Mortality

Learning Objectives

- Discriminate between instantaneous and interval mortality rates
- Estimate mortality using different techniques
- Evaluate the advantages and disadvantages of using different estimation techniques
- Describe assumptions associated with mortality estimation techniques
- Describe techniques associated with estimating natural and fishing mortality
- Evaluate the use of age-specific mortality rates
- Evaluate the influence of mortality on fish population dynamics
- Estimate and interpret mortality caps

Mortality

- If N_t individuals are present in a population at the start of an interval of length t, and N_{t+1} survive at the end of the interval, then $(N_t - N_{t+1})/t$,

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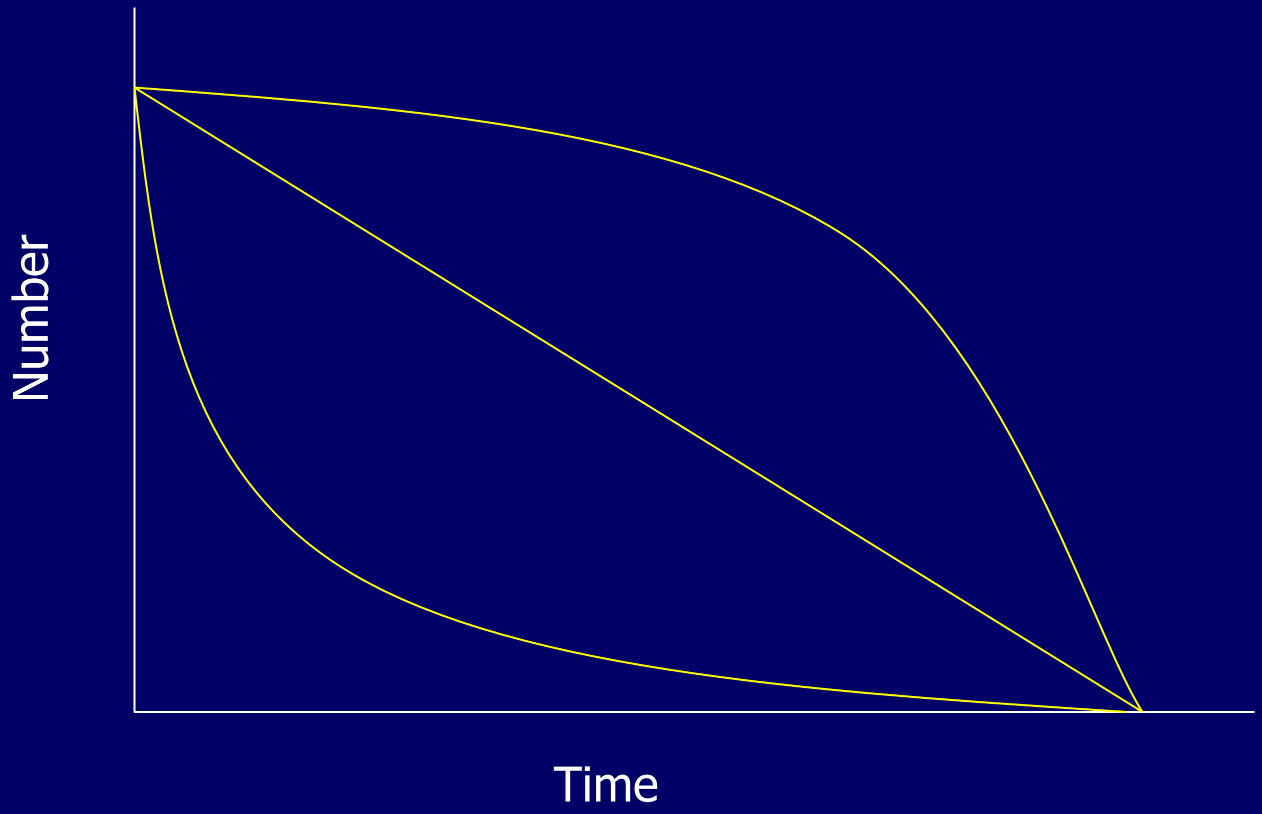
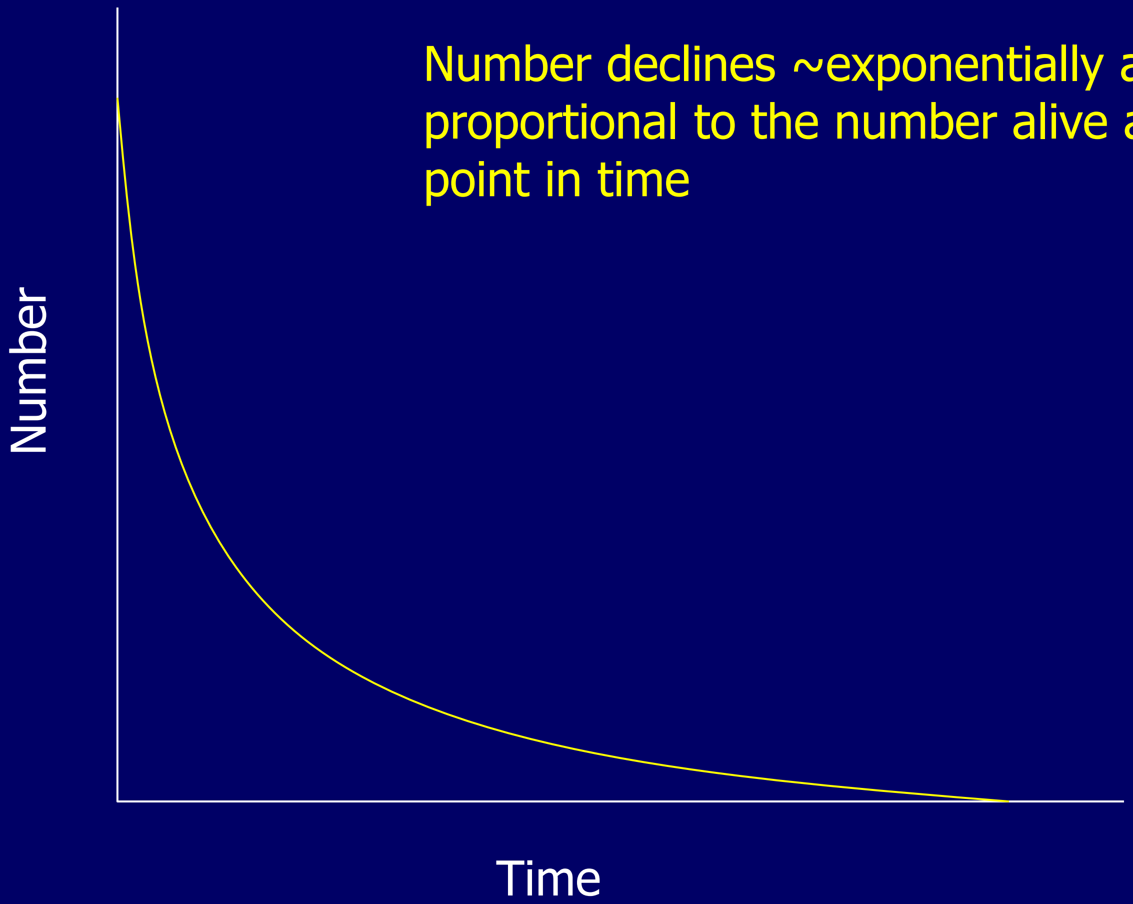
- A more useful expression is to express $(N_t - N_{t+1})/t$ as a fraction of N_t

