Beyond biomass:
valuing genetic diversity in natural resource management

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Salmon transferring from a truck into the Sacramento River
(CBS, 2015)

Camp Resources XXII, August 2015

Collaborators

“Managing natural resources for adaptive capacity: the Central Valley Chinook salmon portfolio”

With:

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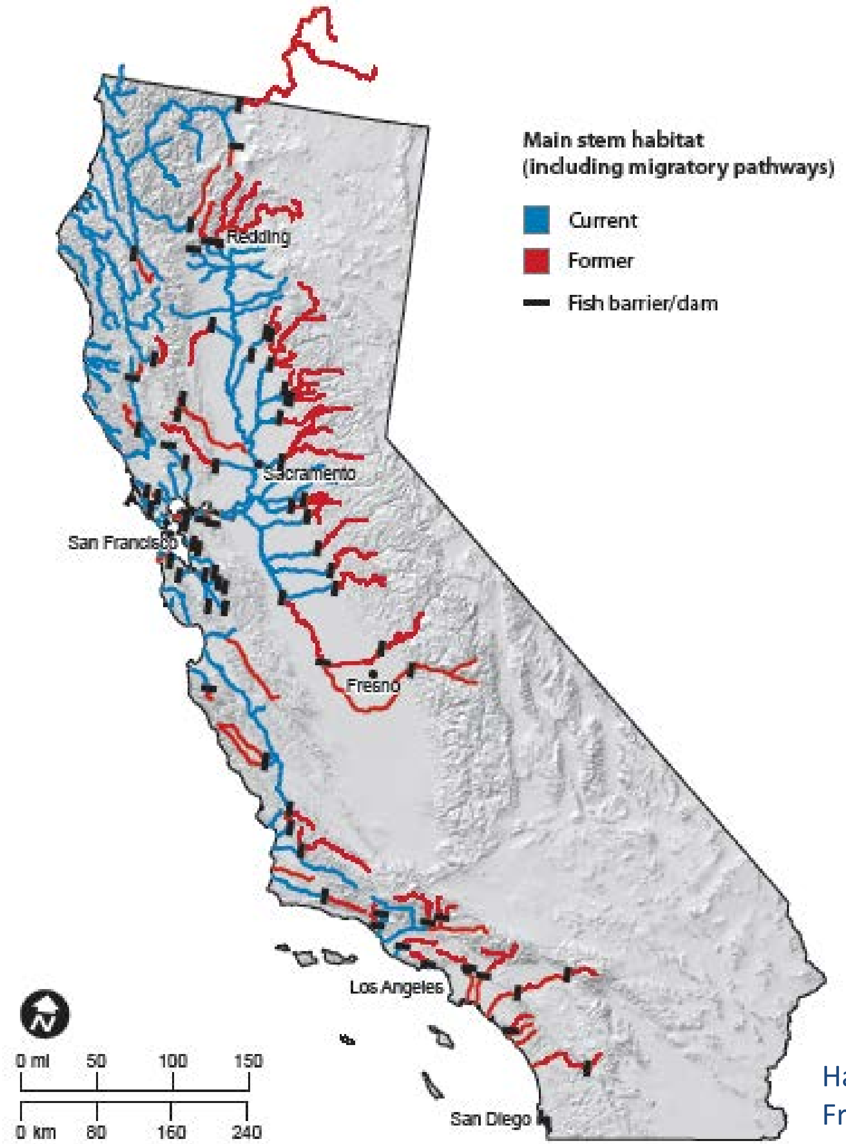
Will Satterthwaite (NOAA-Fisheries),
Steve Lindley (NOAA-Fisheries),
Robin Waples (NOAA-Fisheries)

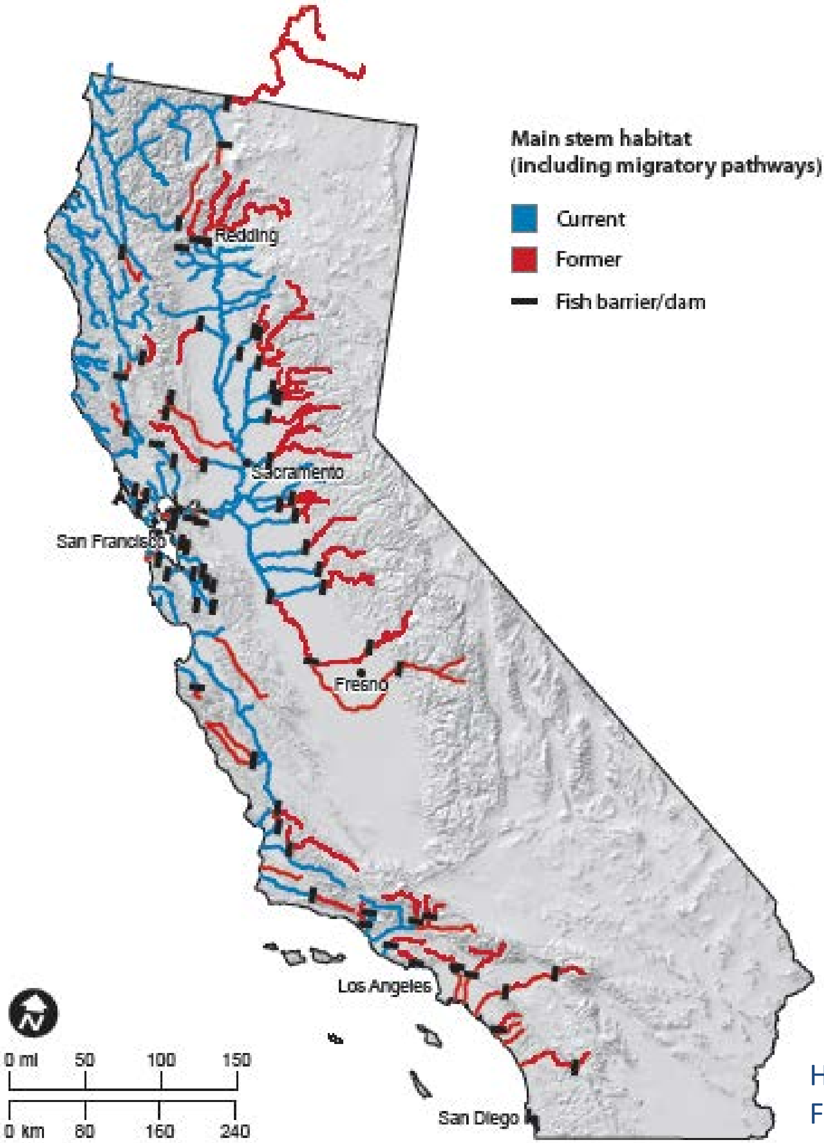
Outline

- Motivation
- Intended Contributions
- Approximate Dynamic Programming



Hanak et al. 2011. Managing California's water: From conflict to reconciliation.

