Lecture 9: Life-history strategies

Outline

I. Reintroducing the intrinsic rate of increase, *r*
II. The periodic strategy ("bet-hedgers")
III. The opportunistic strategy ("r strategists")
IV. The equilibrium strategy ("K strategists")
V. Implications for management

I. Reintroducing the intrinsic rate of increase, *r*

- Remember, the goal of a population is *persistence*
- Typically depends on the ability of a population to propagate itself in its environment, which is often variable
- measured by $r \sim \ln(\Sigma(l_x\ m_x))/T$
- in essence, determined by fecundity, survival of young, and generation time

A. Relationship to life-history parameters

- In an ideal world, you'd want to maximize fecundity and survival and minimize generation time, because...
- High fecundity increases the odds of at least *some* progeny making it
- High juvenile survival increases the odds of *each* progeny making it
- Short generation time increases the speed at which a population can bounce back after a bad year
- Problem is, you can't accomplish *all* of these due to those ever-present evolutionary tradeoffs...

B. Constraints on maximizing *r*

- E.g., you can't produce many large eggs because the ovary and body size issue
- You also can't be fecund and have a short generation time, because you must be large (long-lived) to be fecund
- Not all investments favor all of these factors...
- ...so fish exist on a 3-point continuum based on tradeoff and optimization among different parts of the equation (FIGURE 1)
- Realization of this pattern led to development of a useful framework for characterizing different life-history strategies – it's in your reading assignment (TABLE 1)
- Let's run through them

II. The periodic strategy ("bet-hedgers")

- As the name suggests, these populations take advantage of periodically available resources
- Individuals make regular investments in reproduction because sooner or later, conditions will be optimal and they will realize their fitness
- It's kind of like playing the big-money lottery once a month – the big payoff is worth the many losses

A. Characteristic tradeoffs

- Optimize fecundity (clutch size) by delaying maturity to a large size, packaging young as small eggs, and releasing them in one batch per year (synchrony)
- Tradeoff survival of each offspring and generation time, as well as the ability to tailor reproductive output to current conditions

B. Characteristic environments

- Large-scale variability, both in space and time

- Variability over time may be large, but is predictable – often annual due to climactic variability – causes wide variation in year-class strength (*YCS*) and recruitment (*R*) despite fishes' ability to sense cues for timing
- Spatial variability may also be large because of gradients in productivity or safety (e.g., coral reefs, upwellings) – producing large numbers of offspring ensures that at least *some* will settle in the right places
- Note that migration represents a strategy that reduces spatial uncertainty

C. Variation in recruitment as a limiting factor
- Good recruitment occurs when young are born at a time when competition and predation are minimal, the growing season is long, and there is plenty of food
- Low recruitment when opposite conditions occur
- Note importance of stochasticity
- To this point, when modeling population size over time, we have assumed it is completely a function of population-internal rates (deterministic), but...
- In reality, environmental fluctuations have large influences on the variability in demographic rates (stochastic)
- Periodic strategists are adapted for dealing with large-scale stochasticity

D. Population signatures and strengths
- Very large variance in *R*, but becuase surviving individuals stay in the population so long, population size is somewhat stable
- Only takes one or a few good years to sustain a population
- Important that spawning stock stays large and spawns every year, because you never know when recruitment will be high

E. Examples
- Predominant strategy among commercially exploited fisheries worldwide
- Common in temperate saltwater (e.g., cod, tuna, ocean sunfish) and temperature freshwater (yellow perch, white bass, whitefish)
- North Sea plaice and herring (FIGURE 2)

III. The opportunistic strategy ("*r* strategists")

- Expect heavy, *unpredictable* losses because of a variable environment and/or heavy predation
- Produce young fast and often because you're not going to live that long – spread them out over time and space
- *r*-species often small-bodied because don't have time to grow large and produce more eggs
- When losses are low (this is infrequent), population can boom
- Like playing the scratch-off lottery every day – low payout, but good odds of hitting it

A. Characteristic tradeoffs
- Optimize by having short generation time by maturing early in life
- Also, be as fecund as possible given small body size
- Tradeoff: can't produce many eggs at a time, eggs are small, and parental investment minimal

B. Characteristic environments
- Small-scale variability in space and time
- Environment dynamic and *unpredictable* – change is very rapid
- Areas that are frequently depopulated or where predation is extreme
- Often in shallow, fringe, ecotone habitats, but there are also pelagic examples

D. Population signatures and strengths
- High overlap of generations because they don't live long and don't spawn discrete batches in synchrony
- High variance in *YCS* and *R*
- Very high population density and turnover
- Rapidly repopulate and grow after disturbance
- Important that refugia (spatial and temporal) remain, from which to repopulate – they have to hang on somewhere

E. Examples
- Many pelagic, schooling, forage species (e.g., anchovies, menhaden, gizzard shad)
- Marshy areas (e.g., mosquitofish, killifishes)
- Headwater streams (e.g., daces and some darters)

