Advances on lake sturgeon recovery potential in Canadian designatable units: from allowable harm to recovery targets

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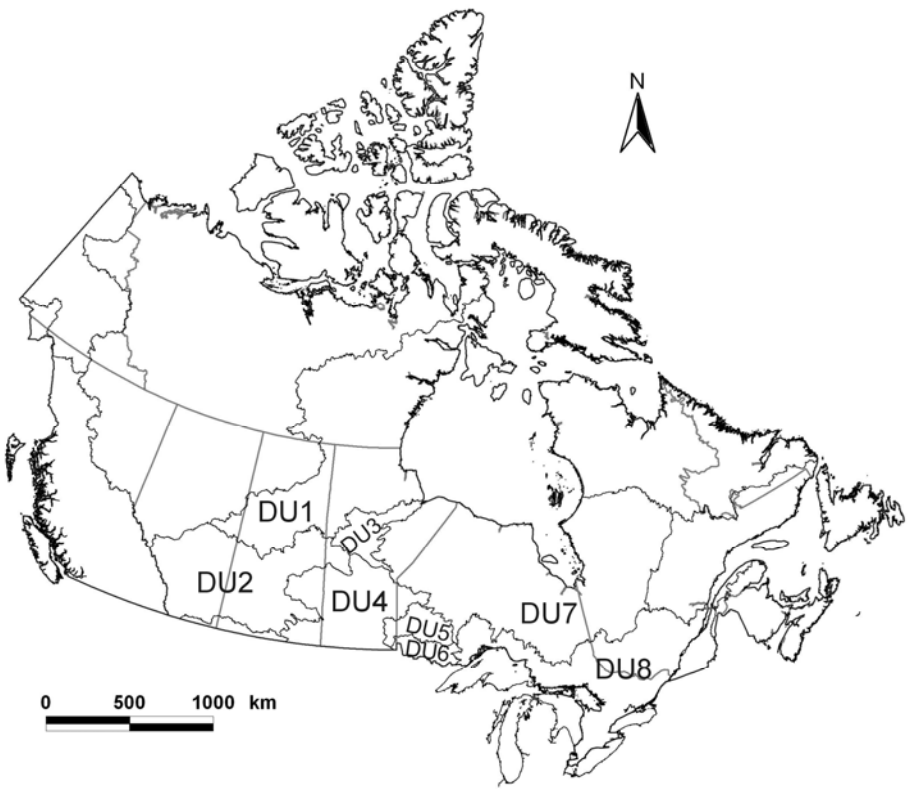
Canadian Designatable Units



Lake Erie-Lake Huron (DU8A)

North Lake Superior (DU8B)

St. Lawrence (DU8C)

Customizing lake sturgeon life history data

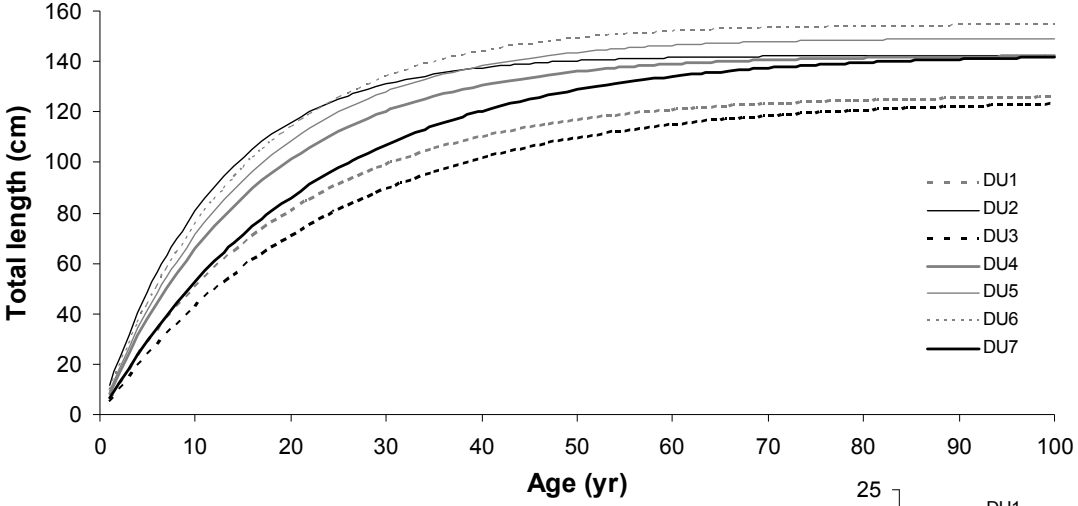
$TL_{23\text{-}27}$ = 2569.6 -49.1 LAT + 11.4 LON