Number of Fish

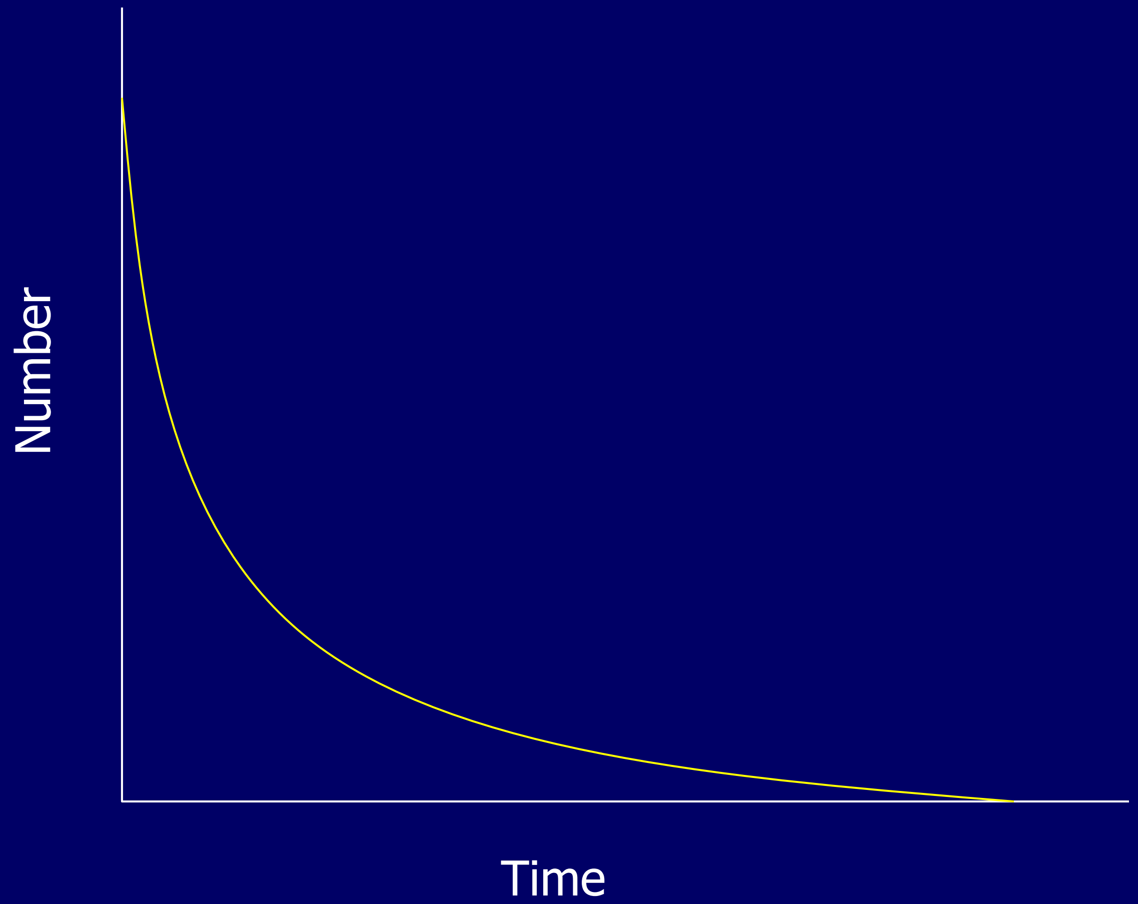


Number of Fish

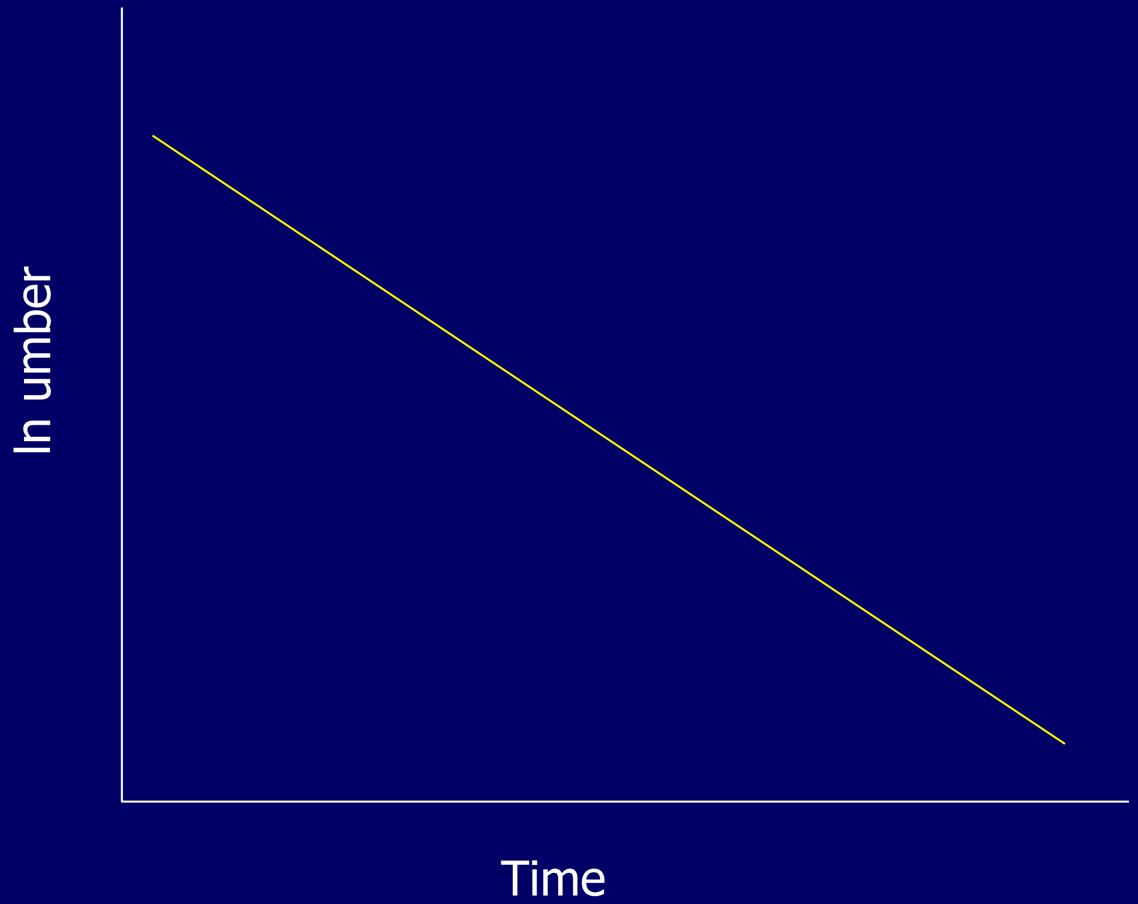
Number declines ~exponentially at a rate proportional to the number alive at any point in time



