful appendices and a glossary. He always tries to keep the narrative going, rather than merely listing theorems. Although different readers may wish for more help at different points, what Gray manages to convey may be more remarkable than what remains obscure. In particular, his treatment of Poincaré's work in topology inspires the hope that these ideas are worth struggling to understand, especially the larger vista, the underlying project, behind the plethora of details.

Poincaré himself characteristically steered his abstract mathematics toward physical and practical issues. We learn from Gray that Poincaré's deepest concerns were for mathematical physics, that he valued intuition at least as much as rigor, and that he was always asking, whether in practical or theoretical matters, "How do you know that?" Indeed, the nature of knowledge was Poincaré's greatest concern in philosophy, which he brought also to his work on physics. Gray gives an engrossing account of Poincaré's long involvement with many sides of physics, from the theory of electricity and magnetism (including very practical questions of telegraphy and transmission), through his independent approach to a relativistic theory, to his fascination, late in life, with the emergent quantum theory.

Despite his many brilliant interventions and mathematical virtuosity, Poincaré, Gray argues, made no great discovery in physics. Nonetheless, Gray emphasizes that for Poincaré "there is no valid or clear distinction to be made between mathematics and physics because the two are so intimately entangled." Gray shows us the full dazzling sweep of what Poincaré accomplished, including the work on dynamical systems and chaos that only came into its own in recent years. A tour de force, Gray's masterful treatment will long remain an invalu-

Poincaré at 57.

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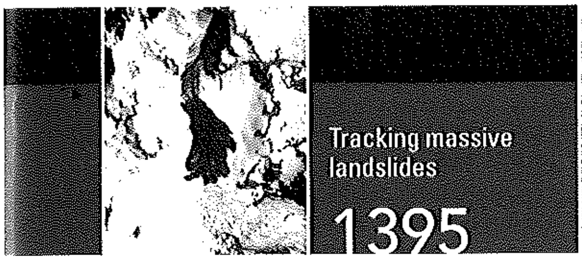

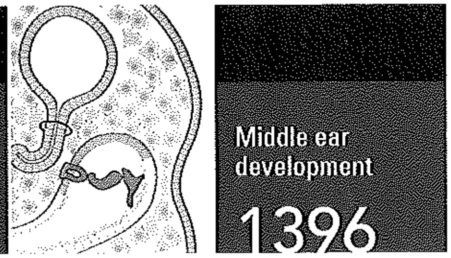

Approximately 8.3% of the country's 120 million hectares of arable land—about the size of South Korea—is contaminated by unbridled mining, trash dumping, and long-term use of pesticides (*1*, *2*). Heavy metals such as cadmium and lead could enter the dining tables of households and restaurants through the rice, fruits, and vegetables grown in contaminated fields (*3*, *4*). Health risks associated with soil contamination so far have been most severe in the industrialized parts of China (*1*, *4*, *5*).

Soil contamination could fundamentally undermine China's efforts for national food security. The country has long been pushing its food production: A required minimum amount of arable land was made part of the basic national policy (*6*), and research funds have poured in for more productive cultivars (*7*). However, all these efforts could be in vain if crops are from tainted fields. It is thus striking that soil contamination has received little attention from the public. Likewise, there has been little government effort to build necessary institutions, such as special laws and monitoring programs, targeting soil pollution.

China's Ministry of Environment and Ministry of Land and Resources conducted a national soil pollution survey from 2006 to 2010 (*8*), but the final report was never released. More recently, the Chinese State Council planned to comprehensively investigate its soil environment by 2015, monitor 60% of its arable lands on a regular basis, and endeavor to establish a national soil environmental protection system by 2020 (*9*).

Releasing information from these surveys will help to raise public awareness of soil contamination and facilitate research for pollution control.

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6. State Council of P. R. China, "National Land-Use Planning Outline (2006–2020)" (2008); www.gov.cn/jrzg/2008-10/24/content_1129693.htm [in Chinese].
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Fostering Public Support for Vulture Protection

THE PERSPECTIVE BY A. BALMFORD, "POLLUTion, politics, and vultures" (8 February, p. 653) reinforces the importance of collaborative efforts by the public and private sectors to protect vultures in the Indian subcontinent from the veterinary use of the painkiller drug diclofenac. The timely ban of diclofenac and its replacement with meloxicam was instrumental in saving vultures from extinction. Now we need to sustain and improve these efforts to return the vulture population to its previous numbers.

Although the ban of diclofenac was effective in reducing the number of contaminated cattle carcasses (*1*), two obstacles could hamper the efforts to completely replace its use with meloxicam. First, meloxicam is 4 to 5 times as expensive as diclofenac, and people are loath to accept new technologies and innovations, even if beneficial, when higher costs are required (*2*). Second, diclofenac for human use is still readily available for purchase, and the environmental effects of a decline in the vulture population may not be perceived as a serious problem by farmers (*3*, *4*).

To encourage the use of meloxicam in lieu of diclofenac, I suggest taking the following steps: First, to avoid increase in the cost of treatment for livestock farmers, the majority of whom fall below the poverty line (*5*), the Indian government should subsidize the cost of meloxicam to make the price commensurate with the price of diclofenac. Second, an awareness campaign should be put in place to educate veterinarians, pharmacists, and farmers about the negative effects of diclofenac and encourage them to use the alternative.

MADHUKAR SHIVAJIRAO DAMA

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References and Notes

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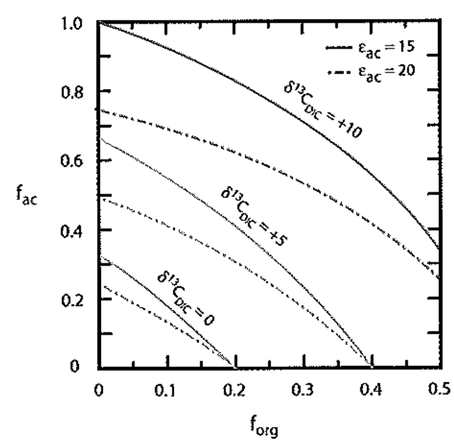
6. The measures expressed in this article solely represent the personal views of the author.

CORRECTIONS AND CLARIFICATIONS

News and Analysis: "What it means for agencies to be under the sequester" by J. Mervis (1 March, p. 1020). The article incorrectly describes the impact of the sequester on the Manufacturing Extension Partnership (MEP) centers within the National Institute of Standards and Technology (NIST). An 8 February letter from NIST to Congress says "NIST would be forced to end work it is currently doing through the Manufacturing Extension Partnership (MEP) Center system." It does not address the potential impact on the staff of the centers.