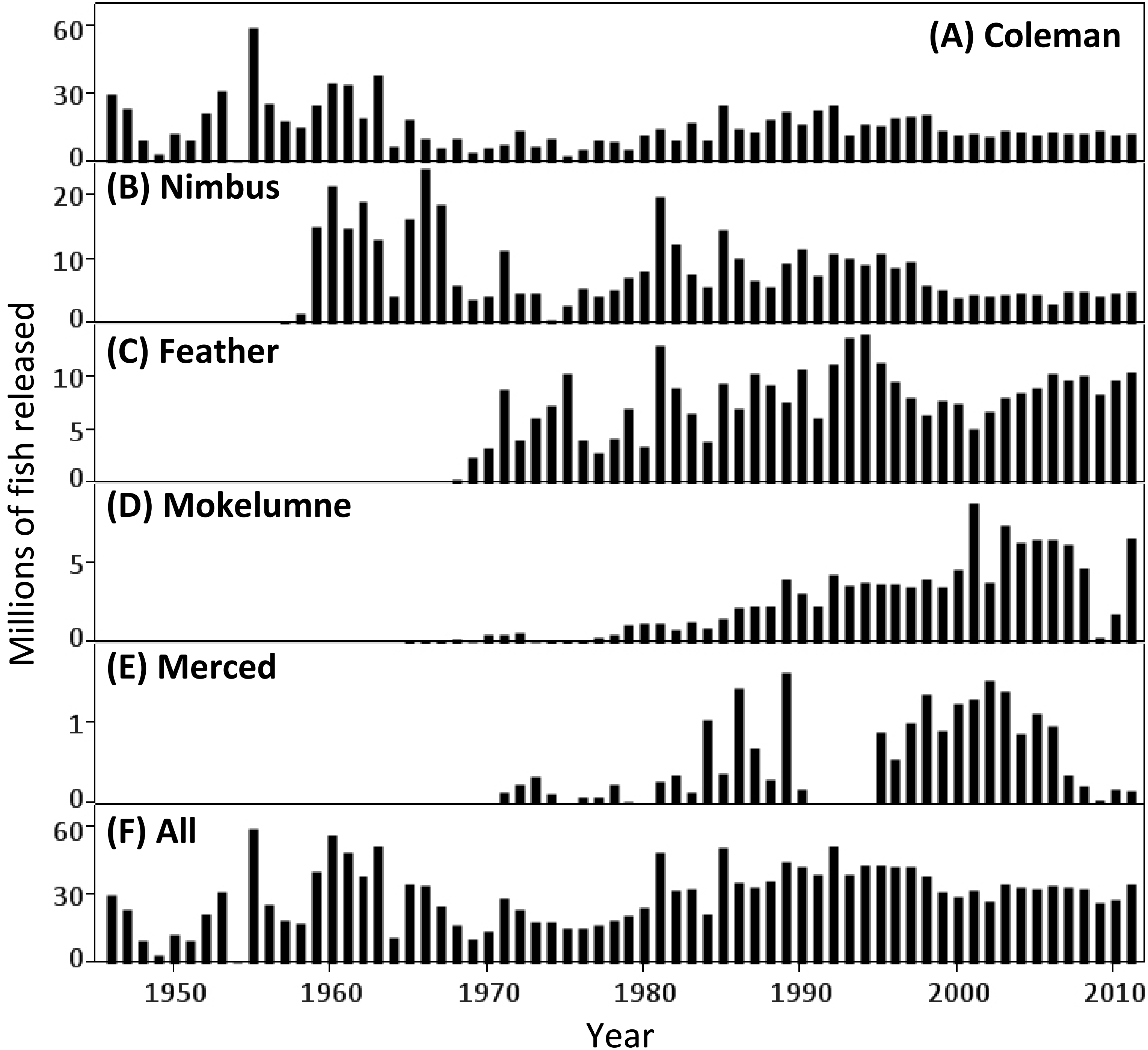
Physical capital (hatcheries) has been developed to compensate for the loss of natural capital (habitat)



Hanak et al. 2011. Managing California's water: From conflict to reconciliation.

> 2 billion hatchery fish released between 1946-2012

~30M/yr

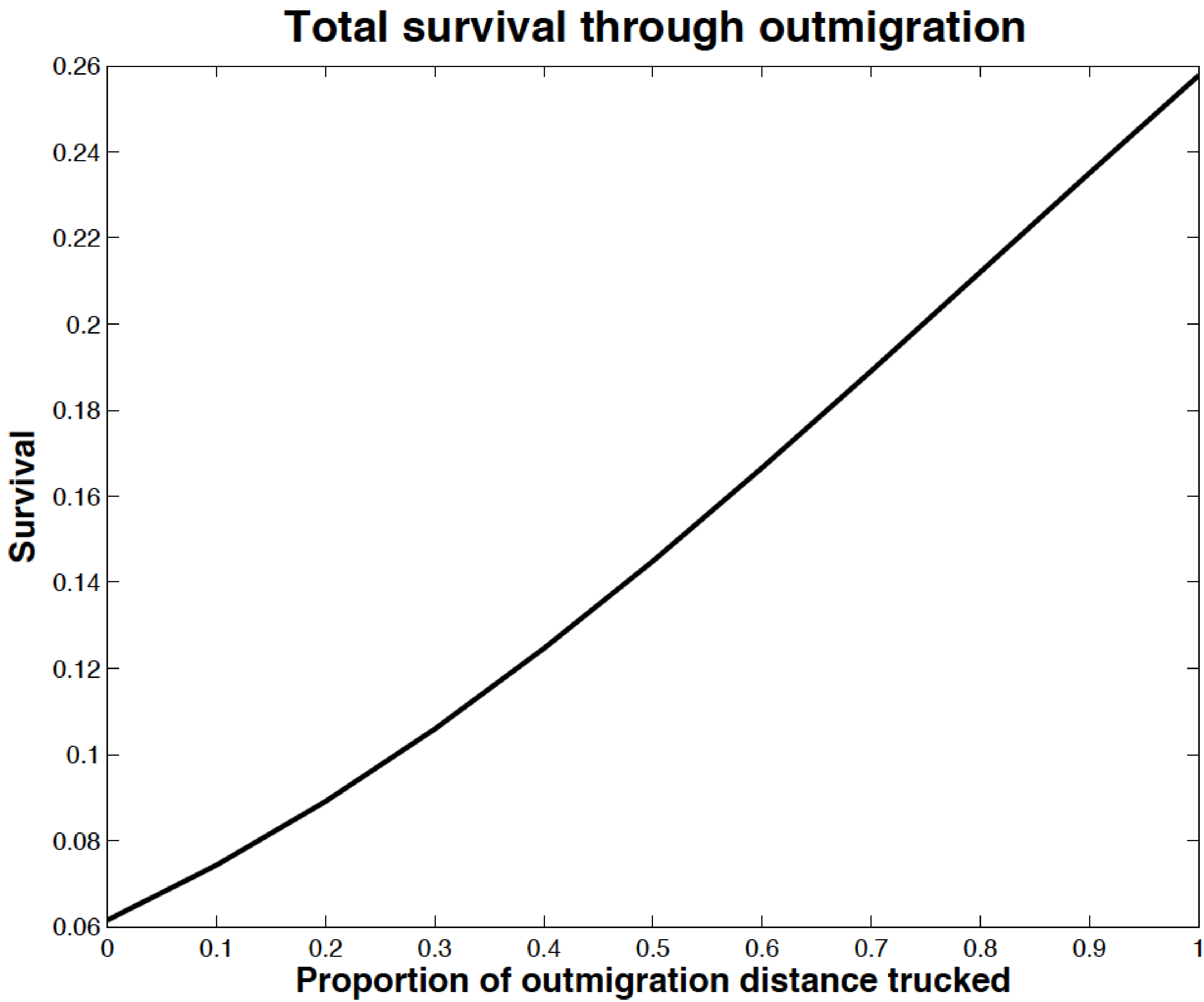


Huber and Carlson, *Accepted*. San Francisco Estuary and Watershed Science.