IV. The equilibrium strategy ("*K* strategists")
- Environment is fairly stable and predictable, so devote resources to increase probability of survival (*S*) of each offspring – no need for fast population growth
- Most factors affecting *S* are biotic and density-dependent, so preparedness helps
- These populations *don't* play the lottery – instead, they live off the small amount they've got

A. Characteristic tradeoffs
- Optimize *S* and development of young through larger eggs and parental care
- Tradeoff: can't produce as many eggs or spread them out much; delayed maturity increases generation time

B. Characteristic environments
- Situations in which resource limitation causes competition
- Competition for food or often space
- Environmental fluctuations are minor and/or infrequent
- Tropical environments, benthic environments

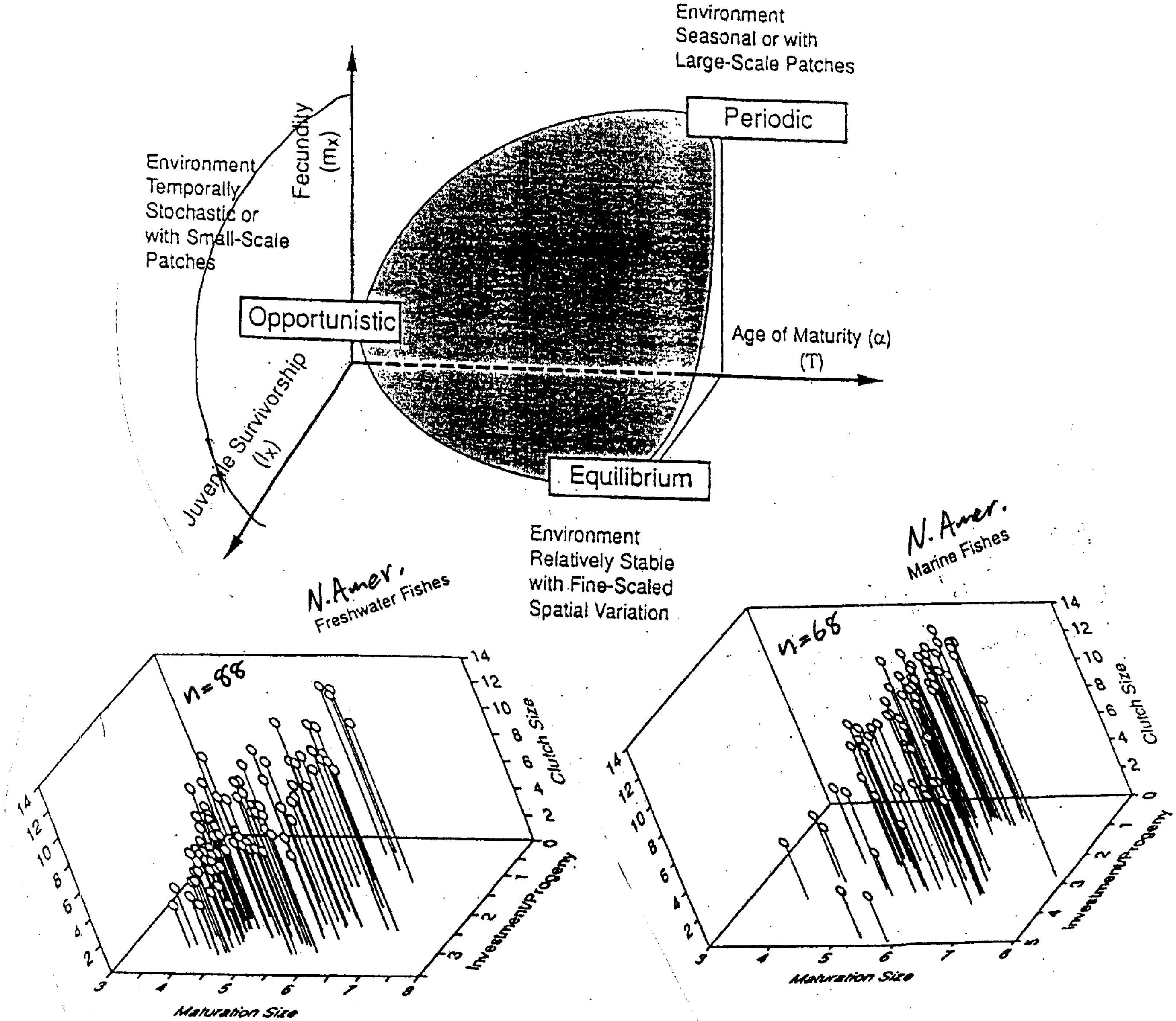
C. Resource limitation as a limiting factor
- Seems intuitive, but environmental variability is often so large that it obscures biotic f_x
- The most striking evidence comes from experimental manipulations
- Cutthroat trout juvenile rearing habitat in stream margins in Oregon – control (12/reach), increased density (26/reach), decreased density (2/reach)