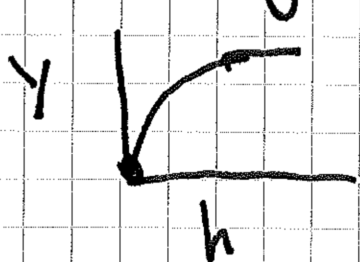
Research Articles: "Authigenic carbonate and the history of the global carbon cycle" by D. P. Schrag *et al.* (1 February, p. 540). The published version of Fig. 2 was not in agreement with the equations in the text. The correct Fig. 2 is below. This error did not affect any conclusions in the paper. The HTML and PDF versions online have been corrected.



Letters to the Editor

Letters (~300 words) discuss material published in *Science* in the past 3 months or matters of general interest. Letters are not acknowledged upon receipt. Whether published in full or in part, Letters are subject to editing for clarity and space. Letters submitted, published, or posted elsewhere, in print or online, will be disqualified. To submit a Letter, go to www.submit2science.org.

- Visiting multiple patches before returning home
- Aging affects foraging ability
- Networks of patches / spatially explicit
- Anthropogenic take
- $\beta = \beta(x)$, $\alpha = \alpha(x)$, $\lambda = \lambda(x)$
- Variable handling / travel time



(Marc's fav's: insect parasitoids)

- Dependent young.
- C, N
- Predator prey games
- Schooling behavior

W.D. Hamilton
(Kate)

IMPLEMENTING THE SDP

- Variables x, t, TCAP, XMAX, XC, I

- DIMENSIONALIZE

ALPHA[3], BETA[3], Y[3], LAMBDA[3]

F[XMAX][TCAP]

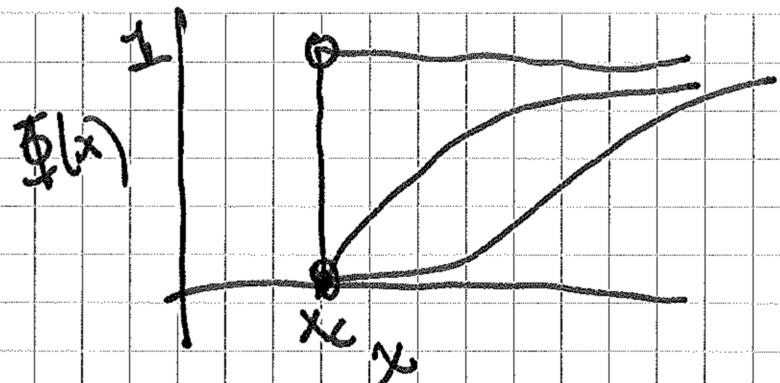
ISTAR[XMAX][TCAP]

V[3][XMAX][TCAP]

PHI[XMAX]

- INITIALIZE

```
For t=1 to TCAP
    F[XC][t] = 0        (Boundary Condition)
NEXT t
```



END CONDITION

BASIC

SWINNING

~~FOR~~ FOR X=XC+1 TO XMAX

PHI(X)=1

NEXT X

SATURATING

FOR X=XC+1 TO XMAX

multiplication

PHI(X) = X/(X+ .2* XMAX)

NEXT X

SIGMOIDAL

FOR X=XC+1 TO XMAX

PHI(X) = X^3/(X^3+(.2*XMAX)^3)

NEXT X

FOR X = XC+1 TO XMAX

F[X][TCAP] = PHI[X]

NEXT X

Loopize

FOR t = TCAP-1 TO 1 STEP -1

~~FOR X = XC+1 TO XMAX~~

Nested loops

FOR X = XC+1 TO XMAX ← VMAX = -E^9

FOR I = 1 TO 3

ADD TO THE INITIALIZATION STEP

XP = X - ALPHA[I] + Y[I]

IF (XP > XMAX) → XP = XMAX

XPP = X - ALPHA[I]

IF (XPP < XC) → XPP = XC

V[I][X][t]

= (1-BETA[I]) * (LAMBDA[I] * F[XP][t+1] + (1-LAMBDA[I]) * F[XPP][t+1])

```
IF V[I][X][t] > VMAX
    VMAX = V[I][X][t]
    ISTAR[X][t] = I
  END IF
 NEXT I
 F[X][t] = VMAX
NEXT X
NEXT T
```

"That's it" ||

$\boxed{\text{Problem \#2 "Due" April 10th}}$

pg 5 of the syllabus ||

"Life must be lived forwards but can only be understood backwards"
S. Kirkegaard (Simon)

Forward Simulations and Behavioral Observations

Simulate K individuals $K=100$

$X_k(t)$ = reserve state of the k^{th} individual at time t

$$A_k(t) = \begin{cases} 1 & \text{alive} \\ 0 & \text{dead} \end{cases}$$

Initialize

FOR k=1 to K

$X_k(1) = XC + U * [XMAX - XC]$

uniform random number between 0 and 1

$A_k(1) = 1$

Next k

For $t=1$ To $T-1$

For $k=1$ to K

IF $A_k(t)=0 \rightarrow$ NEXT k

IF $A_k(t)=1$

$I = \text{ISTAR}[X_k(t)][t]$

$U_1 = \text{RND}$

Predation

IF $(U_1 \leq \text{BETA}[I])$ [Dead]

$A_k(t+1)=0$

END IF

IF $(U_1 > \text{BETA}[I])$ [Not nailed]

$U_2 = \text{RND}$

IF $(U_2 \leq \text{LAMBDA}(I))$

$X_k(t+1) = X_k(t) - \text{ALPHA}(I) + Y(I)$

(check that $X_k(t+1) \leq X_{max}$)

ELSE

$X_k(t+1) = X_k(t) - ALPHA(I)$

IF $(X_k(t+1) \leq X_c) \Rightarrow X_k(t+1) = XC$

END IF

IF $(X_k(t+1) > XC) \rightarrow A_k(t+1) = 1$

o.w. $A_k(t+1) = 0$

Hugh Rossmghan
Brudigtte Tenhunberg

8 April.

Another slogan!

Nothing in the world can take the place of persistence. Talent will not; nothing is more common than unsuccessful men of talent. Genius will not; unrewarded genius is almost a proverb. Education will not; the world is full of educated derelicts. Persistence and determination alone are omnipotent.