Trend towards off-site releases of hatchery fish

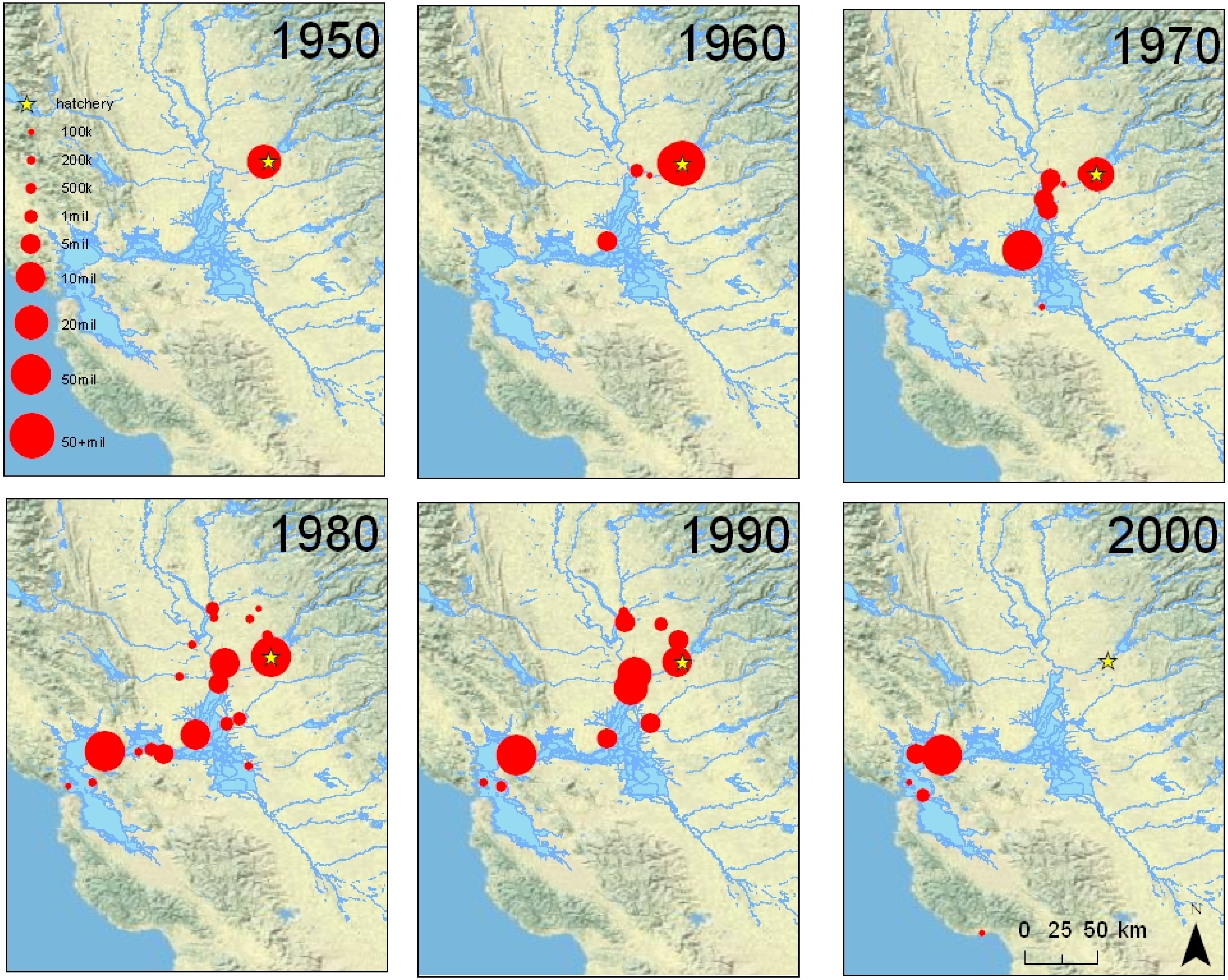
http://www.fisheryfoundation.org/

In 2008, 20.2 million smolts outplanted to San Pablo Bay!



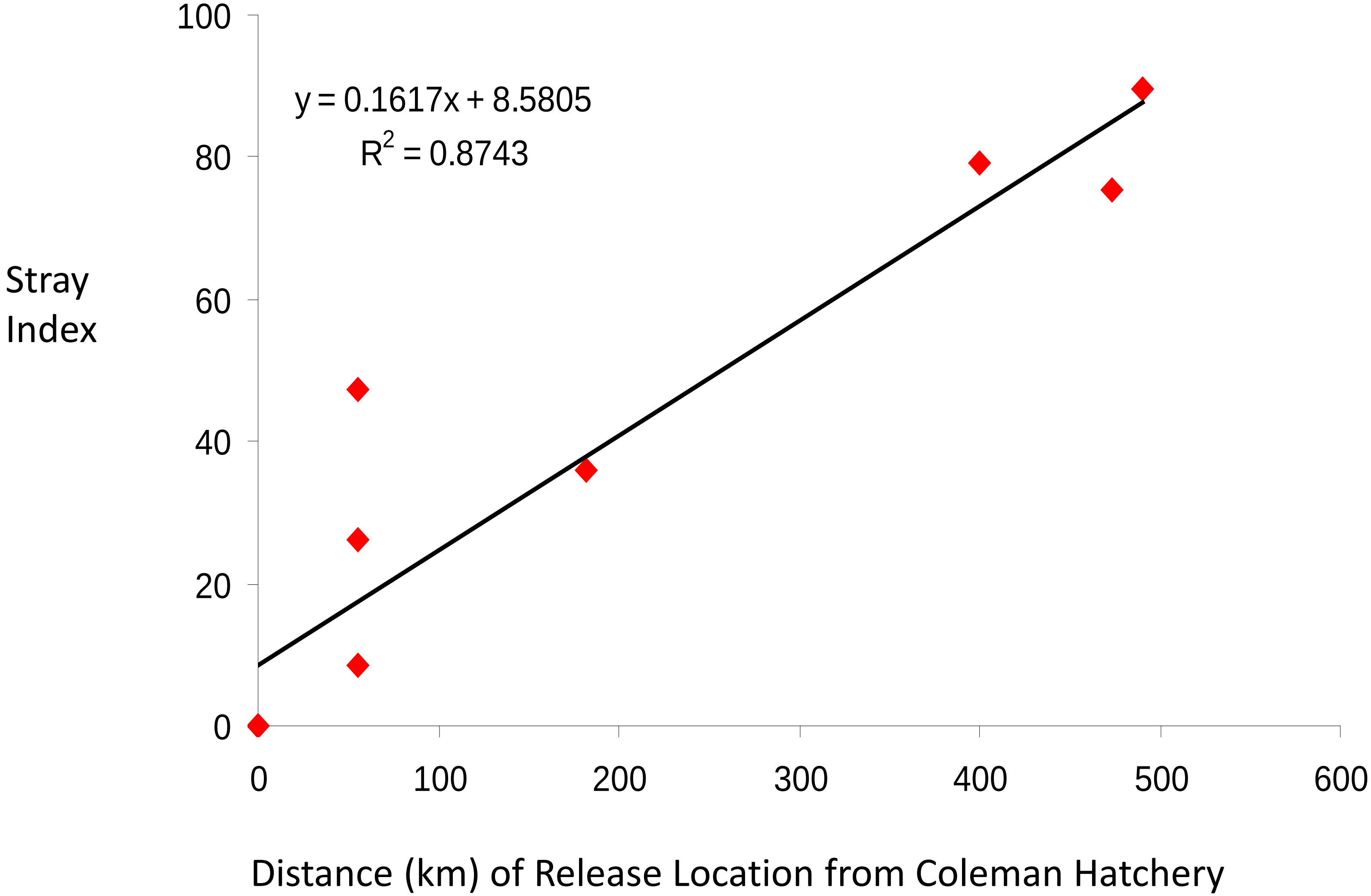
Total survival through outmigration
Survival
Proportion of outmigration distance trucked
0.06
0.08
0.1
0.12
0.14
0.16
0.18
0.2
0.22
0.24
0.26
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1