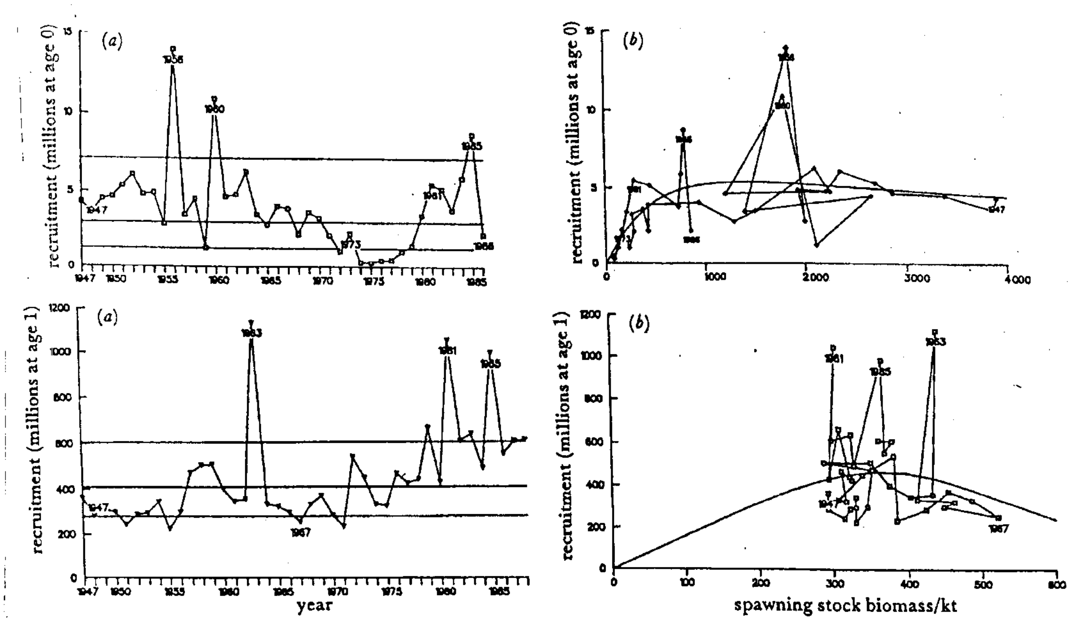
D. Population signatures and strengths
- Low variation in *YCS* and *R*
- Relatively high *S*
- Population size and turnover low and stable, and fluctuate about *K*
- Recovery from disturbance slow
- Important to preserve reproductive habitat and juvenile survival, because they often are limiting

E. Examples
- Many species tied to particular habitats or substrates, e.g., benthic (sculpins, darters, seahorses, gobies), nesters (sunfishes, salmonids), reef fishes
- Parental care extremists like cichlids and catfishes
- Cavefishes and springfishes in very stable environments

V. The Roanoke logperch example

- Let`s look now at a local species, make some predictions about population regulation based on its life history, and see if the population data support our predictions
- See page of information, including figures
- Traits suggest periodic – for a darter
- Stock-recruit curve suggests density-dependent limitation of spawners – maybe equilibrium?
- Inter-annual variability suggests that flow periodicity exerts stochasticity on annual scale – brings us back to periodic





North Sea plaice

North Sea herring

Table 1

	Parameters	Life-history strategies: Periodic	Opportunistic	Equilibrium
Tradeoffs				
1. Generation time	Body size	Large	Small	Small
	Maturation	Delayed	Rapid	Delayed
2. Offspring production	Eggs / clutch	Many	Few	Few
	Clutches / yr	Few	Many	Few
	Spawning season	Short	Long	Short
	Migration	Common, extensive	Uncommon	Uncommon
3. Offspring survival	Egg size	Small	Small	Large
	Growth rate of young	Fast	Fast	Slow
	Parental care	Uncommon	Uncommon	Common
	Survival of young	Low	Low	High
4. Summary	Optimize...	Offspring production	Generation time	Offspring survival
	At expense of...	Offspring survival Generation time	Offspring production Offspring survival	Offspring production Generation time
Environmental characteristics driving selection	Signature environment	Predictably variable	Unpredictably variable	Stable
	Primary limiting factor	Environmental seasonality (density independent)	Disturbance or predation (density independent)	Resource limitation (density dependent)
Population characteristics	r	Medium	High	Low
	Population density	Moderate	High	Low
	Population turnover	Moderate	High	Low
	Recruitment fluctuation	High	High	Low
	Strength	Maintaining pop. size despite variability in R and S	Rapid re-colon. population growth	Maintaining pop. size at stable level
Examples	Most common in..	Temperate FW and SW	Tropical freshwaters Shallow ecotones	Tropical FW and SW Benthic fish
	Example fishes	cod, cobia, tuna, ocean sunfish, whitefish	anchovies, silversides, killifishes, mosquitofish	catfishes, cavefishes, gobies, seahorses, cichlids

Roanoke logperch (*Percina rex*)

Maturation - 2 years
Fecundity - 180-640 eggs
Batch spawning - ?
Egg size - small

Parental care - none
Spawning season - April-May
Body size - 5-6"
Lifespan - 6 years

Population density - low
Growth rate of young - fast
Survival rates - ?
Migration - assume no