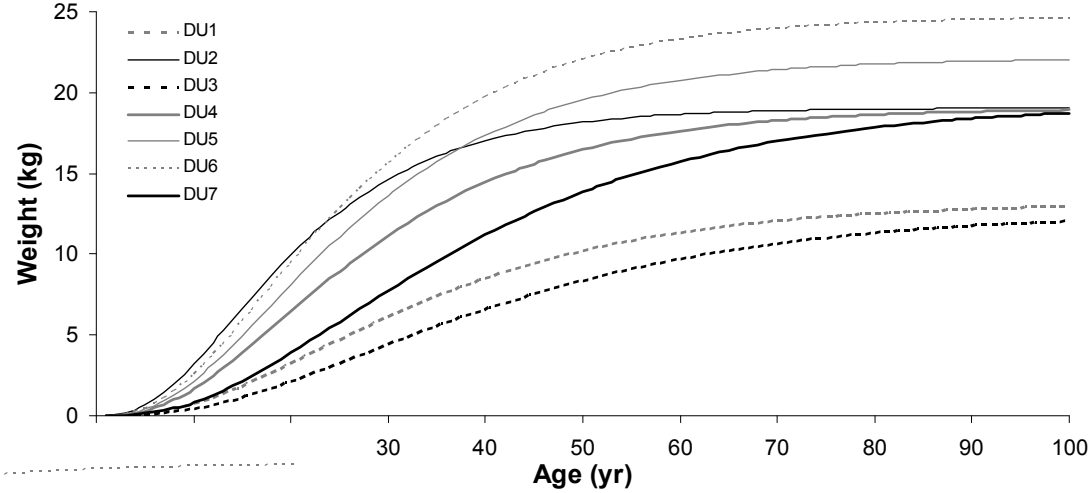
Fortin et al. (1996)

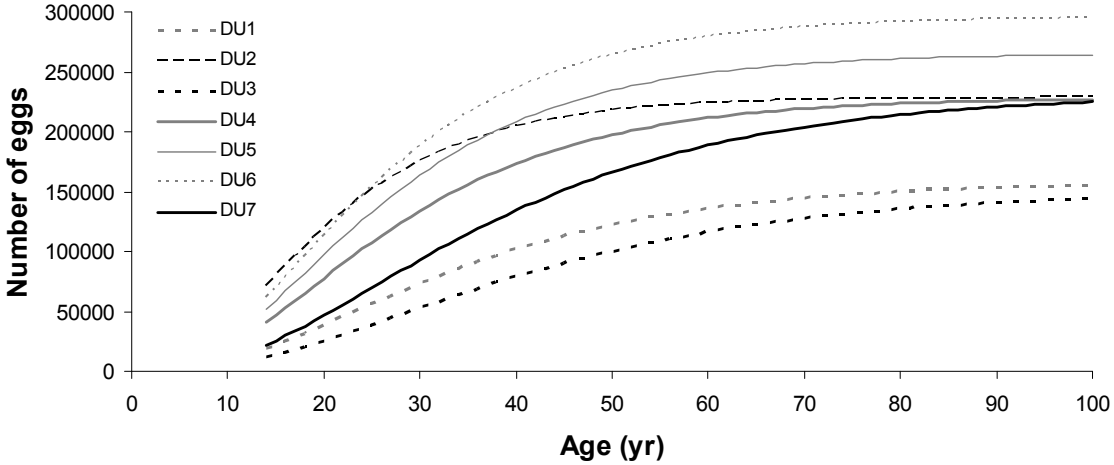
L_∞ = -3.47 LAT + 322.88

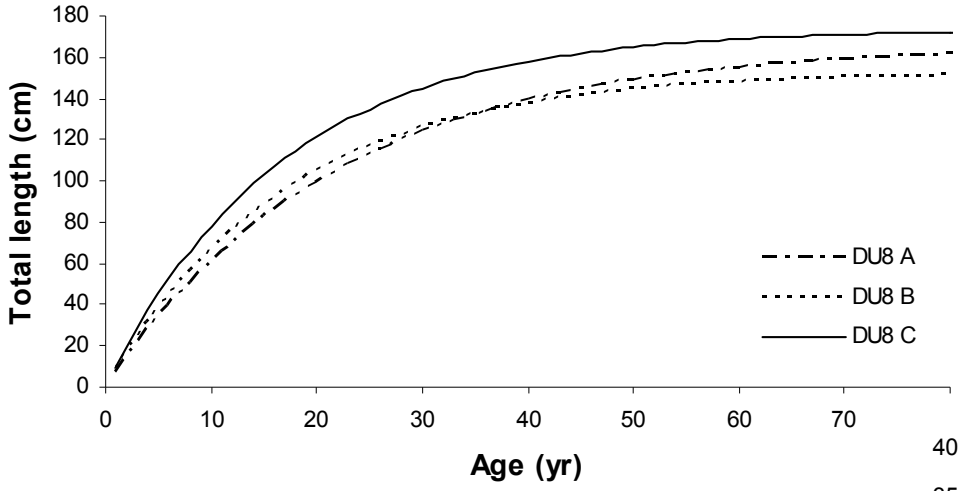
Power and McKinley (1997)