Release locations for the Nimbus Hatchery



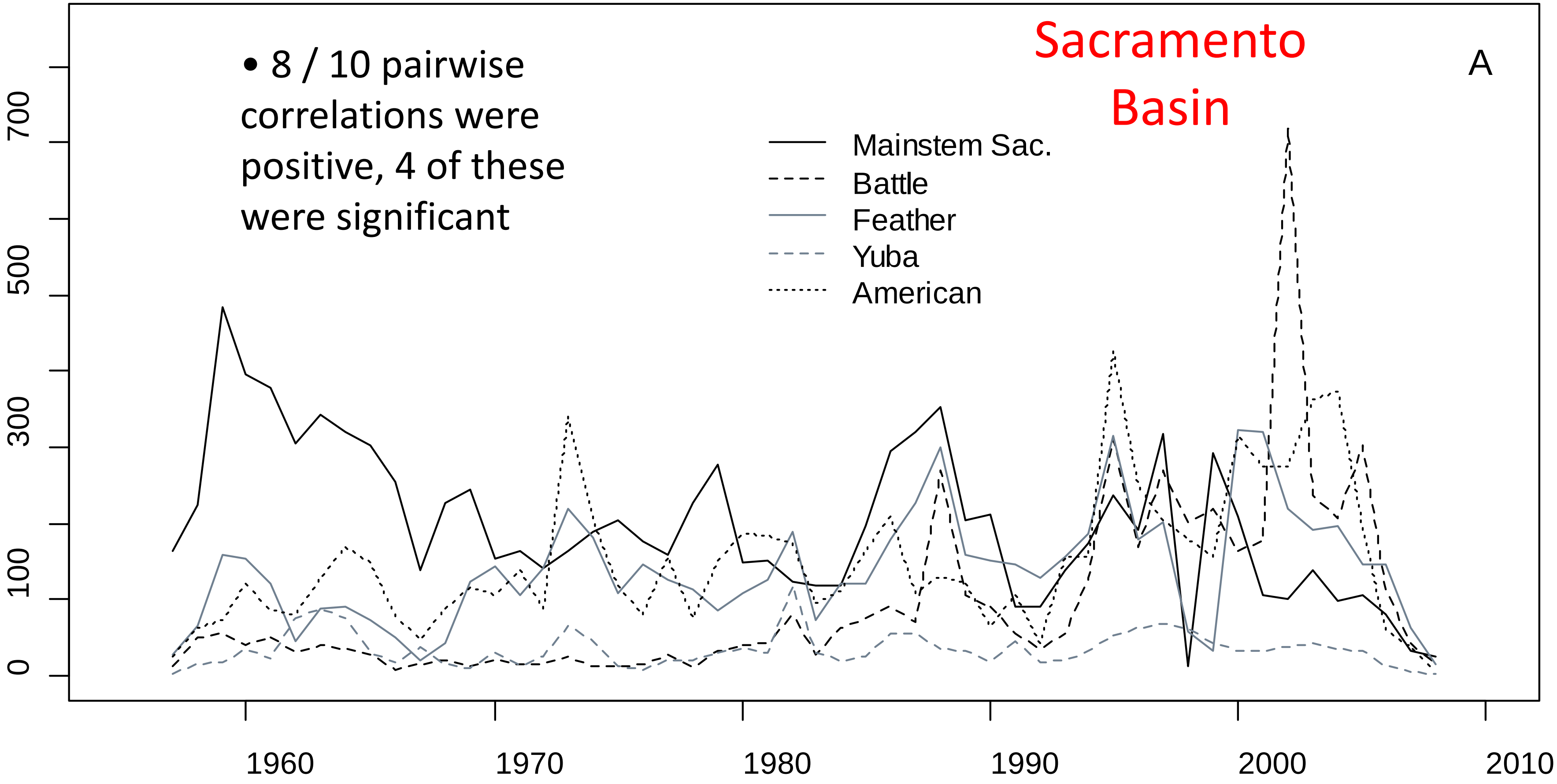
Slide courtesy of Kristina Cervantes-Yoshida; Sturrock et al. in prep

Straying is increasing in the trucking distance



CDFG/NMFS. 2001. Final report on anadromous salmonid fish hatcheries in California.

Population time series show evidence of increasing synchrony in dynamics of Sacramento River Fall Run Chinook



Carlson and Satterthwaite. 2011. Canadian Journal of Fisheries and Aquatic Sciences.

Salmon collapse in the Central Valley results in unprecedented fishery closures (2008)

San Francisco Chronicle

★★★★★ Z 3 Printed on recycled paper | WEDNESDAY, JANUARY 30, 2008 | sfgate.com 415-777-1111 46¢ plus tax

It's a hard homecoming for season's fall-run salmon

By *Jane Kay*
CHRONICLE ENVIRONMENT WRITER

The Central Valley fall run of chinook salmon apparently has collapsed, portending sharp fishing restrictions and rising prices for consumers while providing further evidence that the state's water demands are causing widespread ecological damage.

The bad news for commercial and sport fishermen and the salmon-consuming public surfaced Tuesday when a fisheries-management group warned that the numbers of the bay's biggest wild salmon run had plummeted to near record lows.

In April, the Pacific Fishery Management Council will set restrictions on the salmon season, which typically starts in May. A shortage could drive up the price of West Coast wild salmon. The council's leaders said the news is troubling because normally healthy runs of Central Valley chinook salmon are heavily relied upon by fishermen. Runs on the other river systems historically have been smaller.

"The low returns are particularly distressing since this stock has consistently been the healthy

▶ FISH: Page A10

The numbers of salmon returning to spawn are well below what fishermen expected.

KIM KOMENICH / *The Chronicle* 2004

Intended contributions

1. Determine how hatchery and fishery management can improve fishery value and resilience.
    - Externality to hatchery production.

2. Develop approximate dynamic programming tools and introduce ADP to resource economics.

Unique Aspects

- Calibrated to Central Valley Chinook salmon.
- 2 stream model
- Dynamic optimization with three control variables and seven state equations. (This is big).
- Quantitative genetics.

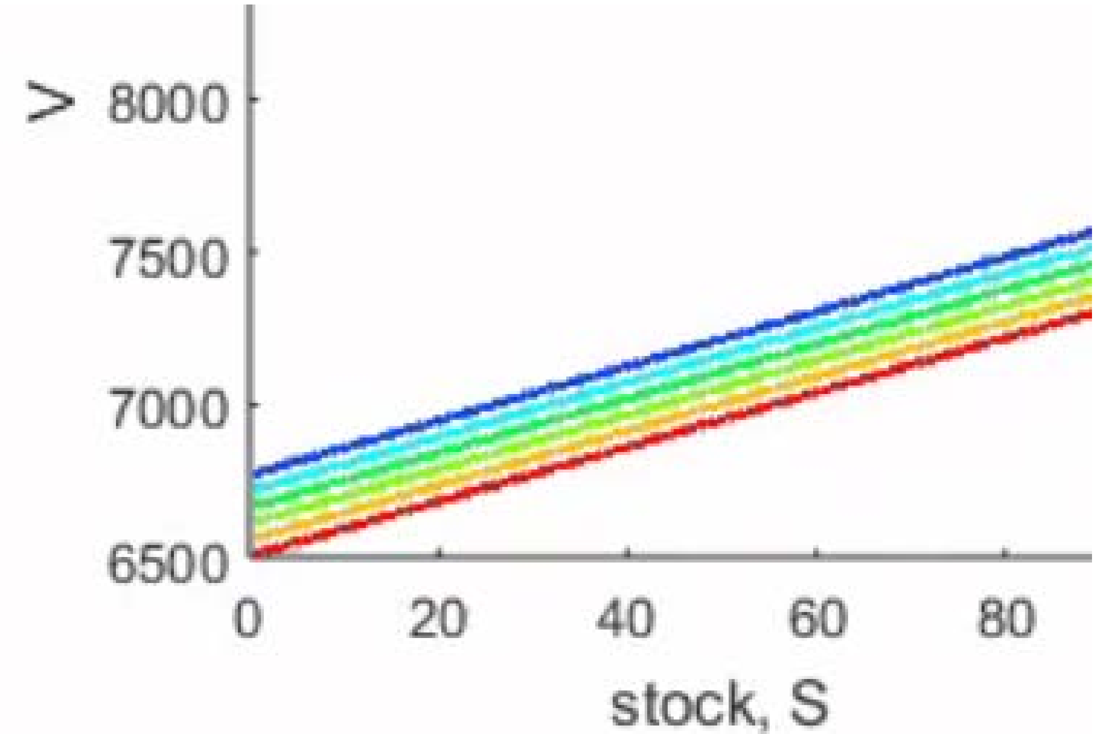
Intended contribution: develop approximate dynamic programming tools – forward simulation

- Traditionally, numerical methods to solve dynamic optimization problems iterate backwards through time. (e.g. Value-Function Iteration)

- As the number of stocks and control variables increase, memory becomes a limiting factor.