—Calvin Coolidge, 1932

There's no such thing as an easy two

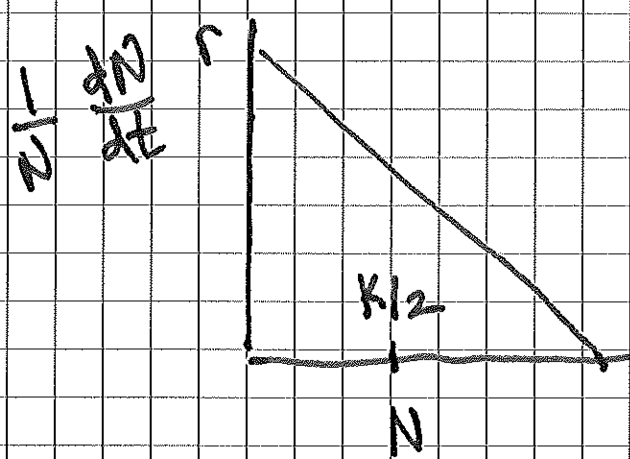
Bernard King

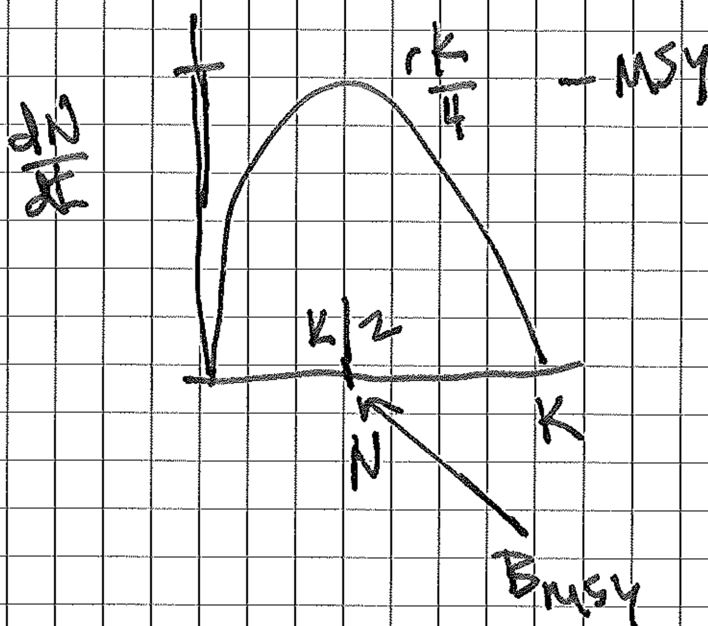
The Whistling Woman

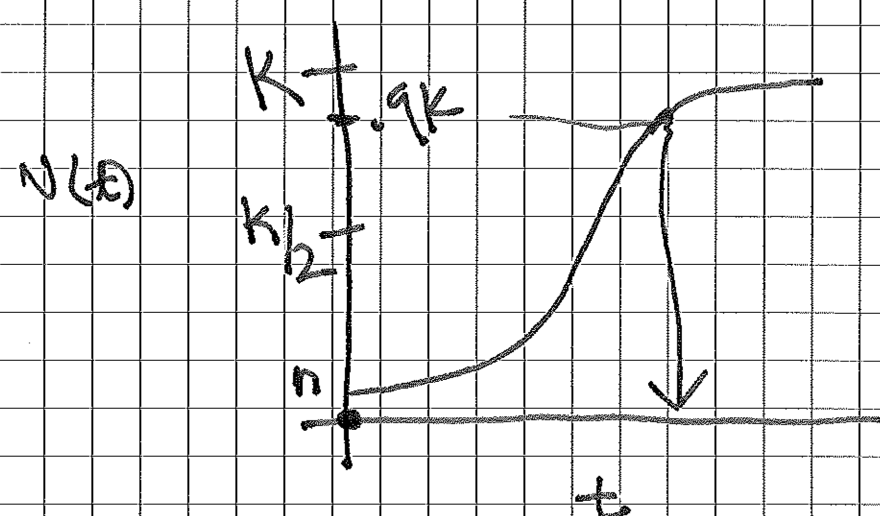
AS Byatt !!

Stochastic Population Theory

$$\frac{dN}{dt} = rN\left(1 - \frac{N}{K}\right)$$







Deterministic Context

1) Recolonization

$N(0) = n$ propagule

Question: How long does it take to reach $0.9K$?

Problem 4a (due April 15)
Do Exercise 2.7 in The Theoretical Ecologist's ToolBox

② A Harvesting Problem   MB Schaefer

$$\frac{dN}{dt} = rN\left(1 - \frac{N}{K}\right) - FN \quad \text{yield}$$

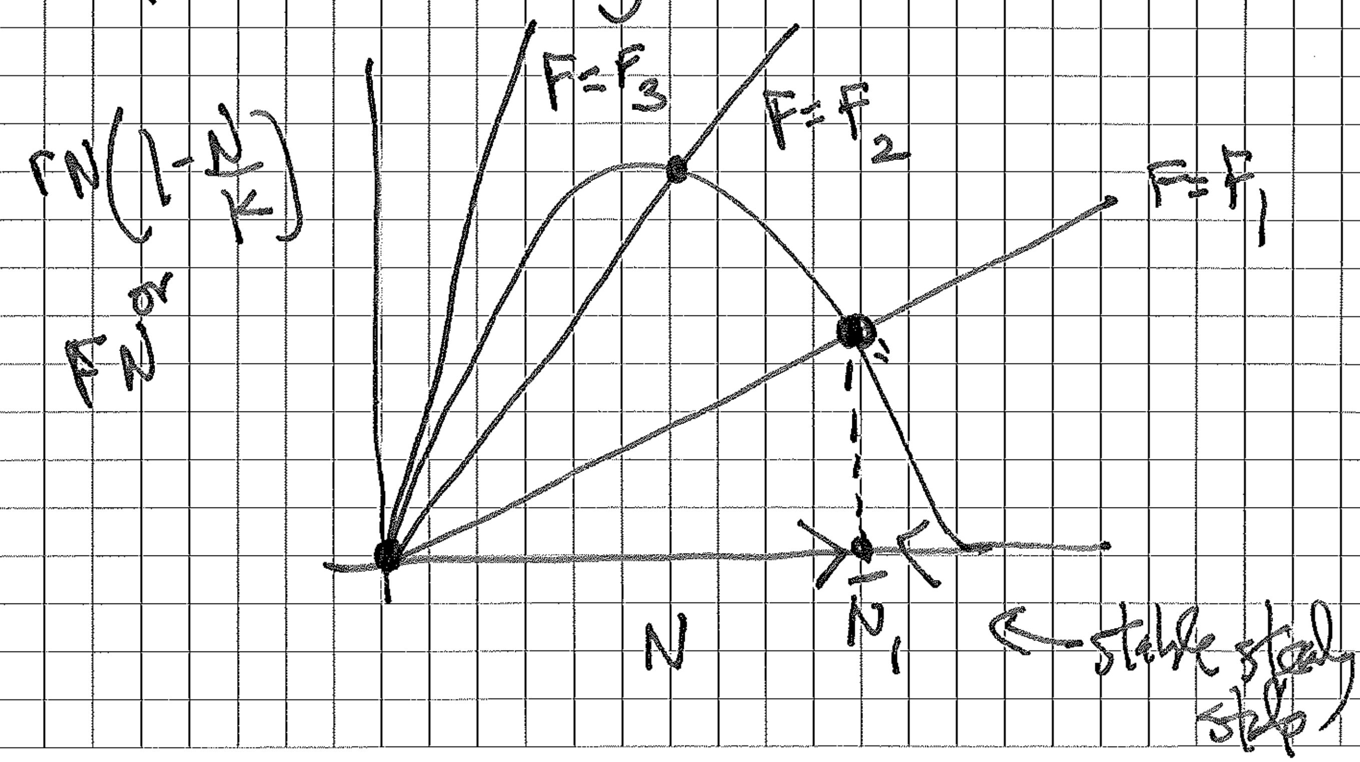
$[F] = 1/\text{time}$ (F is the rate of harvest mortality)