Number of Fish



Number of Fish



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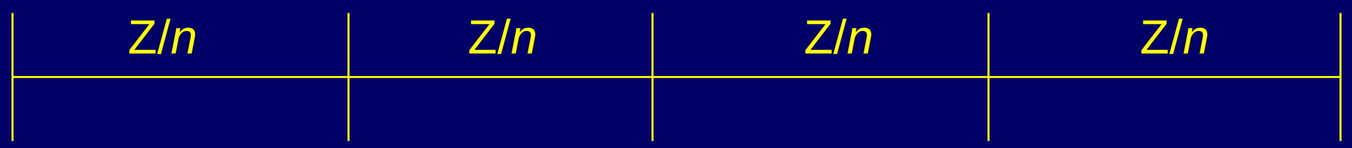
What does instantaneous really mean?

n = 4 intervals



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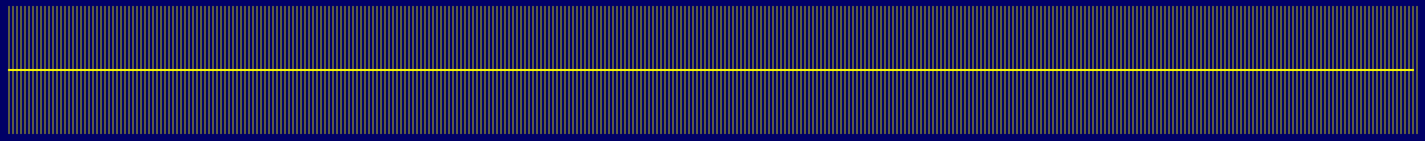
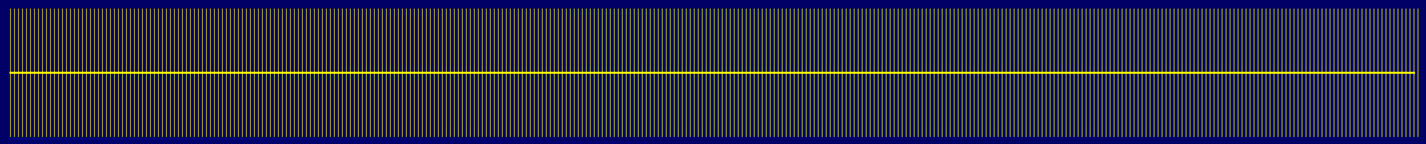
n = 1,000 intervals



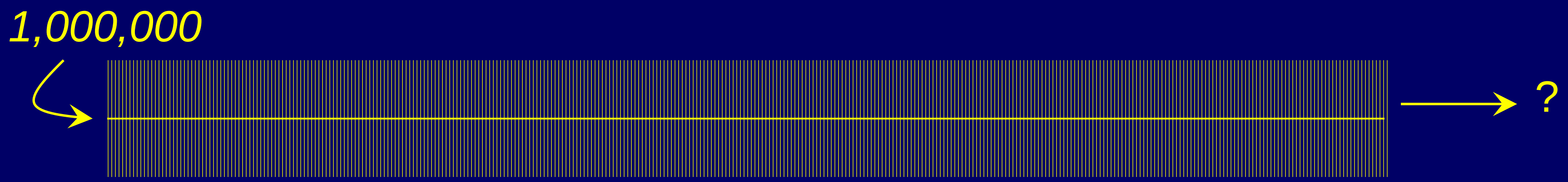
Mortality

n = 1,000 intervals



Mortality

- Duplicate 1,000 times, leaving:



Techniques to Estimate Mortality

Heincke’s Method

- Given,

Heincke's Method

- A = n_o / N

  where, n_o =

  N =

Heincke’s Method

Age (yrs)	1	2	3	4	5	6	7+
Number	150	352	139	31	16	8	5

A =

Heincke's Method

Robson and Chapman's Method

- $S = T / (N + T - 1)$

  where, N =

  T =

Robson and Chapman's Method

Age (yrs)	1	2	3	4	5	6	7	8
Number (N_x)	150	352	139	31	16	8	3	2
Coded age (x)	-	0	1	2	3	4	5	6

Code ages starting with zero for the youngest age considered fully recruited

$$S = T / (N + T - 1)$$

Robson and Chapman's Method

Age (yrs)	1	2	3	4	5	6	7	8
Number (N_x)	150	352	139	31	16	8	3	2
Coded age (x)	-	0	1	2	3	4	5	6

Code ages starting with zero for the youngest age considered fully recruited

Mortality

- Take the ln of $N_{t+1} = N_t e^{-Zt}$

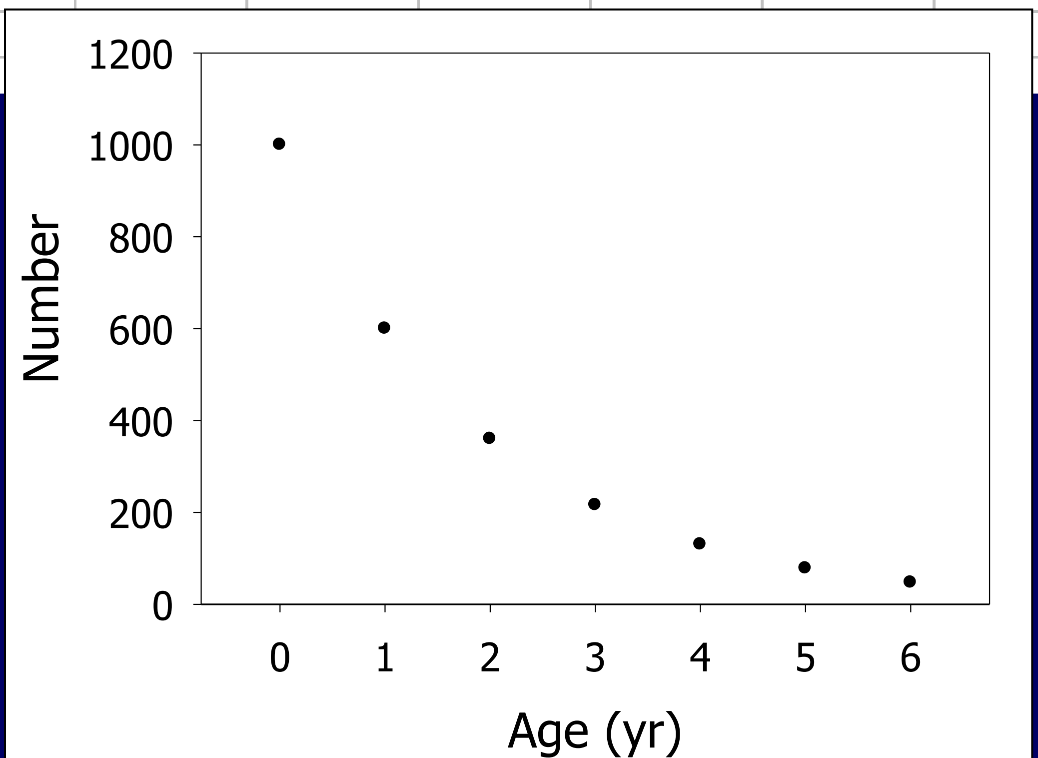
Catch Curve

- Use linear regression to estimate the slope parameter (i.e., Z)

General “Rules”