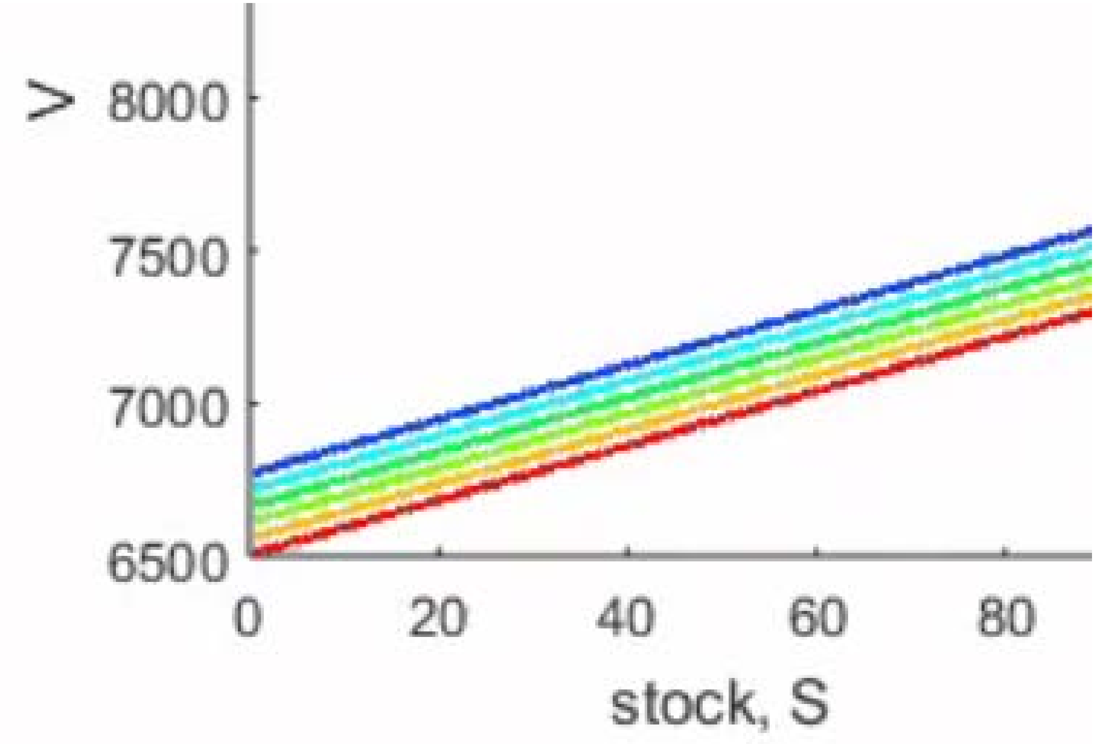
- ADP allows for high dimensionality without as much loss of resolution or slow run time.

Intended contribution: develop approximate dynamic programming tools – forward simulation



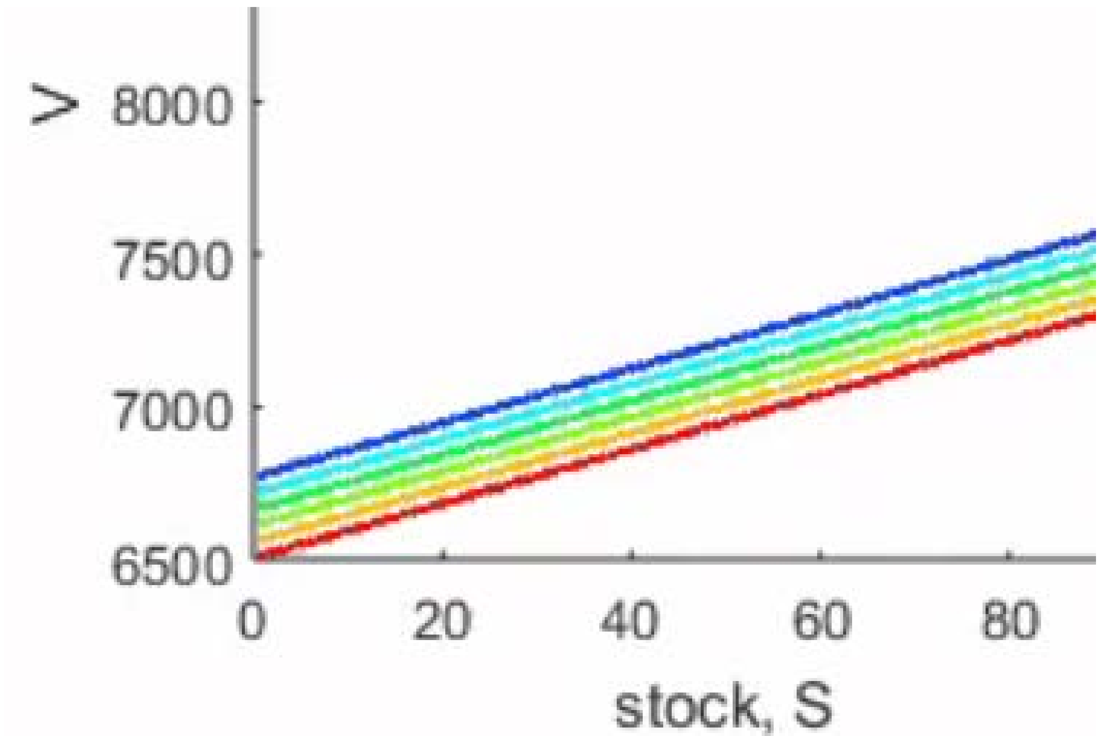
Start with an initial guess of the value function. V(s,z)

Intended contribution: develop approximate dynamic programming tools – forward simulation



Randomly choose an initial state.

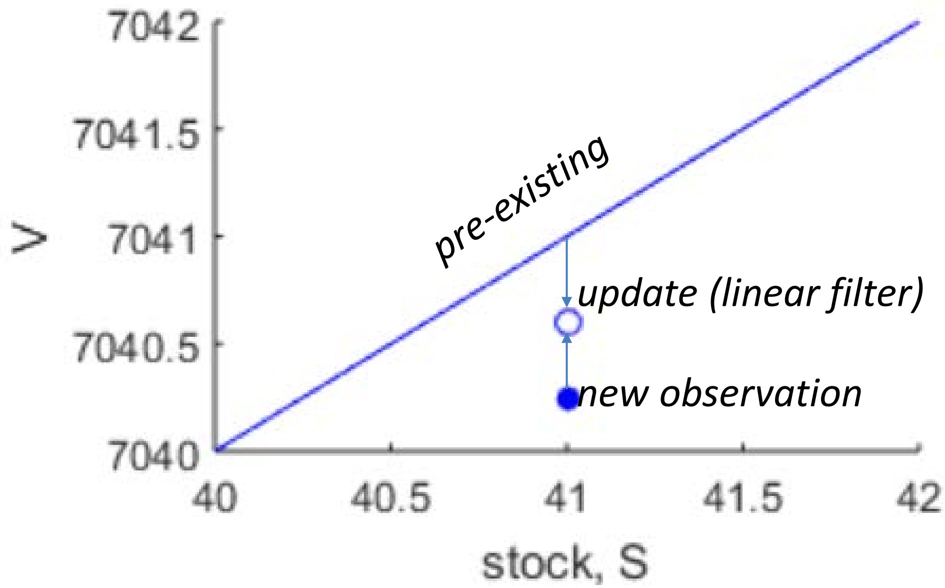
Intended contribution: develop approximate dynamic programming tools – forward simulation



Given the value function, calculate the optimum control/action at the current state(s).

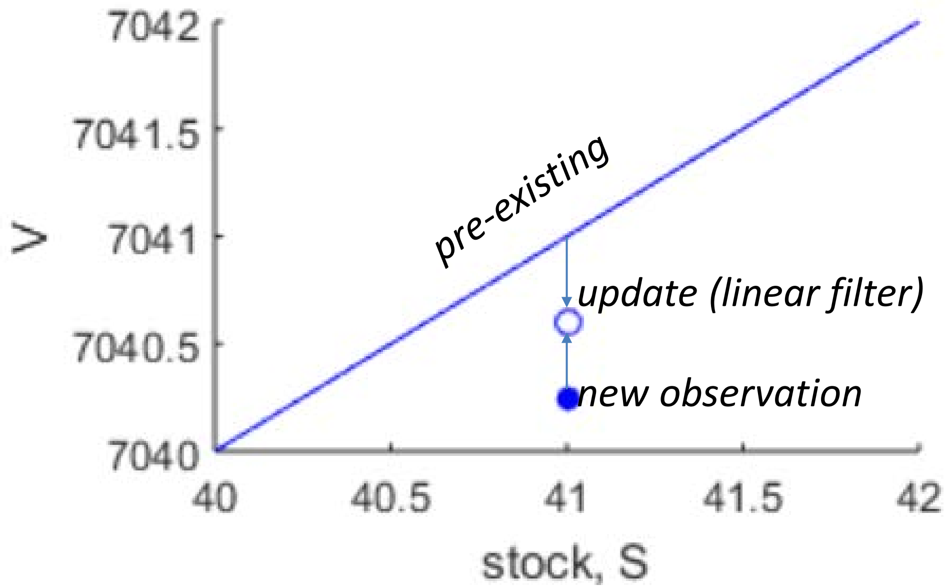
$$V^*(s_t,z_{t-1}) = \max_a \{ \pi(s_t,z_t,a_t) + \beta V(s_{t+1},z_t) \}$$

Intended contribution: develop approximate dynamic programming tools – forward simulation



Update the value function.