$$F = q\,E$$

E ← effort

q ← catchability

$dN/dt = 0 \Rightarrow$ steady population size



(8.4)

$F_3 \Rightarrow$ extinction

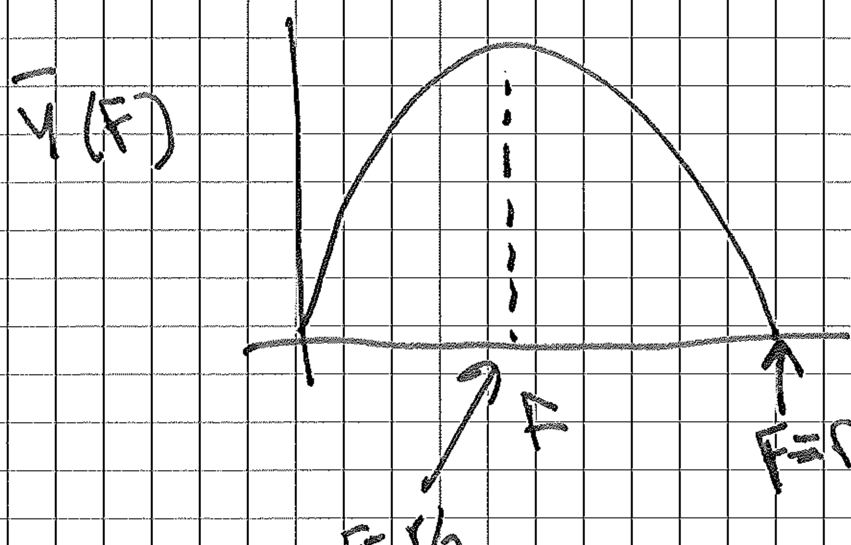
To do for your edification

Show that

$$\bar{N}(F) = K\left(1 - \frac{F}{r}\right)$$

The steady state yield

$$\bar{Y}(F) = F \cdot K\left(1 - \frac{F}{r}\right)$$



(8.5)

What if

Instead of

$$\frac{dN}{dt} = rN\left(1-\frac{N}{K}\right)$$

we had

$$\frac{dN}{dt} = \text{"} \underbrace{rN\left(1-\frac{N}{K}\right)}_{\text{deterministic}} + \underbrace{\text{Fluctuating Stuff}}_{\text{random}} \text{"}$$

~~RR~~ Randomness

Stochasticity

Q.SPT #1 What does this mean?

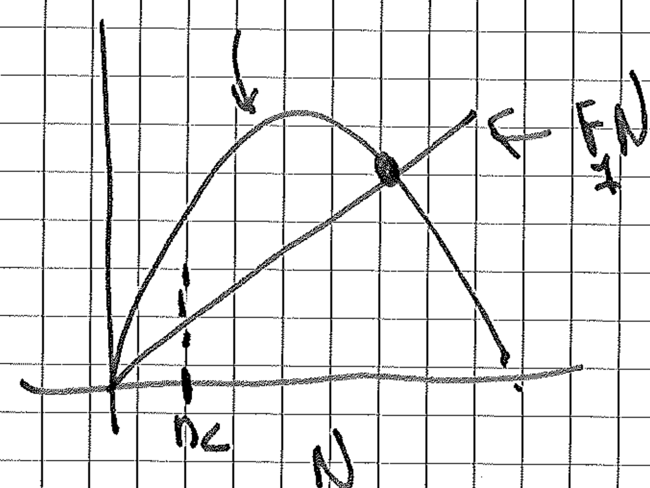
Colonization Question

Q.SPT #2 What is $\Pr\{\text{hitting } 0.9K \text{ before } 0 \mid N(0)=n\}$?

Q.SPT #3 What is the average time for this to happen?

Harvesting

Deterministic



What is the Pr{ population falls below some critical level n_c }

harvest mortality is F_I

(8.7)

Increasing Fidelity to Nature

Time dependent parameters

State dependence to parameters (e.g. size dependent predation)

Variable handling and/or travel times

Anthropogenic mortality

Visiting multiple patches before returning home

Per-period reproduction

Needing to forage for multiple nutrients (e.g. sources of carbohydrate, sources of protein – like that mosquito which experienced a mortality event during lecture on 3 April 2013)

Disease (both $\beta_1 > 0$ and disease causes α or β to increase or λ to decline)

Patch depletion

Age structure (affecting foraging ability, and perhaps predator avoidance)