Catch Curve

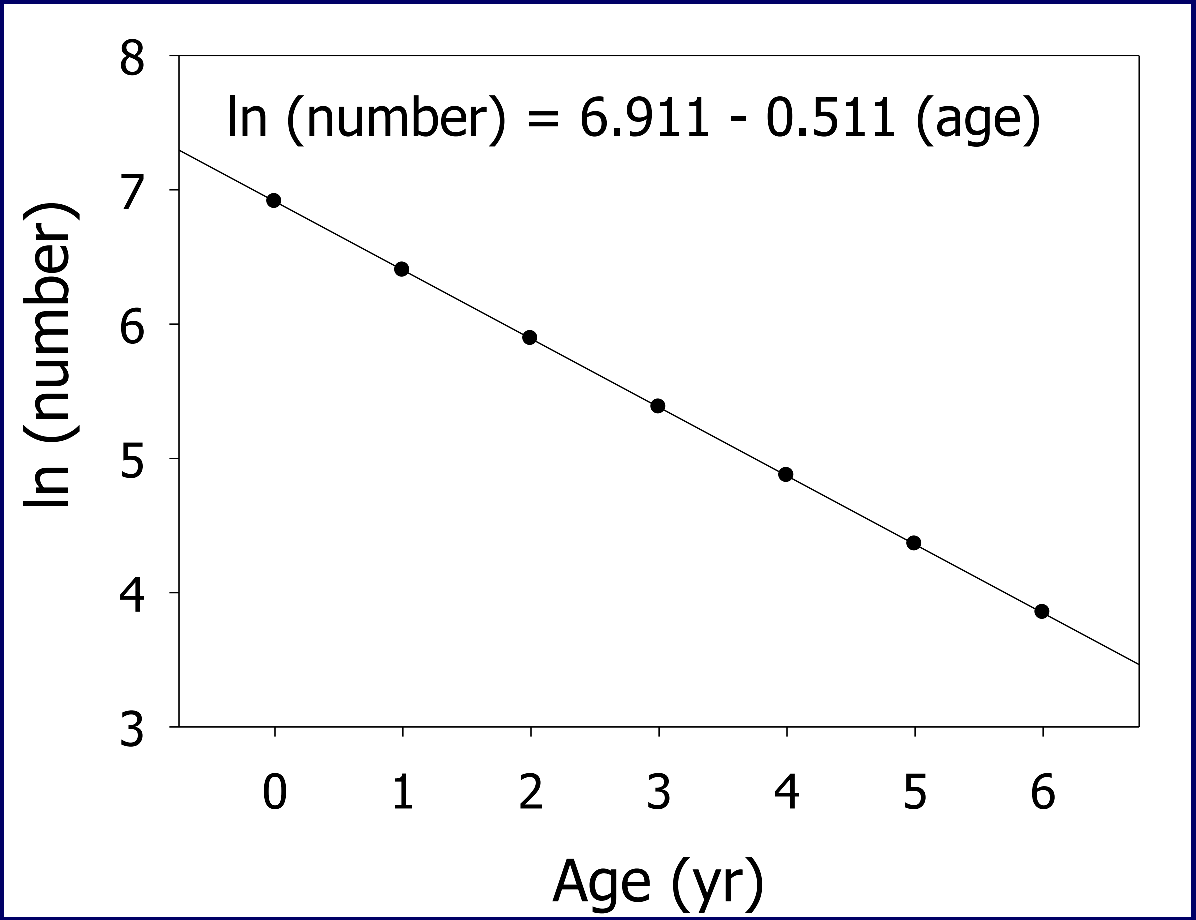
	Year1	Year2	Year3	Year4	Year5	year6	year7	year8
	1000	600	360	216	130	78	47	28
		1000	600	360	216	130	78	47
1,000 recruits per year			1000	600	360	216	130	78
A= 40%				1000	600	360	216	130
					1000	600	360	216
						1000	600	360
							1000	600
								1000



Age	number
0	1000
1	600
2	360
3	216
4	130
5	78
6	47
7	28

Catch Curve

Age	number	ln (number)
0	1000	6.91
1	600	6.40
2	360	5.89
3	216	5.38
4	130	4.87
5	78	4.36
6	47	3.85
7	28	3.33



Catch Curve

1999	2000	2001	2002	2003	2004	2005	2006
?	?	?	?	?	?	?	1
	?	?	?	?	?	?	2
		?	?	?	?	?	1
			?	?	?	?	10
				?	?	?	25
					?	?	43
						?	123
							15

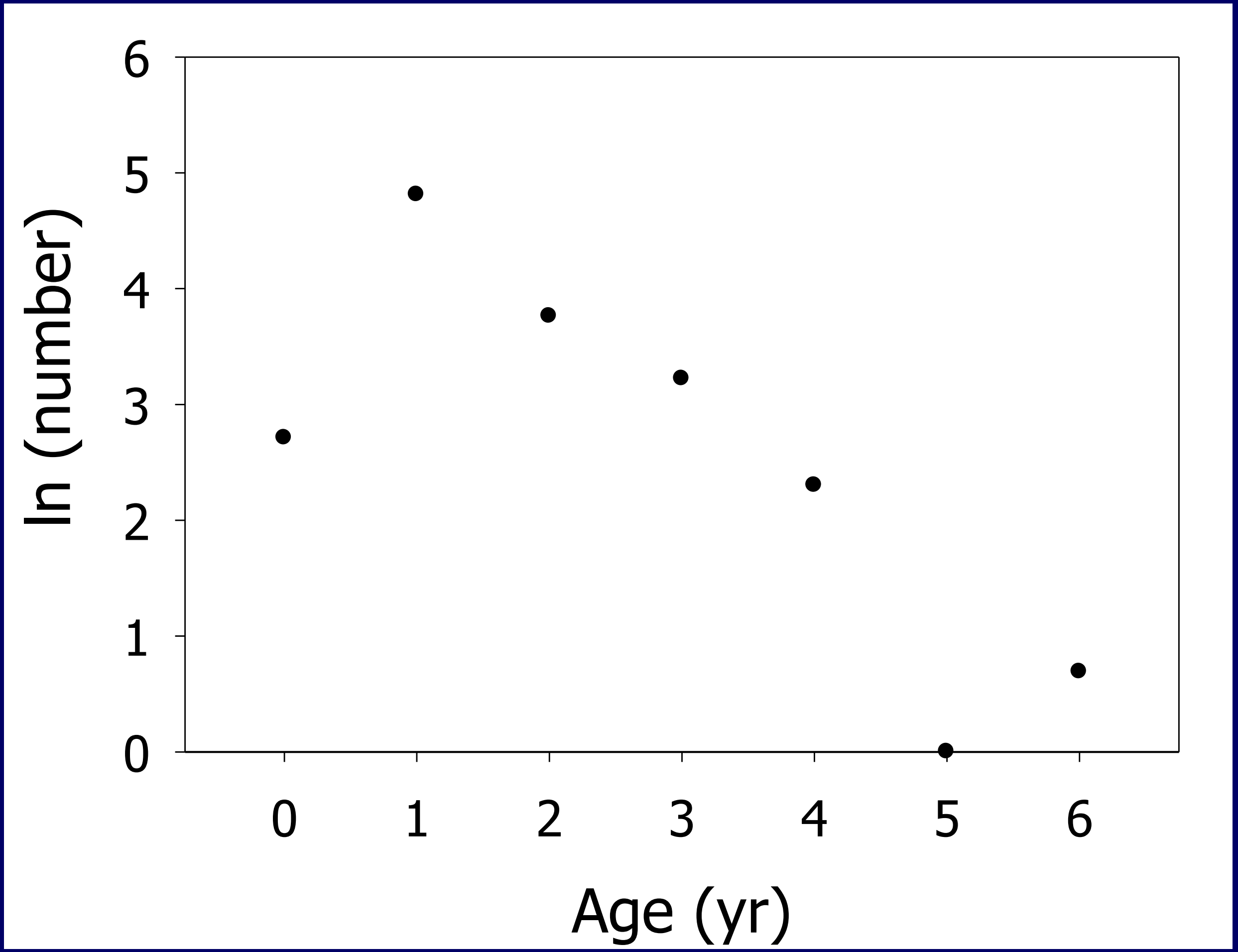
Catch Curve

1999	2000	2001	2002	2003	2004	2005	2006
?	?	?	?	?	?	?	1
	?	?	?	?	?	?	2
		?	?	?	?	?	1
			?	?	?	?	10
				?	?	?	25
					?	?	43
						?	123
							15