Intended contribution: develop approximate dynamic programming tools – forward simulation



Update the value function.

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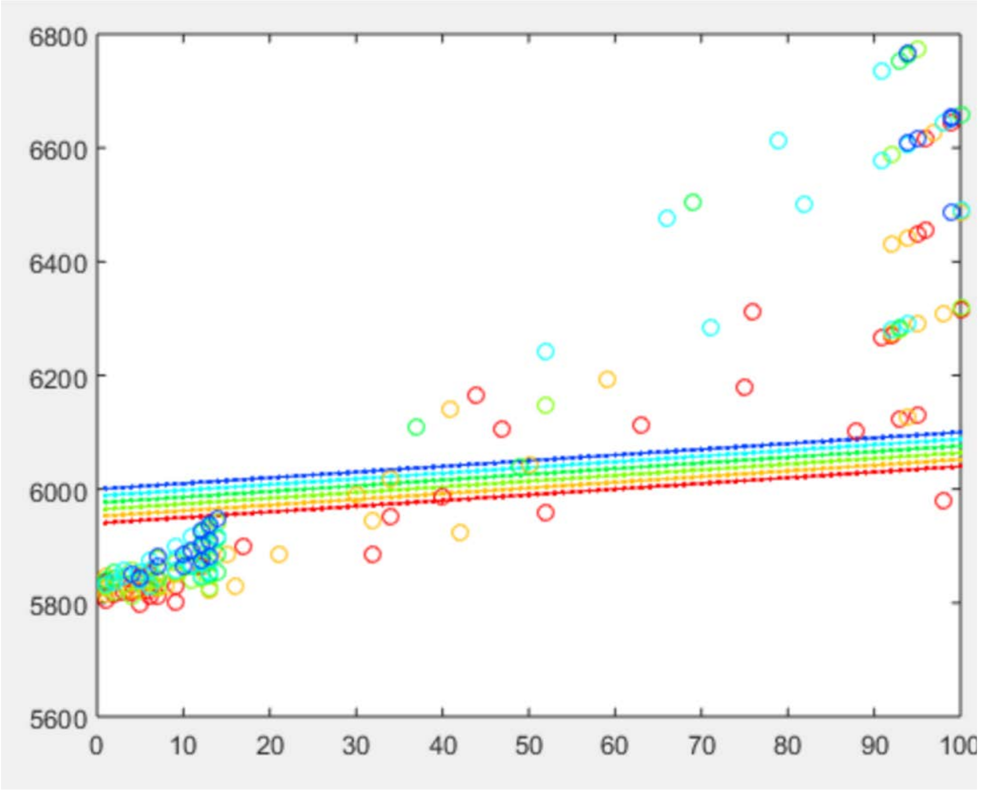
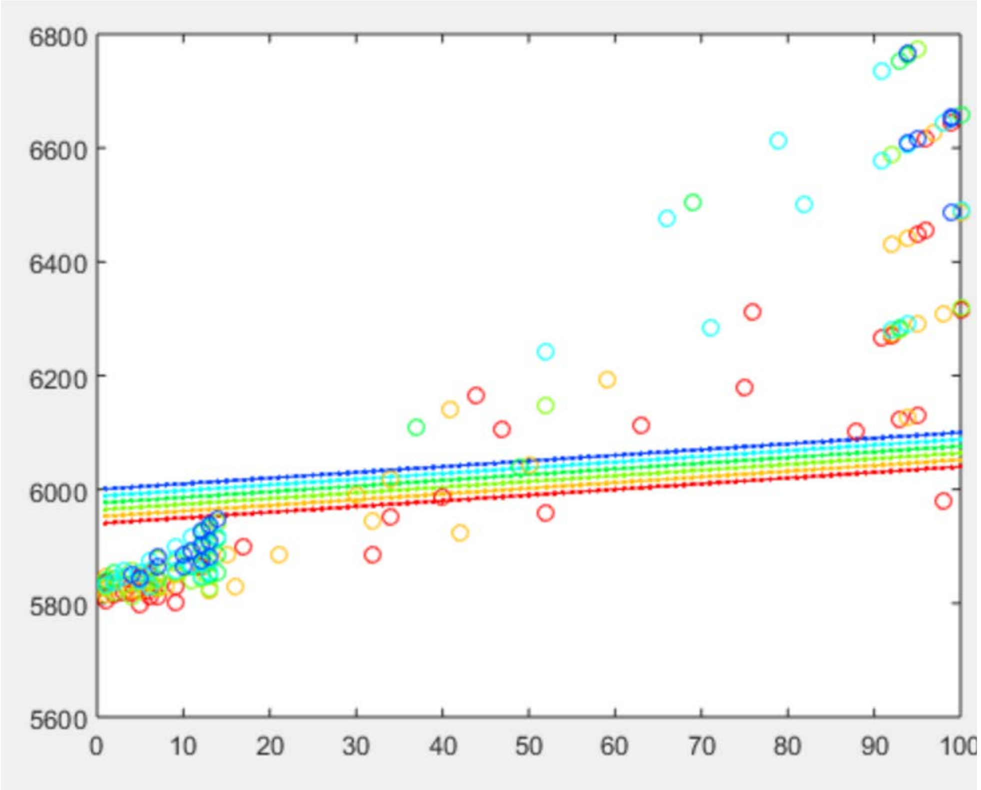


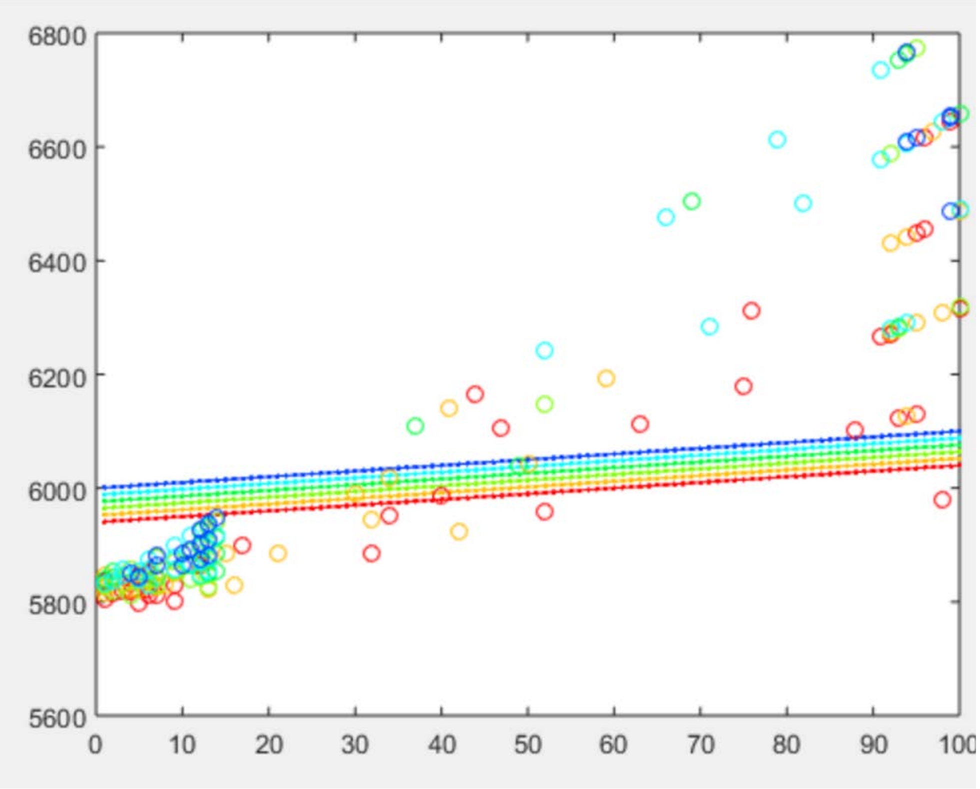
Repeat this process for T periods, where s_{t+1} is a result from the previous period and z_{t+1} is drawn from the stochastic process.

