## Life history variation in fishes

**Life history** = the allocation of time and resources to accomplish survival and reproduction

**Life history trait** = a trait that contributes to lifetime survival and reproduction

**Examples of traits:**

| | |
|---|---|
| Age at maturity | Spawning frequency |
| Size at maturity | Parental care |
| Maximum size | Time to hatch |
| Longevity | Larval growth rate |
| Clutch size | Juvenile growth rate |
| Egg size | Adult growth rate |
| Duration of spawning | Episodic or batch spawn |

## Life history variation in fishes

**Life history strategy** = the suite of life history traits that adapt a fish to its particular environment

| | |
|---|---|
| Age at maturity | Spawning frequency |
| Size at maturity | Parental care |
| Maximum size | Time to hatch |
| Longevity | Larval growth rate |
| Clutch size | Juvenile growth rate |
| Egg size | Adult growth rate |
| Duration of spawning | Episodic or batch spawn |

**"Considerable variation among and within species"**

## Life history variation in fishes

**Some examples:**

| | |
|---|---|
| Maximum size | |
| 25 mm | pigmy sunfishes |
| 2 m | ocean sunfishes |
| Clutch size | |
| 12 | surfperches |
| $12 \times 10^6$ | tarpons |
| Egg size | |
| 0.45 mm | bay anchovy |
| 20.5 mm | gafftopsail catfish |
| Maximum age | |
| 1 year | Silversides |
| 50 years | Red drum |
| Early growth rate | |
| 1.3mm/month | whitefish |
| 1.3mm/day | bluefish |

## Life history variation in fishes

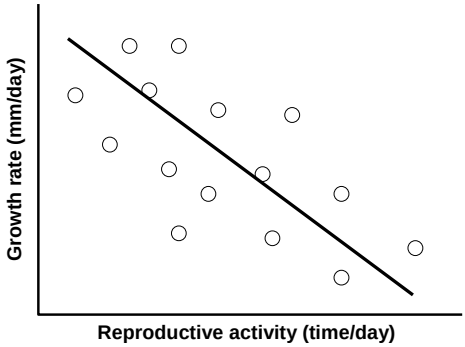
**What suite of traits would a 'superfish' have?**

- Fast growth
- Long life
- Early maturation
- Frequent spawning
- Large clutches
- Large eggs
- High parental care
- Large maximum size

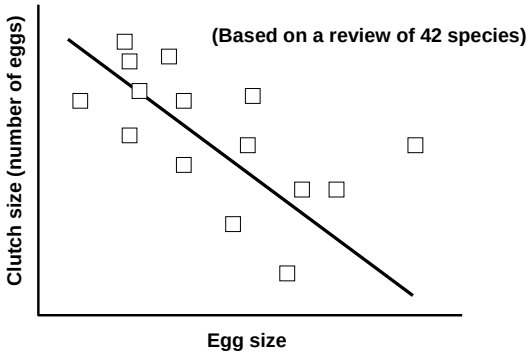
**Why no 'superfish'?**

- Resources and time limited
- Traits are in competition (trade-offs)

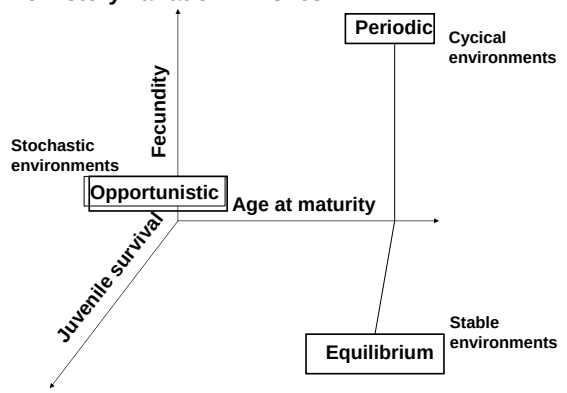
## Reproduction vs. growth



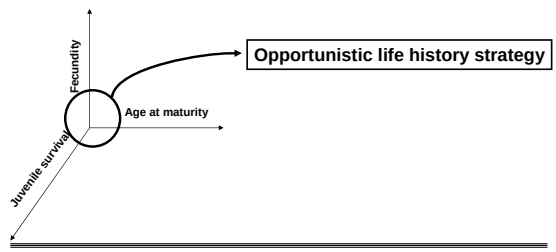

## Offspring number vs. offspring size



## Life history variation in fishes

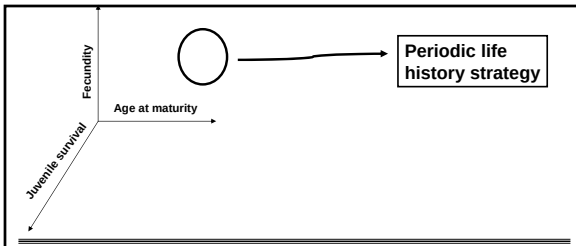



Winemiller and Rose 1992



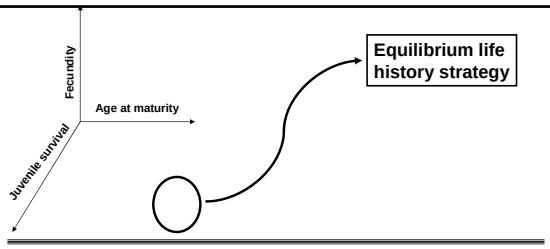

**Opportunistic: (1) early maturation, (2) low fecundity, and (3) low juvenile survival**

- **Maximize population growth (r) with short generation time**
- **Ideal for stochastic environments**
- **Small eggs, small clutches, continuous spawning**
- **High capacity for production (e.g., anchovies, sardines)**