Age	number	ln (number)
0	15	2.71
1	123	4.81
2	43	3.76
3	25	3.22
4	10	2.30
5	1	0.00
6	2	0.69
7	1	0.00

Catch Curve

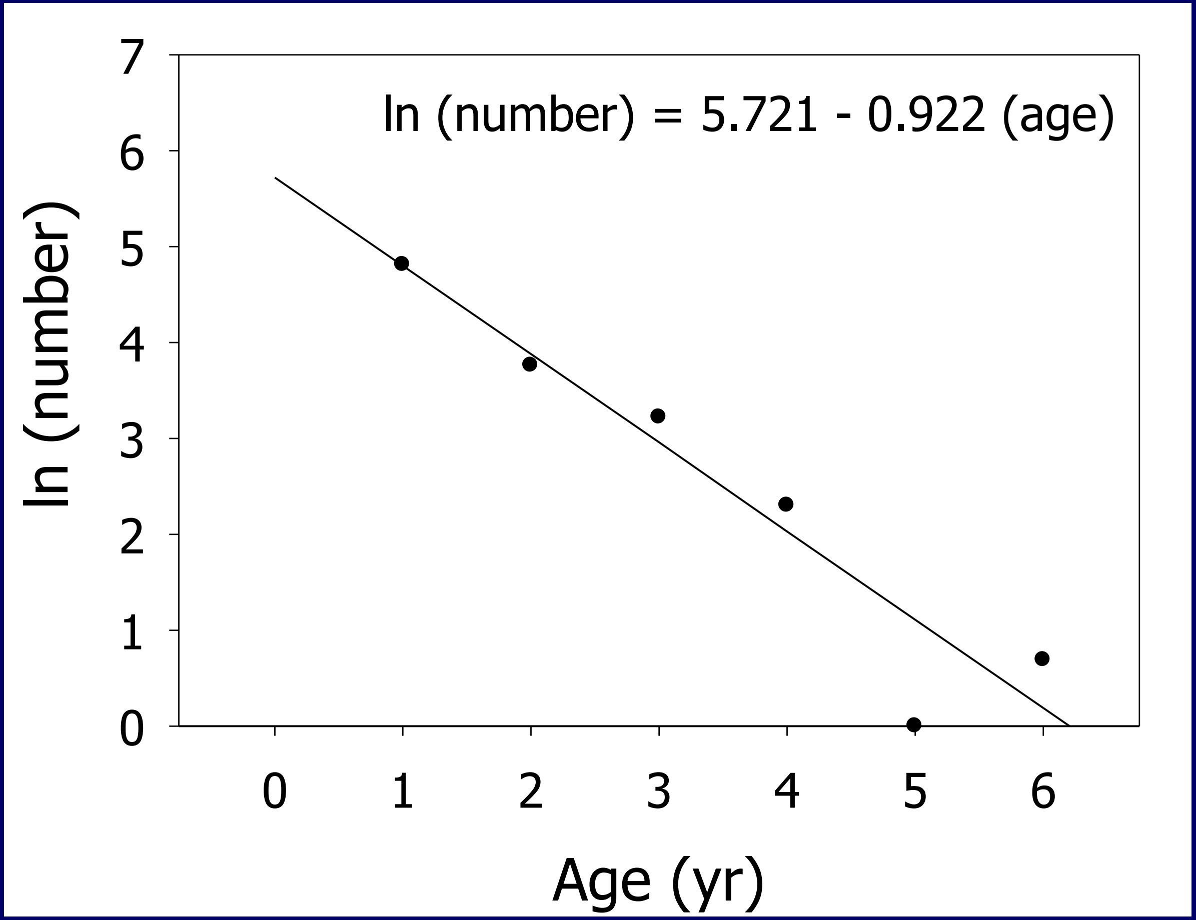
Age	number	ln (number)
0	15	2.71
1	123	4.81
2	43	3.76
3	25	3.22
4	10	2.30
5	1	0.00
6	2	0.69
7	1	0.00



Weighted Catch Curve

Age	Number	Ln(Number)	Pred Number	Pred Ln(Number)	Residual
1	123	4.812	121.428	4.799	0.013
2	43	3.761	48.302	3.877	-0.116
3	25	3.219	19.214	2.956	0.263
4	10	2.303	7.643	2.034	0.269
5	1	0	3.04	1.112	-1.112
6	2	0.693	1.209	0.19	0.503
7	1	0	0.481	-0.732	0.732