Intended contribution: develop approximate dynamic programming tools – forward simulation



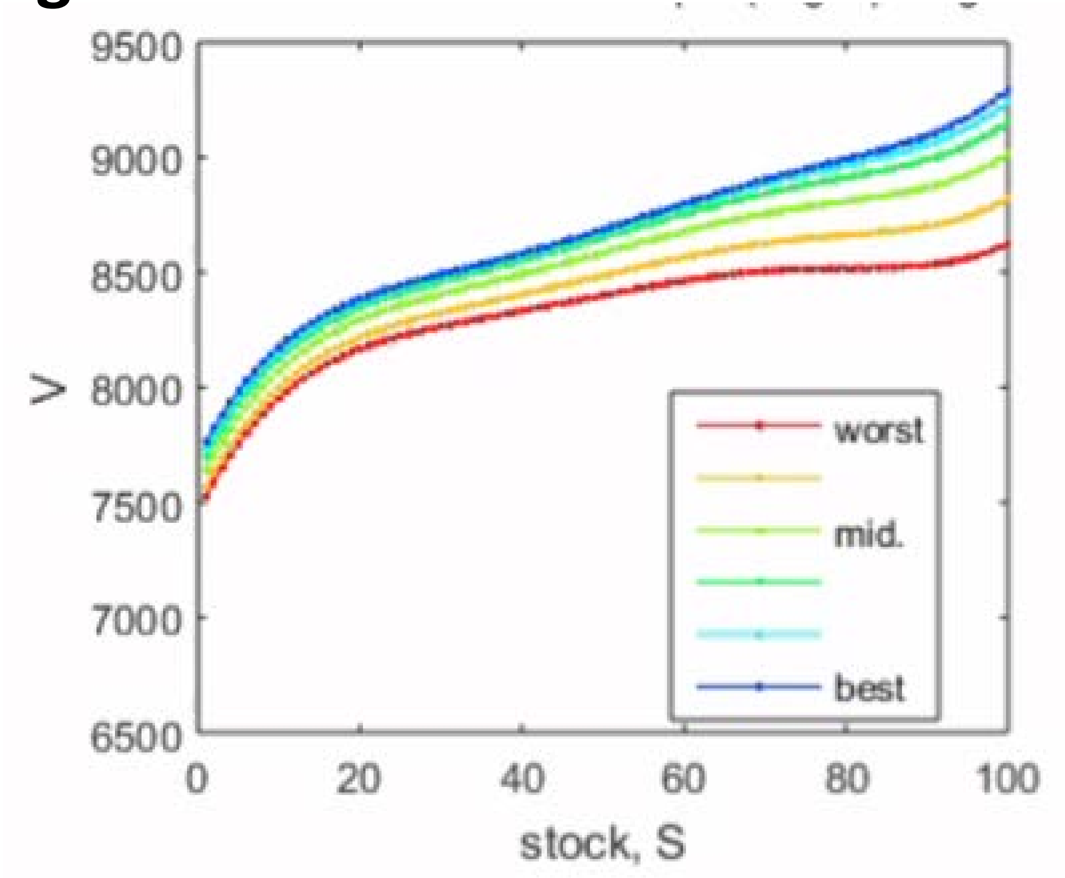
- After T periods, pick a new state randomly and repeat for another T periods.

Intended contribution: develop approximate dynamic programming tools – forward simulation



After N iterations of the entire process, regress.

Intended contribution: develop approximate dynamic programming tools – forward simulation



After N iterations of the entire process, regress.

Intended contribution: develop approximate dynamic programming tools – forward simulation

- Iterating forward in time while drawing shocks from the stochastic process eliminates the need for integration.
- Using regressions to characterize the value function eliminates the need for massive value function matrices.
- This makes forward-simulating ADP particularly powerful tool for dynamic optimization with many states and/or controls.

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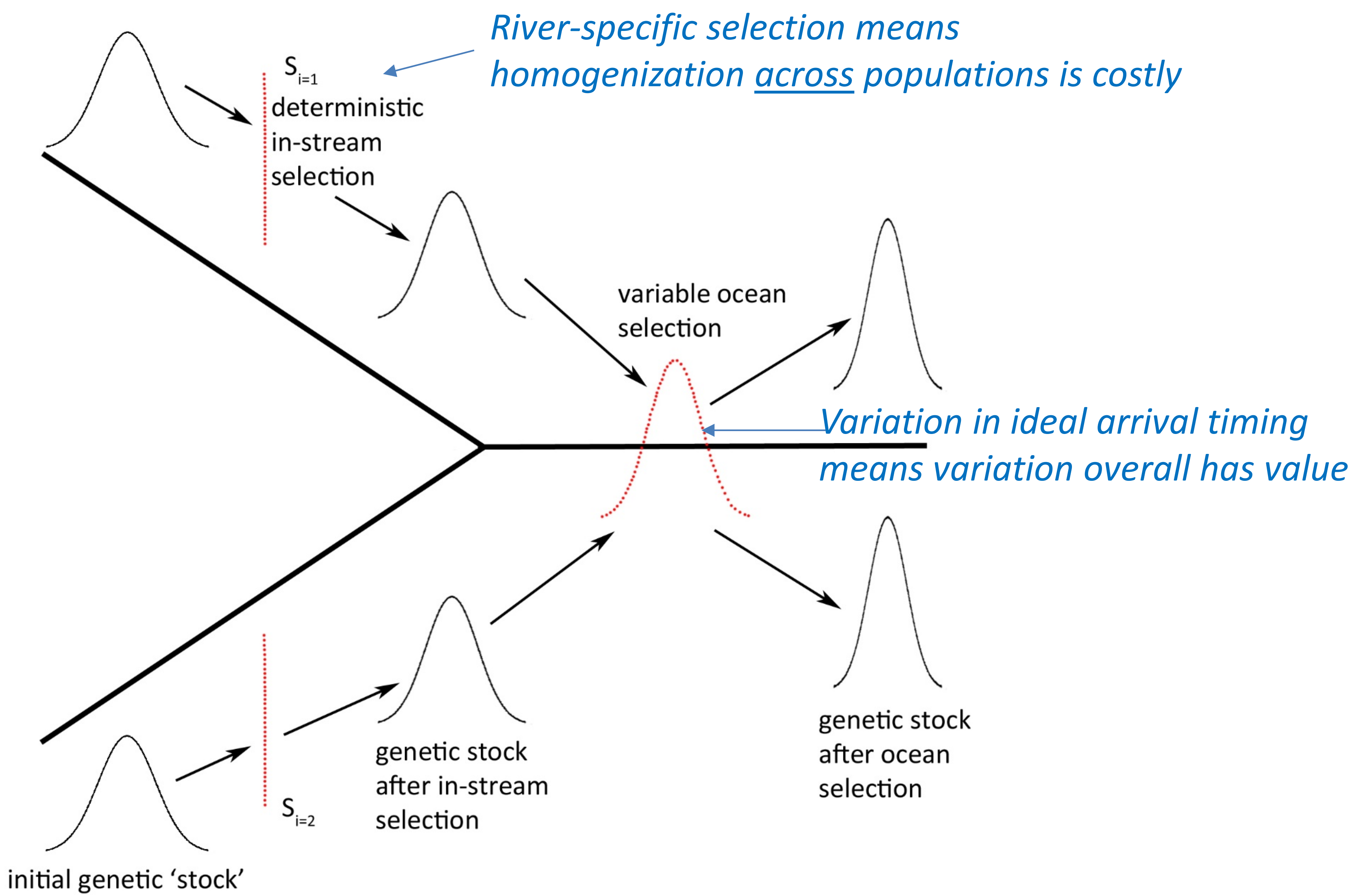
Conceptual model: two populations face individual selection events and a shared selection event in the ocean