**Periodic: (1) late maturation, (2) high fecundity, and (3) low juvenile survival**

- **Maximize fecundity by delaying maturation**
- **Found in predictably variable environments**
- **Reproductive seasonality timed to good conditions**
- **Variable recruitment, age structure protects against collapse**
- **"Bet-hedgers" that spread reproductive effort over many years (e.g., striped bass, tunas)**




**Equilibrium: (1) late maturation, (2) low fecundity, and (3) high juvenile survival**

- **Maximize juvenile survival by delaying maturation**
- **High maternal investment in offspring**
- **Stable, resource limited environments**
- **Low population growth (r), vulnerable to overfishing (e.g., sharks, rays, sturgeons)**

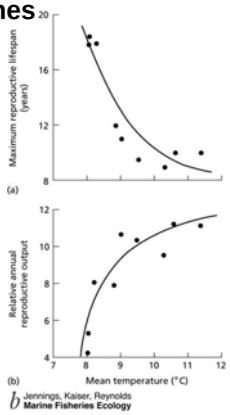
## Life history variation in fishes

**Particular life history strategies represent:**

**(1) Adaptations to particular environments and……**

**(2) Determine population response to harvest and sustainability**

**Example: Atlantic herring stocks**




## Incorporating life history variation using life tables

- Age-or size-structured models
- Survival, maturity, and fecundity are modeled as functions of age or size
- Can follow unique cohorts (age classes) and sum up reproductive output

## Simple life table (survival only)

| X | $S_x$ | $d_x$ | $q_x$ | $l_x$ |
|---|---|---|---|---|
| 0 | 180 | 100 | 0.555 | 1 |
| 1 | 80 | 20 | 0.250 | 0.445 |
| 2 | 60 | 15 | 0.250 | 0.333 |
| 3 | 45 | 5 | 0.111 | 0.250 |
| 4 | 40 | 4 | 0.100 | 0.222 |

**X = age class**
**$S_x$ = numbers in each age class**
**$d_x$ = number of deaths ($S_x$ - $S_{x+1}$)**
**$q_x$ = mortality rate ($d_x$ / $S_x$)**
**$l_x$ = cumulative survivorship to each age ($S_x$ / $S_0$)**

## Simple life table (adding reproduction)

| X | $S_x$ | $l_x$ | $b_x$ | $l_x * b_x$ |
|---|---|---|---|---|
| 0 | 180 | 1 | 0 | 0 |
| 1 | 80 | 0.445 | 0.333 | 0.148 |
| 2 | 60 | 0.333 | 0.8 | 0.266 |
| 3 | 45 | 0.250 | 1.5 | 0.375 |
| 4 | 40 | 0.222 | 1.0 | 0.222 |
| sum | | | | 1.011 |

**$b_x$ = age-specific fecundity (average # of offspring per individual)**

$$R_0 = \sum_0^\infty (l_x \bullet b_x)$$

## Life tables: incorporating reproduction

$$R_0 = \sum_0^\infty (l_x \bullet b_x)$$

What is $R_0$?

- The reproductive potential of a female during her entire lifetime adjusted for age-specific mortality

  if $R_0 = 1$, population is constant
  if $R_0 < 1$, population is decreasing
  if $R_0 > 1$, population is increasing

## Simple life table (adding reproduction)

| X | $S_x$ | $l_x$ | $b_x$ | $l_x * b_x$ | $F_x$ |
|---|---|---|---|---|---|
| 0 | 180 | 1 | 0 | 0 | 0 |
| 1 | 80 | 0.445 | 0.333 | 0.148 | 26.6 |
| 2 | 60 | 0.333 | 0.8 | 0.266 | 48 |
| 3 | 45 | 0.250 | 1.5 | 0.375 | 67.5 |
| 4 | 40 | 0.222 | 1.0 | 0.222 | 40 |
| sum | | | | 1.011 | 182.1 |

**$F_x = (S_x \cdot b_x)$ = total # of offspring per year class (repro. output)**

$$R_0 = \frac{\sum_0^\infty F_x}{S_0} = \frac{\sum_0^\infty (S_x \bullet b_x)}{S_0} = \frac{\textit{reproductive output}}{\textit{original \# individuals}}$$

## Life table (example for long-lived fish)

| X | Sx | lx | bx | lx * bx | Fx |
|---|---|---|---|---|---|
| 0 | 1000 | 1 | 0 | 0 | 0 |
| 1 | 600 | 0.60 | 0 | 0 | 0 |
| 2 | 400 | 0.40 | 0 | 0 | 0 |
| 3 | 300 | 0.30 | 0 | 0 | 0 |
| 4 | 225 | 0.23 | 0 | 0 | 0 |
| 5 | 160 | 0.16 | 0 | 0 | 0 |
| 6 | 110 | 0.11 | 0 | 0 | 0 |
| 7 | 80 | 0.08 | 0 | 0 | 0 |
| 8 | 60 | 0.06 | 2 | 0.12 | 120 |
| 9 | 45 | 0.05 | 3 | 0.135 | 135 |
| 10 | 35 | 0.04 | 4 | 0.14 | 140 |
| 11 | 30 | 0.03 | 4 | 0.12 | 120 |
| 12 | 25 | 0.03 | 5 | 0.125 | 125 |
| 13 | 20 | 0.02 | 6 | 0.12 | 120 |
| 14 | 16 | 0.02 | 8 | 0.128 | 128 |
| 15 | 12 | 0.01 | 8 | 0.096 | 96 |
| **Sum** | | | | **0.984** | **984** |

## Life table (graphical example)