Weighted Catch Curve



Catch Curve

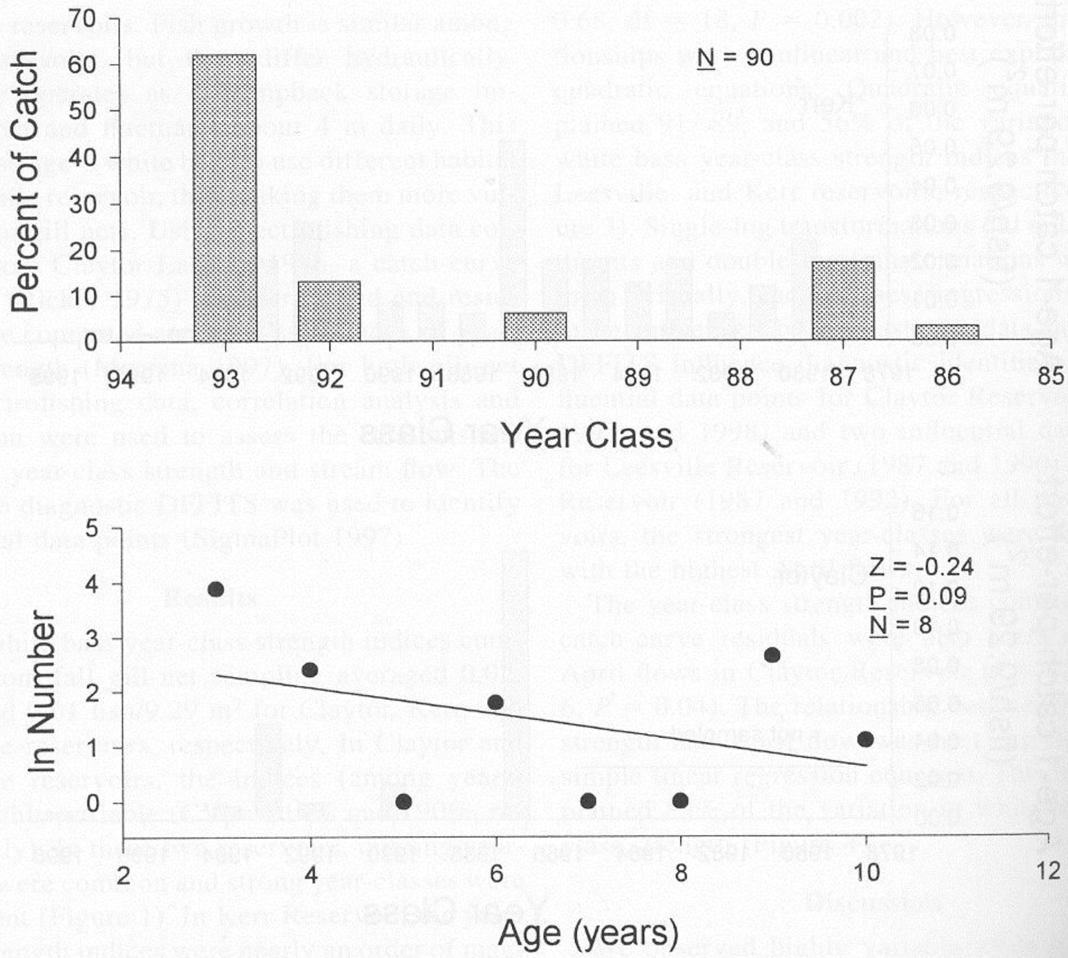
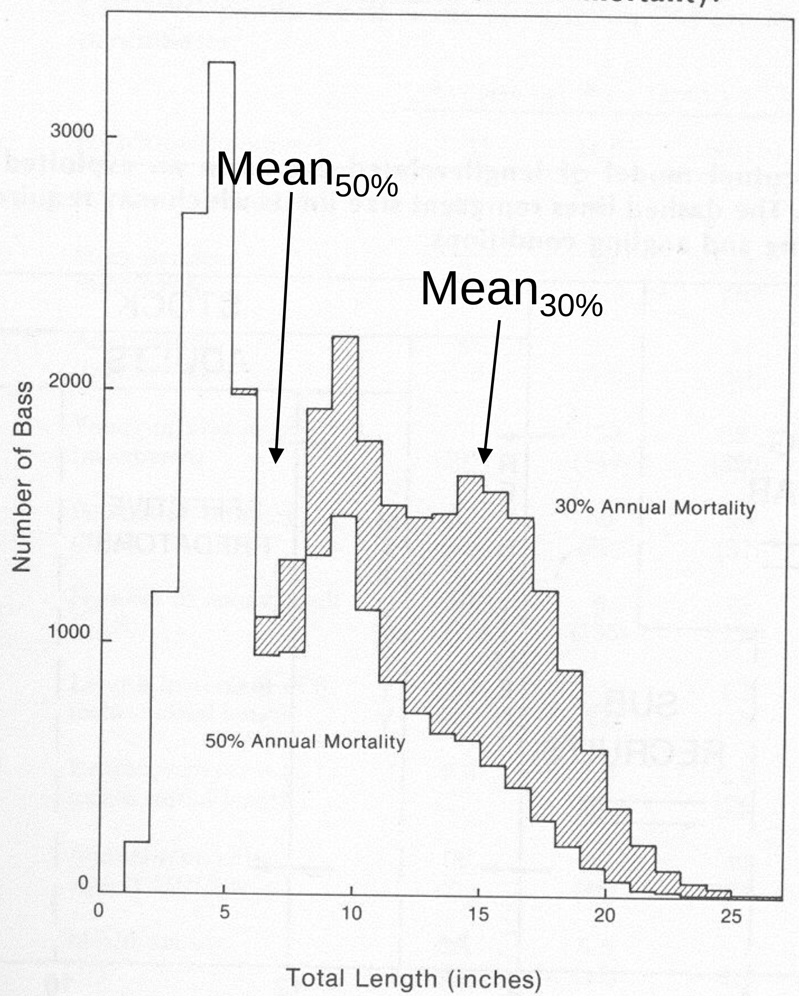


FIGURE 2.—Year-class frequency distribution (top panel) and catch-curve regression (bottom panel) of white bass collected from Claytor Lake by electrofishing in spring 1996. The symbol Z is the instantaneous mortality rate.

Length-Based Models

Length-Based Models

Figure 4. Model length-frequency of a largemouth bass population, assuming average growth, 10,000 age-I recruits each year and 30 or 50% constant annual mortality.



Assumptions

1) Constant recruitment within the period covered by the length distribution, or at least recruitment has varied in a random fashion
2) Mortality is constant over ages
3) Only lengths fully recruited to the gear are included
4) Growth is constant and adequately described by the growth model
5) Sampling gear adequately represents the standing length distribution
6) Recruitment into the smallest length considered for analysis is constant through time each year, so that the shape of length distribution and mean length does not vary seasonally (multiple years can help with this one too)

Estimates from Average Length

Estimates from Average Length

- If K =0.299 and L_∞ = 189.9 and

Length group	Number	Mean length	
40	1	41	
50	1	42	42
60	10	62	620
70	13	74	962
80	22	82	1804
90	15	94	1410
100	12	103	1236
110	2	116	232
120	4	121	484
130	9	138	1242
140	8	143	1144
150	6	153	918
160	5	164	820
170	4	171	684
180	1	180	180
	111		11736
			105.7297

L_x = 60 mm

L_{mean} = 105.7 mm

Others

- BAND, BROWNIE, CAPQUOTA, CONTRAST, ESTIMATE, JOLLY, JOLLYAGE, MARK, MULT, POPAN, RELEASE, SURGE, SURPH, SUVIV, TMSURVIV