Dependent young

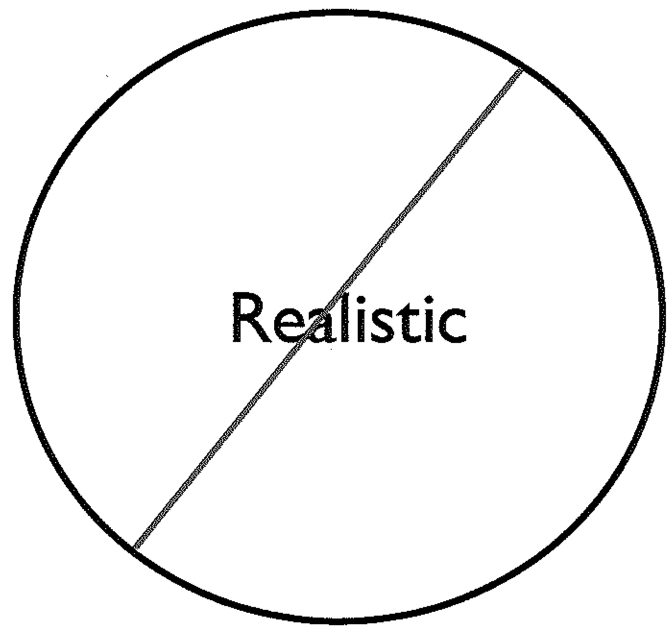
Learning

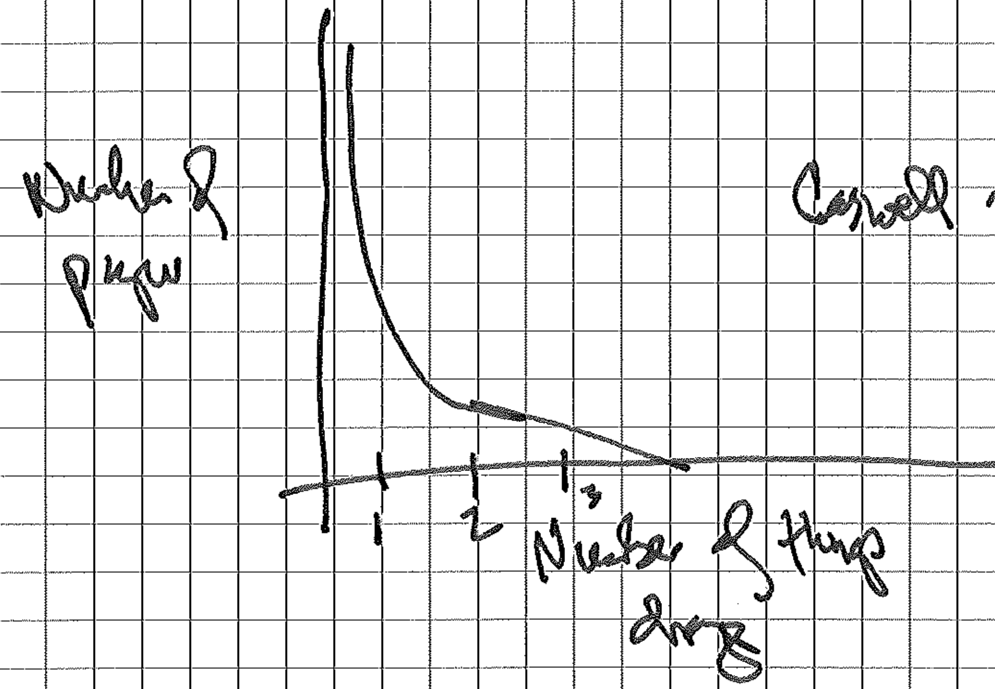
Schooling behavior

Spatial structure and networks of patches

Games against conspecifics

Predator-prey games


Realistic

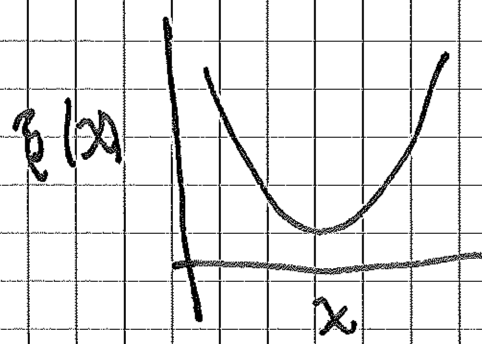


Caswell ~1986-88

Time and State Dependence to Parameters

- Mass dependent predation

$\beta = \beta(x)$



- |

(8.9)

• Metabolic Rate Depends on Mass

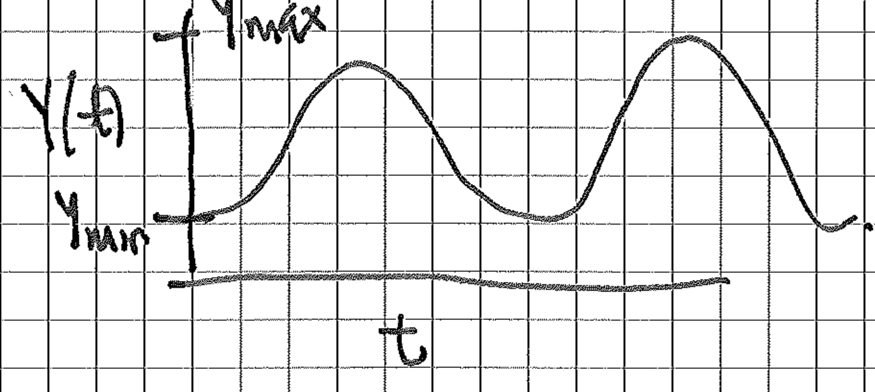
$\alpha(x) = x(1-f)$ patch 1 BMR

$= x(1-f)(1+\delta)$ patches 2,3 AMR

$f<1$

Activity multiplier

• $Y = Y(t)$



$$Y(t) = Y_{min} + (Y_{max} - Y_{min}) \sin(\omega t)$$

All measurable

period (omega)

- *Rate* of mortality (biology)
- Linear interpolation (computing)

Rate of Mortality

$\beta_i = \Pr\{$ being killed on a single visit to patch $i \}$

$m_i(x)$ = Rate of mortality in patch i when reserves are x

$$\Downarrow$$

$\Pr\{$ getting killed in the next Δt time units $\}$

$$\approx m_i(x)\,\Delta t$$

Actually this means

$$\Pr\{\text{getting killed} \ldots\} = m_i(x)\,\Delta t + \boxed{o(\Delta t)}$$

Landau order symbol

...