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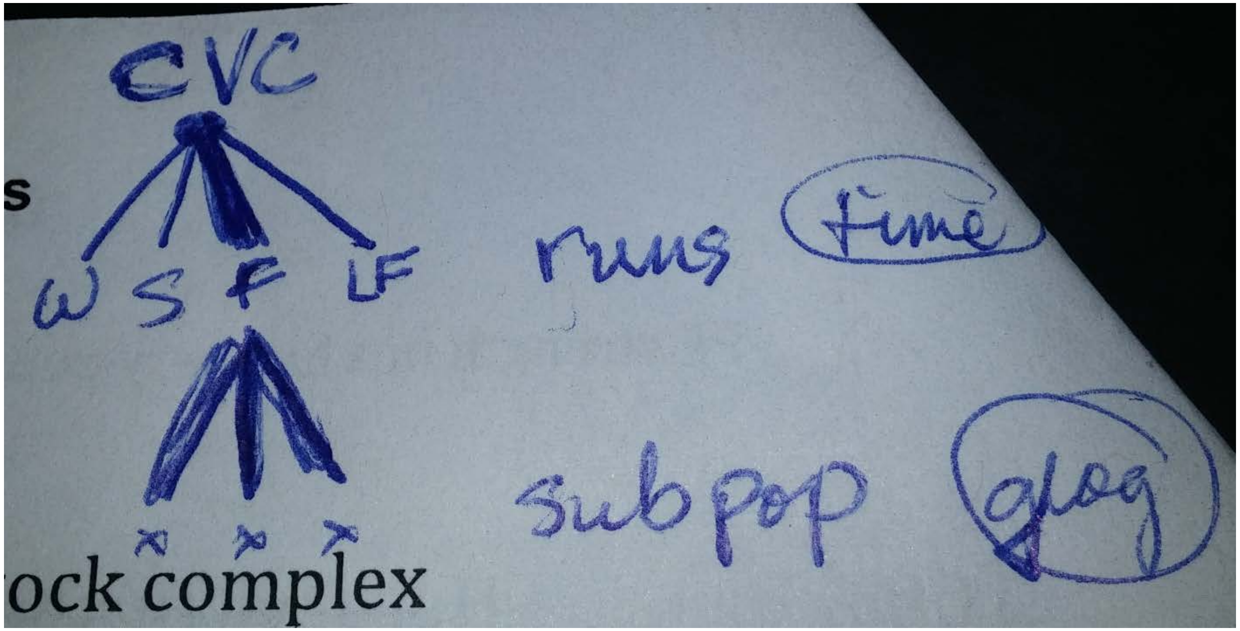
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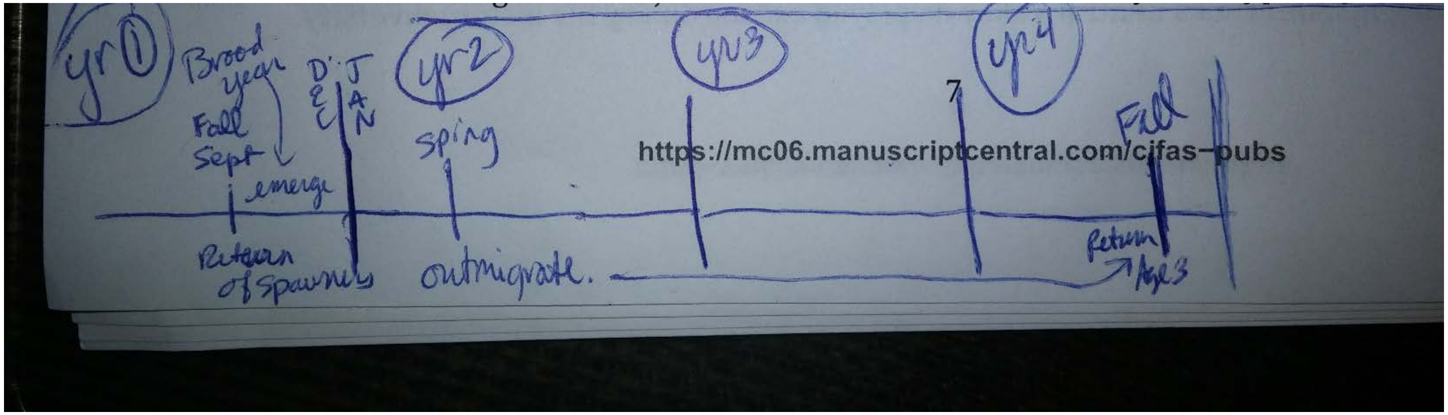
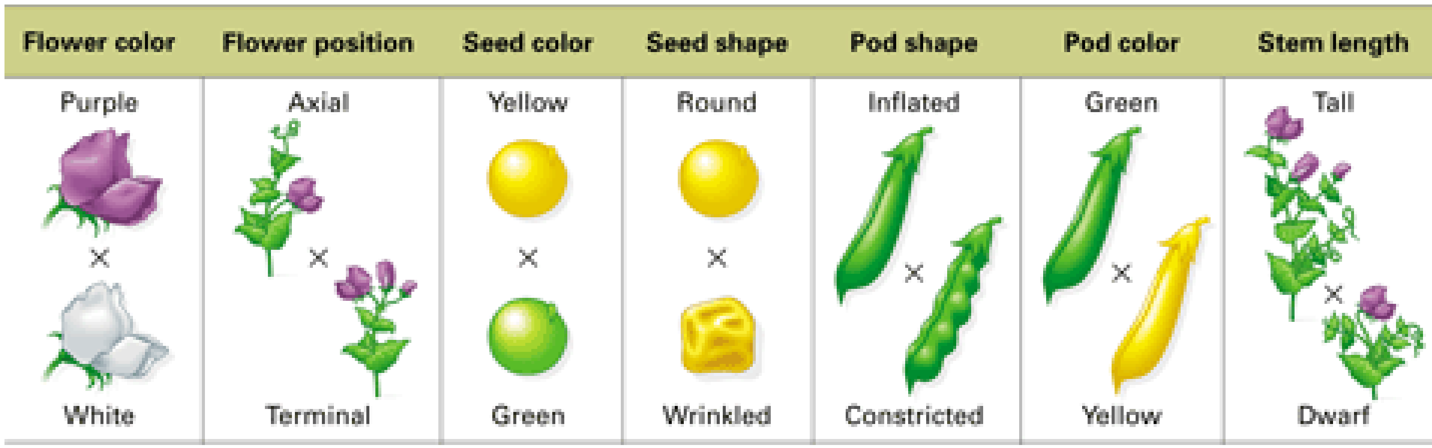
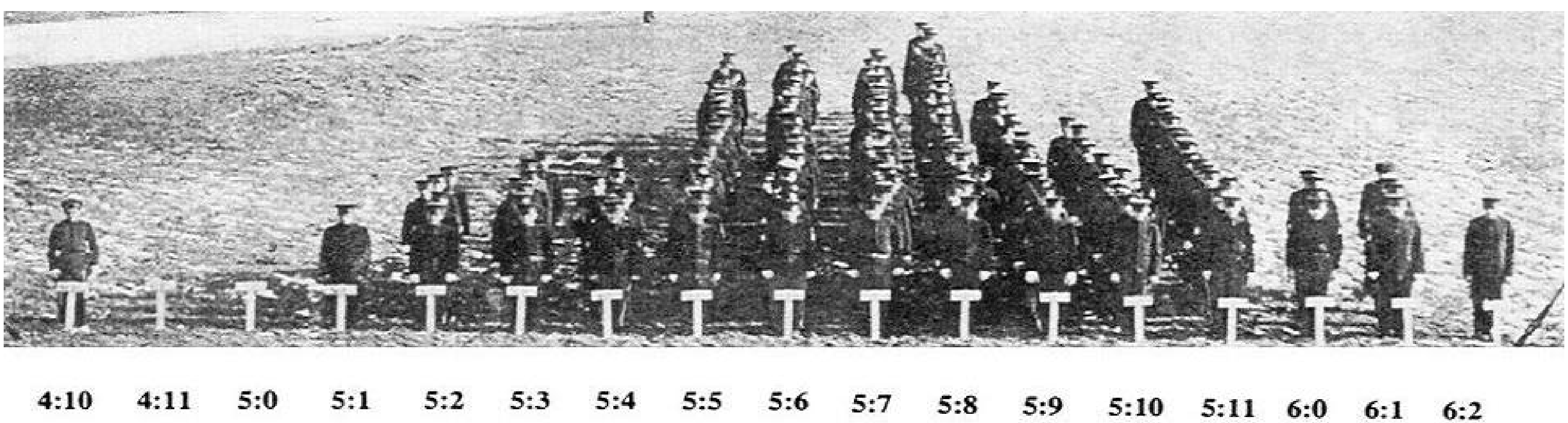

yr1
Brood year
Fall
Sept
emerge
DEC
JAN
yr2
spring
yr3
yr4
7
https://mc06.manuscriptcentral.com/cjfas-pubs
Fall
Return of spawners
outmigrate.
Return Age 3

Mendelian vs. quantitative traits

Mendelian trait



Quantitative trait



Populations without hatcheries are starting to behave like the rest of the system