Fishing and Natural Mortality

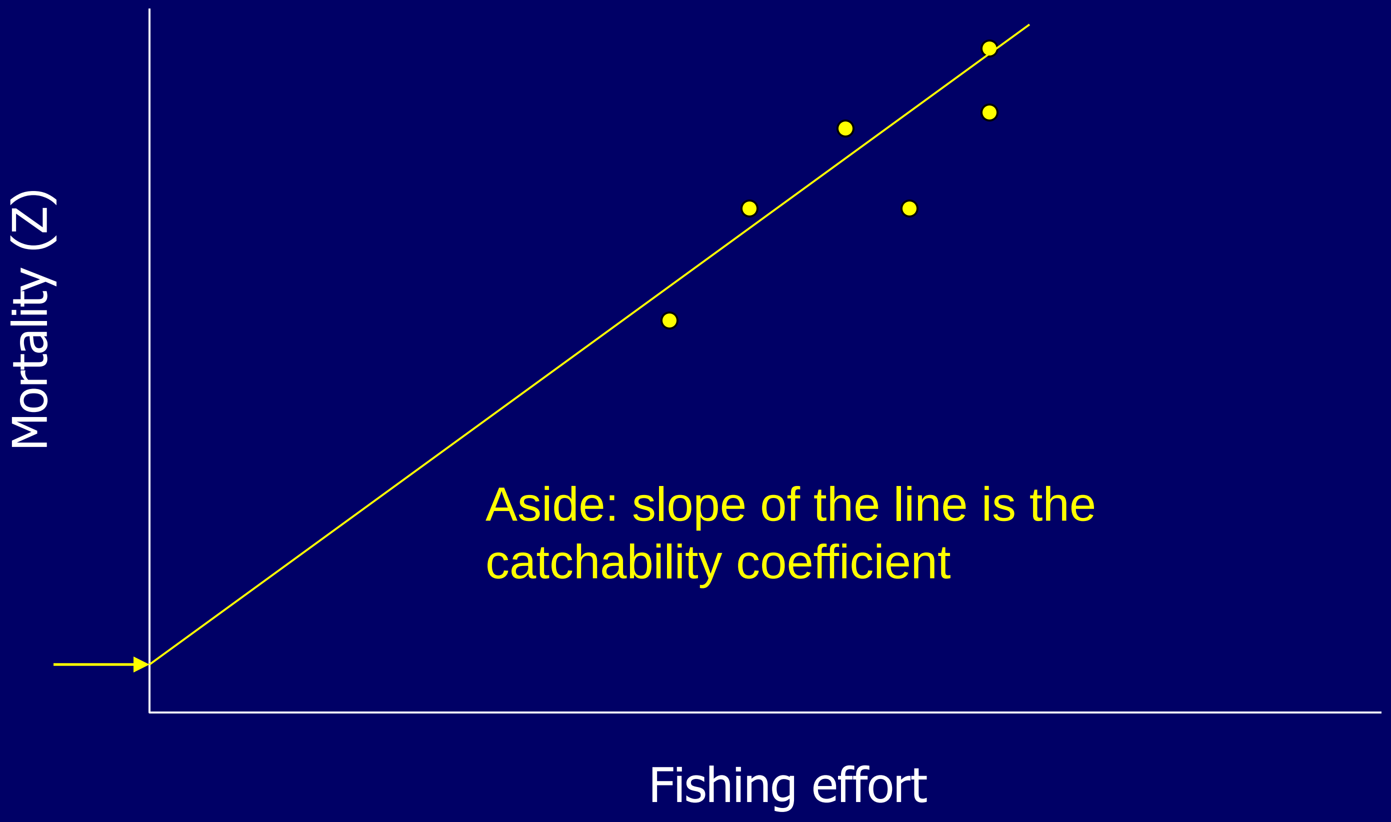
Fishing and Natural Mortality

- At least six ways to estimate M, F, or both

Fishing and Natural Mortality

1) Regression of Z as a function of fishing effort to estimate M

Fishing and Natural Mortality



Fishing and Natural Mortality

- Drawbacks:

Fishing and Natural Mortality

2) Catch-curve analysis to estimate M

Fishing and Natural Mortality

3) Mark-recapture to estimate F

Fishing and Natural Mortality

4) Direct “census” to estimate F

Fishing and Natural Mortality

5) Production modeling to estimate M

Fishing and Natural Mortality

6) Meta-analysis to estimate M, F, and Z

Other Techniques Associated with Mortality Estimation

Other Techniques

- Age-specific mortality (essentially Heincke's method)

Age (yrs)	1	2	3	4	5	6	7+
Number	150	352	139	31	16	8	5

$A_{2\text{-}3}$ =

$A_{3\text{-}4}$ =

Age-Specific Mortality

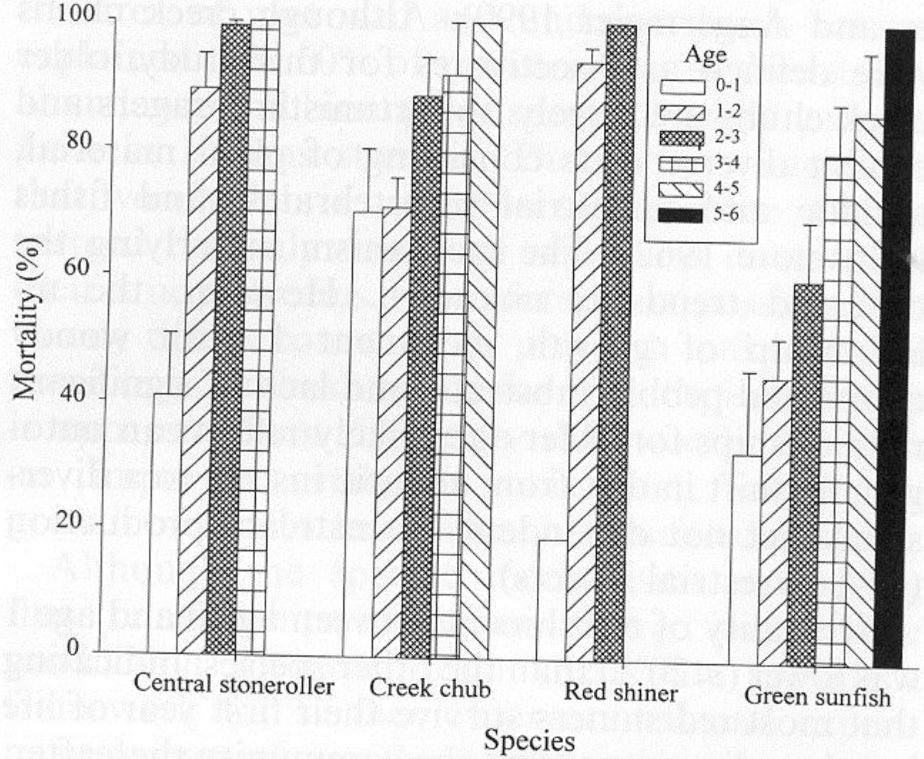


Fig. 1. Mortality between age-0 to age-1 (0–1), age-1 to age-2 (1–2), age-2 to age-3 (2–3), age-3 to age-4 (3–4), age-4 to age-5 (4–5), and age-5 to age-6 (5–6) for central stonerollers, creek chubs, red shiners, and green sunfish sampled from streams on Fort Riley Military Reservation, Kansas, during June and July, 1997 and 1998. The error bars represent one standard error

Mortality Caps

- Remember that:
- $Z = K \dfrac{L_\infty - L_{\text{mean}}}{L_{\text{mean}} - L_x}$
- where, L_x is the length above which all fish are equally vulnerable to capture by the collection gear and L_{mean} is the mean length of fish larger than L_x

Mortality Caps

- Suppose $L_t = 353\,[1 - e^{-0.374(t - 1.210)}]$; regulated with a 200-mm minimum length limit; management objective is for fish in the angler's creel to average $\geq$ 250 mm (modified from Miranda 2002)
- Parameters:
  - $K = 0.374$
  - $L_\infty = 353$ mm
  - $L_x = 200$ mm
  - $L_{mean} = 250$ mm
- $Z =$