$\overset{S}{\wedge}$
Something is $o(\Delta t)$ if

$$\lim_{\Delta t \to \phi} \frac{S}{\Delta t} = \phi$$

example $S = (\Delta t)^2$ is $o(\Delta t)$ because $\frac{(\Delta t)^2}{\Delta t}$

$S = (\Delta t)^3$ " $= \Delta t$
$\downarrow$
ϕ as $\Delta t \to \phi$

Pr{ getting killed in the next Δt }

$$= m(x)\,\Delta t + o(\Delta t)$$

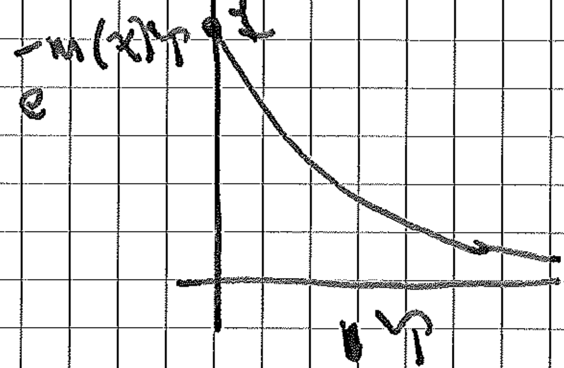
Q What is the Pr{ surviving for τ units in a patch.. }

Derivative Box 3.2
ToolBox Start of
Ch 2
$\Rightarrow$ $e^{-m(x)\tau}$

(negative exponential)

8.13

$\Pr\{\text{surviving for } \tau \text{ units of time}\} = e^{-m(x)\tau}$



Suppose τ is small, $\Pr\{\text{survive}\}$ close to but less than 1

Recall the Taylor expansion of e^z

$$e^z = 1 + z + \frac{z^2}{2} + \frac{z^3}{3!} + \cdots$$

Taylor expand $e^{-m(x)\tau}$ for small τ

$$e^{-m(x)\tau} = 1 - m(x)\tau + \frac{1}{2}(m(x)\tau)^2 - \frac{1}{3!}(m(x)\tau)^3 + \cdots$$

$$= 1 - m(x)\tau + o(\tau)$$

(8.14)

$$\boxed{Pr\{\text{surviving for } \tau \text{ units}\} = e^{-m(x)\tau}} = \underbrace{1 - m(x)\tau + o(\tau)}_{\text{Analysis}}$$

$\underbrace{e^{-m(x)\tau}}_{\text{Computation}}$

Two examples

small birds in winter

$$m(x) = m_0 + m_1 x$$

$m_0, m_1 \sim$ constants > 0

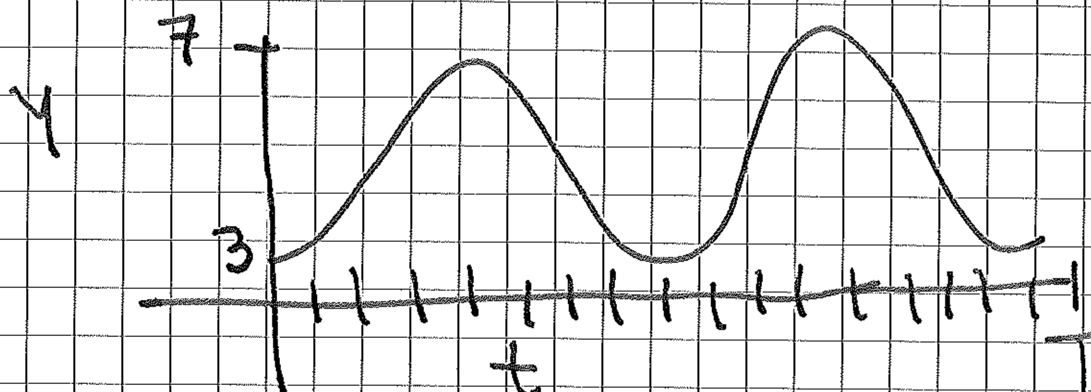
$$m(x) = m_0 + \frac{m_1}{x^{1/3}}$$

" "

like a ||length||

Mass dependent predation, time dependent food only (8.15)

$$F(x,t) = \max_i e^{-m_i(x)\cdot 1}\Big[\lambda_i F(x-\alpha_i+Y_i(t), t+1) + (1-\lambda_i)F(x-\alpha_i, t+1)\Big]$$



In general $Y_i(t)$ is not an integer

so

$x' = x-\alpha_i+Y_i(t)$ is not an integer

this will lead to an error in your current code.

10 April

Hints on solving

$$\frac{dN}{dt} = rN\left(1-\frac{N}{K}\right)$$

$$\frac{dN}{N\left(1-\frac{N}{K}\right)} = r\,dt$$

$$\frac{1}{N\left(1-\frac{N}{K}\right)} = \frac{A}{N} + \frac{B}{1-\frac{N}{K}}$$

$$= \frac{A\left(1-\frac{N}{K}\right)+BN}{N\left(1-\frac{N}{K}\right)} = \frac{1+0\cdot N}{N\left(1-\frac{N}{K}\right)}$$

$$A - A\frac{N}{K} + BN = 1 + 0\cdot N$$

$$N\left[-\frac{A}{K}+B\right]$$

Recall 1) Derivative of $\ln(N)$

2) Chain Rule

Better Ecological models
Appendix A

You: 2 weeks

Me (conservative): 25 yrs

$$\text{"Skill Ratio"} = \frac{25 \text{ yrs} \cdot 52 \text{ wks/yr}}{2 \text{ wks}}$$

$$\gtrsim 625$$

PROCEEDINGS OF THE ROYAL SOCIETY B | BIOLOGICAL SCIENCES

10-2

Balancing sampling and specialization: an adaptationist model of incremental development

Willem E. Frankenhuis and Karthik Panchanathan

Proc. R. Soc. B 2011 **278**, doi: 10.1098/rspb.2011.0055 first published online 13 April 2011

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- How might you use this

~2 pages to me

Developmental Science

Developmental Science (2013), pp 1–15 DOI: 10.1111/desc.12053

10.3

PAPER

Bridging developmental systems theory and evolutionary psychology using dynamic optimization

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Abstract

Interactions between evolutionary psychologists and developmental systems theorists have been largely antagonistic. This is unfortunate because potential synergies between the two approaches remain unexplored. This article presents a method that may help to bridge the divide, and that has proven fruitful in biology: dynamic optimization. Dynamic optimization integrates developmental systems theorists' focus on dynamics and contingency with the 'design stance' of evolutionary psychology. It provides a theoretical framework as well as a set of tools for exploring the properties of developmental systems that natural selection might favor, given particular evolutionary ecologies. We also discuss limitations of the approach.

Research highlights

- This paper introduces developmental psychologists to dynamic optimization, a method that has generated much interesting work in biology.
- Dynamic optimization can help bridge the current divide between developmental systems theory and evolutionary psychology.
- Dynamic optimization can be used to explore the properties of developmental systems that natural selection might favor depending on environment.
- Dynamic optimization provides an integrative theoretical framework as well as a set of tools.

Introduction

> Evolution is the control of development by ecology. (Leigh van Valen, 1973)

Developmental systems theorists and evolutionary psychologists interact less than they should, and when they do, these interactions tend to be antagonistic (Lickliter & Honeycutt, 2003a, 2003b, 2003c; and commentaries by Buss & Reeve, 2003; Crawford, 2003; Krebs, 2003; Tooby, Cosmides & Barrett, 2003). There have, of course, been both points of agreement (Badcock, 2012; Barrett, 2006, 2007; Bjorklund, 2003; Bjorklund, Ellis & Rosenberg, 2007; Ploeger, van der Maas & Raijmakers, 2008) and disagreement (Dennett, 2011; Sterelny & Griffiths, 1999). Where the sides seem to differ is in explanatory focus. Developmental systems theorists accuse evolutionary psychologists of underplaying the role of developmental causation in building phenotypes (i.e. genetic determinism). Evolutionary psychologists, on the other hand, claim that developmental systems theorists underplay the role of natural selection in organizing development (i.e. unconstrained holism), resulting in a lack of ability to predict species-typical cognition and behavior (Bjorklund *et al.*, 2007). Each 'camp' perceives the other's criticism to be unfair.

The current stalemate is unfortunate because potential synergies between the two fields remain unexplored. These synergies can be built on the assumption, shared by both approaches, that developmental systems are the central units of evolution (Barrett, 2006, 2007; Johnston & Turvey,

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(10.4)

AMS 215 Revised Problems, Spring 2013

Many of these exercises involve numerical computation. **Rule number 1: When doing this remember that you should produce approximately 10 times as many pictures as you submit. Rule number 2: Don't forget Rule number 1.**

Problem 1: What addition to the patch selection problem would you like?

Problem 1a: Do Exercise 2.7 in *The Theoretical Biologist's Toolbox* Due 15 April

Problem 2: Code the patch selection problem with the parameters in Mangel and Clark (1988) pg 54, which we will call the basic parameters, and confirm that you get the results shown on page 55.

Problem 3. For the basic patch selection problem, we had the end condition $F(x,T)$ if $x > x_c$ and 0 otherwise for survival. We also discussed using a more general formulation in which $F(x,T) = \Phi(x)$ where we might have

$$\Phi(x) = \frac{x - x_c}{(x - x_c) + (x_{1/2} - x_c)} \tag{1}$$

Here $x_{1/2}$is a parameter. a) What is its interpretation? b) Now assume that we replace Eqn 1 by

$$\Phi(x) = \frac{(x - x_c)^\gamma}{(x - x_c)^\gamma + (x_{1/2} - x_c)^\gamma} \tag{2}$$

Where γ is a parameter. Use either analytical or numerical methods to explore the behavior of $\Phi(x)$ as γ increases. c) Solve the SDP for the basic parameters with both of these new end conditions and interpret your results. Due 22 April

Problem 4. Here you will do an experiment to study the effect of risk on the decisions. First, increase $x_{max} = 15$ and run the code with survival as the end condition again. Then, hold $\lambda_3 \cdot Y_3$ constant but vary $Y_3 = 3, 4, 5, 6, 7$. Interpret your results. How does your choice of end condition affect the results? Due 22April

Problem 5 Convert your code for the basic problem from using β_i to mortality m_i in patch i. a) Using the basic parameter set and a uniform distribution for initial conditions, simulate forward the fates of 100 individuals, assuming no mortality during activity (all the $m_i = 0$). Report the final distribution of state and the number of individuals who died as a function of time. b) Now assume that mortality occurs during activity and repeat the analysis. c) Finally, assume that there is anthropogenic mortality in patch i given by $F_i = m_i$. Repeat part b) and interpret your results, doing mortality only in patch 2, only in patch 3, or in both of them Due 22 April

Problem 6 What is the interpolation formula for the (x, x_{max}) to (n, N) transformation?

Problem 7. a) Suppose that we were doing a two dimensional problem, so that the

Patch Selection with Time Varying $Y(t)$

$$F(x,t) = \max_i e^{-m_i}\Big[\lambda_i F(x-\alpha_i+Y(t), t+1) + (1-\lambda_i)F(x-\alpha_i, t+1)\Big]$$

$$F(x,T) = \Phi(x)$$

$$1-\beta_i = e^{-m_i}$$

Variable Travel Time

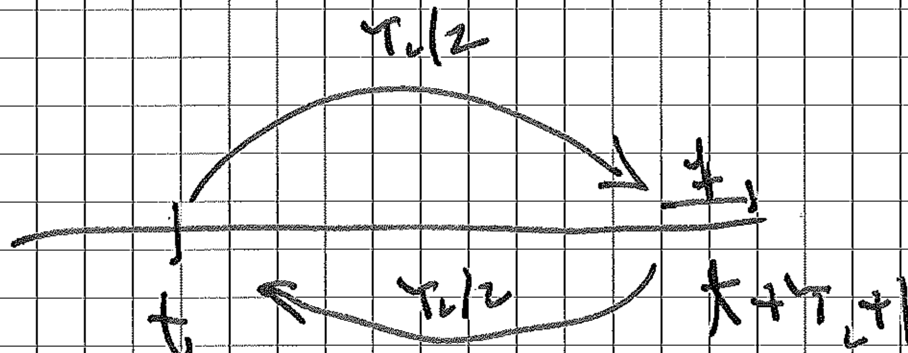
- τ_i = Travel time to patch i and back
- 1 period of foraging additional
- Mortality in transit plus while in the patch