Mortality Caps

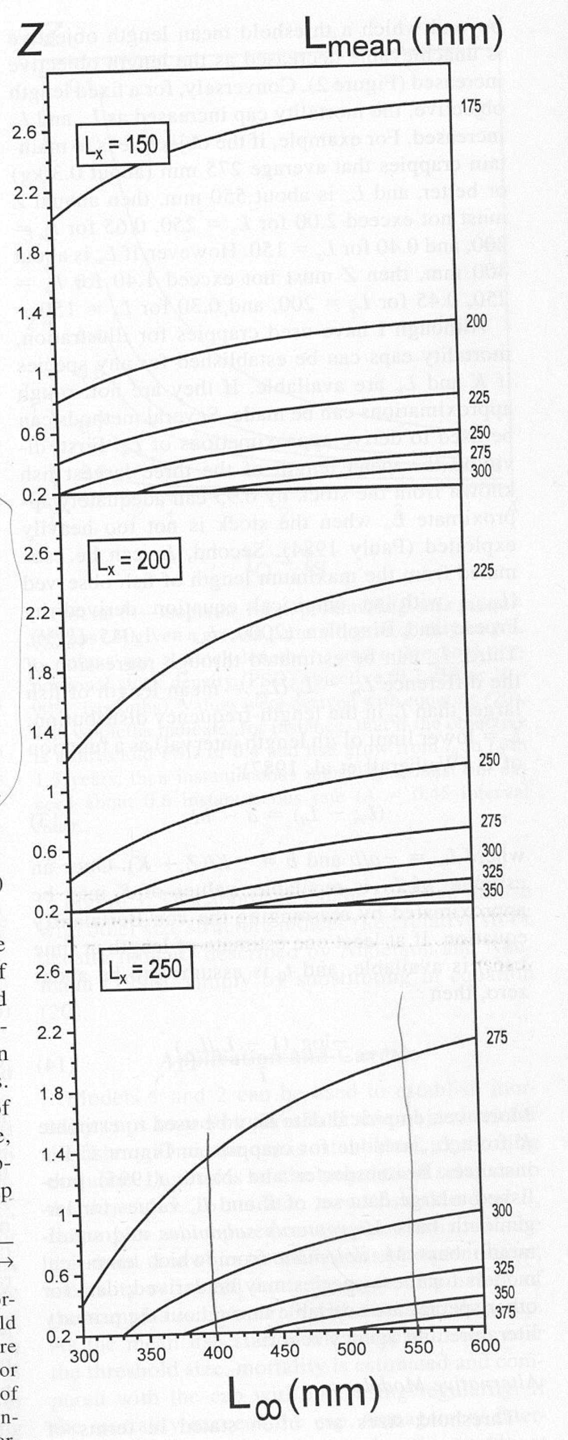


FIGURE 2.—Isopleths for approximating crappie mortality caps (Z) given a growth pattern (L_∞) and a threshold mean length objective (L_{mean}; isopleths). Values were derived with equation (12). The isopleths indicate, for instance, that if the objective is an average fish size of 250 mm or more and L_∞ is 450 mm and L_x (e.g., a minimum length limit) is 200 mm, then instantaneous mortality Z must not exceed about 0.9 (A = 0.59 interval rate).

Mortality Caps

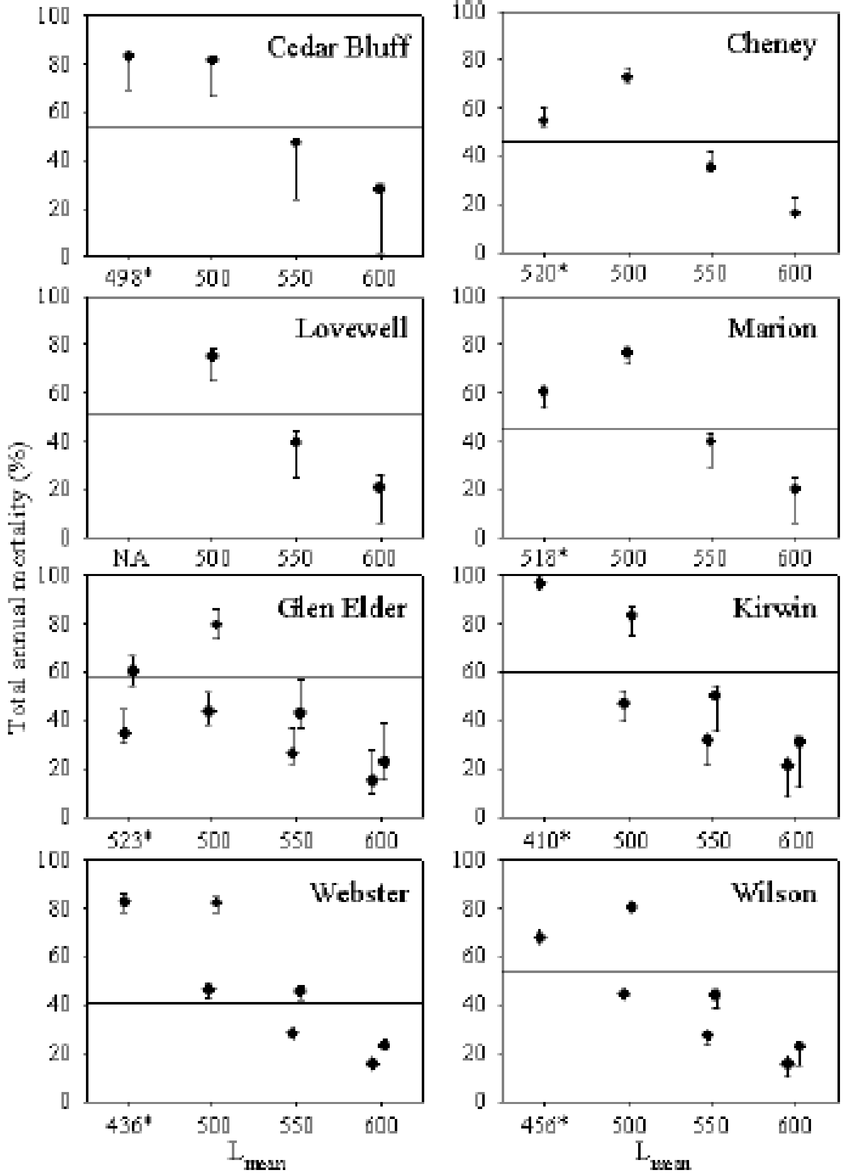


FIGURE 4.—Estimated mortality caps for eight Kansas reservoirs based on model 1 described by Miranda (2002). Overall mortality cap estimates (solid symbols) and year-specific mortality cap estimates (bars indicate maximum and minimum estimates) were calculated based on the theoretical maximum length (L_{inf}) and the growth coefficient (K). Mortality caps were estimated for a mean length objective (L_{mean}) equal to the current mean length of harvested walleyes (asterisks) and for L_{mean} values of 500, 550, and 600 mm. The minimum length available for harvest (L_x) was set at 457 mm for Cedar Bluff, Cheney, Lovewell, and Marion reservoirs to represent current harvest regulations. The mortality cap for the current mean length of harvested walleyes in Lovewell Reservoir was not plotted because the current mean was lower than the minimum length limit. For Glen Elder, Kirwin, Webster, and Wilson reservoirs, mortality caps were estimated based on L_x values of 381 mm (diamonds; current regulations) and 457 mm (circles) (the two estimates at each L_{mean} are offset to prevent overlap and to aid interpretation). The horizontal lines represent empirical estimates of total annual mortality for each reservoir.

Additive versus Compensatory Mortality

- Additive—
- Compensatory—

Relationships Between Parameters

- Instantaneous: $Z = F + M$
- Interval (annual): $A = u + v$

$S = 1 - A = e^{-Z}$

$m = 1 - e^{-F}$

$n = 1 - e^{-M}$

$F = u Z / A$

$M = vZ / A$

$$\frac{Z}{A} = \frac{F}{u} = \frac{M}{v}$$

$m + n - nm = A$

Relationships Between Parameters

Mortality rates	Total	Fishing	Natural
Interval	**A** = $u+v=1-e^{-Z}$	***u*** = $FA/Z = vF/M$	***v*** = $MZ/Z=uM/F$
Instantaneous	**Z** = $F+M=-\ln(1-A)$	**F** = $uZ/A=um/v$	**M** = $vZ/Z=vF/u$
Conditional	**A** = $m+n-mn$	***m*** = $1-e^{-F}$	***n*** = $1-e^{-M}$