A visit to patch i takes $\tau_i + 1$ time units

The SDP becomes

$$F(x,t) = \max_{i} e^{-m_i(\tau_i+1)}\Big[\lambda_i F(x-\alpha_i+Y(t),\, t+\tau_i+1)$$

$$+ (1-\lambda_i) F(x-\alpha_i,\, t+\tau_i+1)\Big]$$



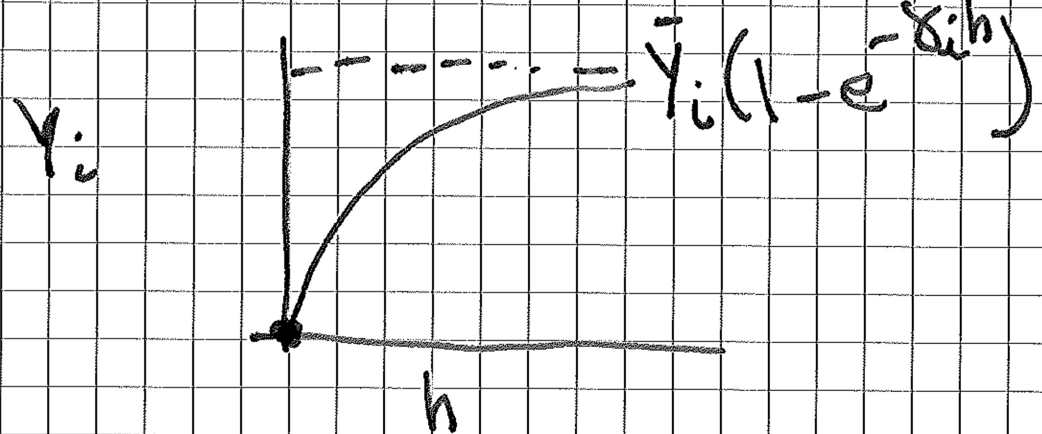
$$F(x,T) = \Phi(x)$$

I set

$$t_i' = \min\left[T,\, t+\tau_i+1\right]$$

TP

If food is encountered in patch i, the gain in reserves now depends on the handling time h



Suppose patch i is visited and if food is found handling time is h

TOTAL TIME IS: $\tau_i + 1 + h$

travel time

foraging time

handling time

Suppose food is not found

TOTAL TIME IS: $\tau_i + 1$

$$F(x,t) = \max_i \Big[(1-\lambda_i)\, e^{-m_i(\tau_i+1)}\, F(x-\bar{\alpha}_i, \underbrace{t+\tau_i+1}_{t_i''})$$

$$+ \max_h \lambda_i\, e^{-m_i(\tau_i+1+h)}\, F\big(x-\alpha_i(h)+\bar{Y}_i(1-e^{-\delta_i h}),\ \underbrace{t+\tau_i+1+h}_{t_i'(h)}\big) \Big]$$

This is awesome!!

$\bar{\alpha}_i(h+1)$

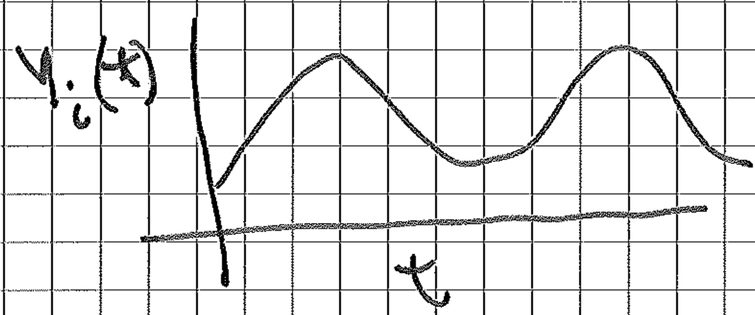
cost of foraging for one time unit

The Pesky Problem of Non-Integer Indices

Recall the good, old simple SDP

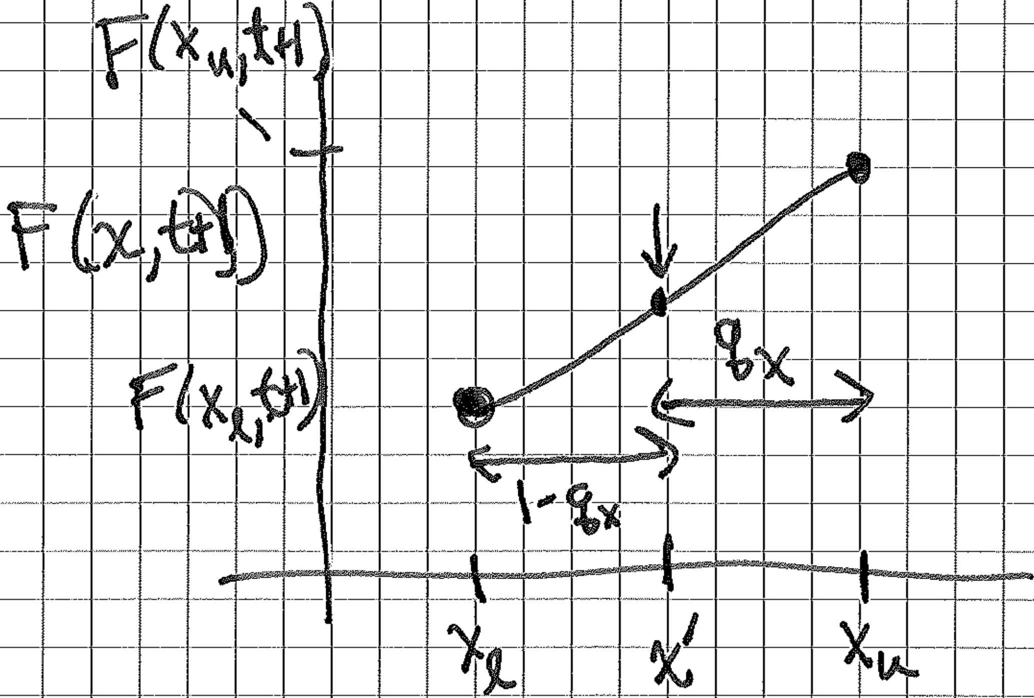
$$F(x,t) = \max_i e^{-m_i}\Big[\lambda_i F(x-\alpha_i + Y_i(t), t+1)$$

$$+ (1-\lambda_i) F(x-\alpha_i, t+1)\Big]$$



Problem: what to do if $x' = x-\alpha_i + Y_i(t)$ is not an integer?

Linear Interpolation



$$x_l = \mathrm{INT}[x'] = \mathrm{FLOOR}[x']$$

$$x_u = x_l + 1$$

$$q_x = x_u - x'$$

$$F(x', t+1) = q_x F(x_l, t+1) + (1-q_x) F(x_u, t+1)$$

Approximating in the computer