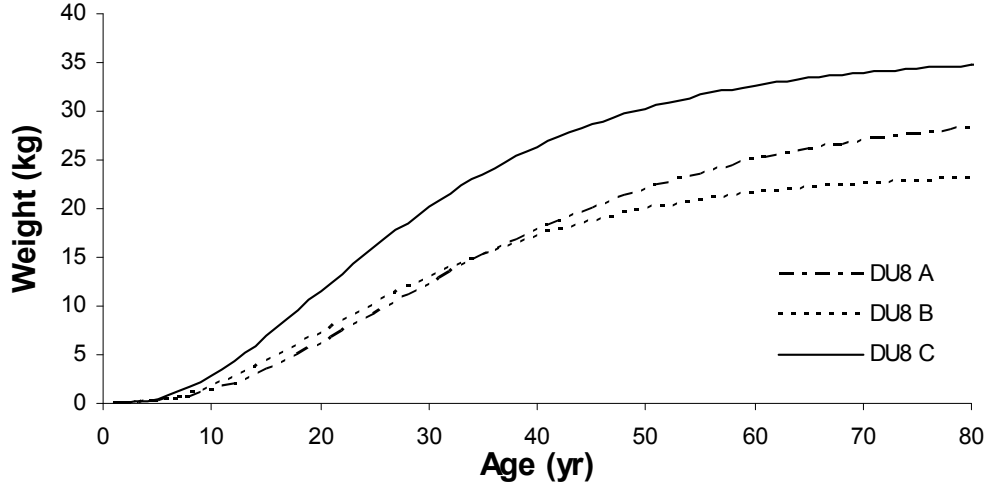
$$k = \frac{\ln(1 - \frac{TL_{25}}{L_\infty})}{-25}$$

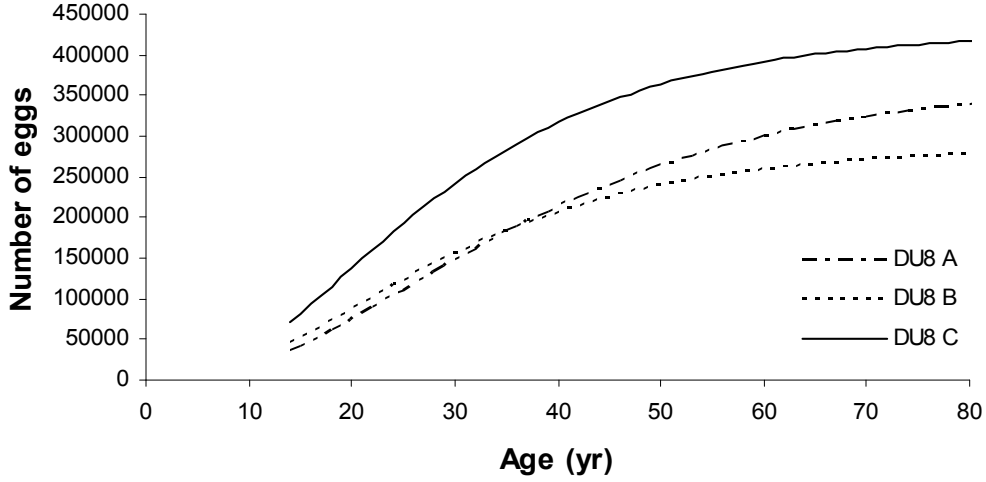

Total length (cm)
Age (yr)
DU1
DU2
DU3
DU4
DU5
DU6
DU7


Weight (kg)
Age (yr)
DU1
DU2
DU3
DU4
DU5
DU6
DU7


Number of eggs
Age (yr)
DU1
DU2
DU3
DU4
DU5
DU6
DU7

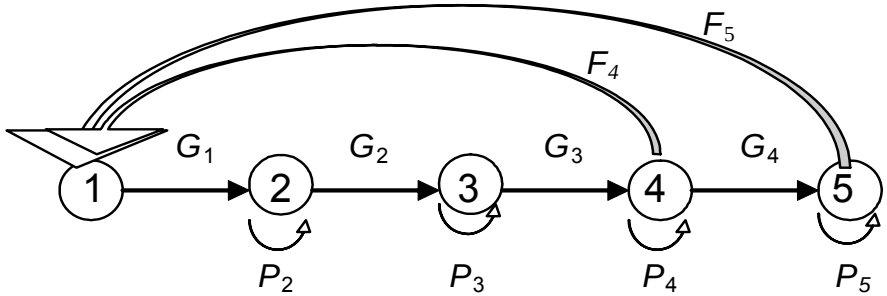

Total length (cm)
Age (yr)
DU8 A
DU8 B
DU8 C


Weight (kg)
Age (yr)
DU8 A
DU8 B
DU8 C


Number of eggs
Age (yr)
DU8 A
DU8 B
DU8 C

Matrix model

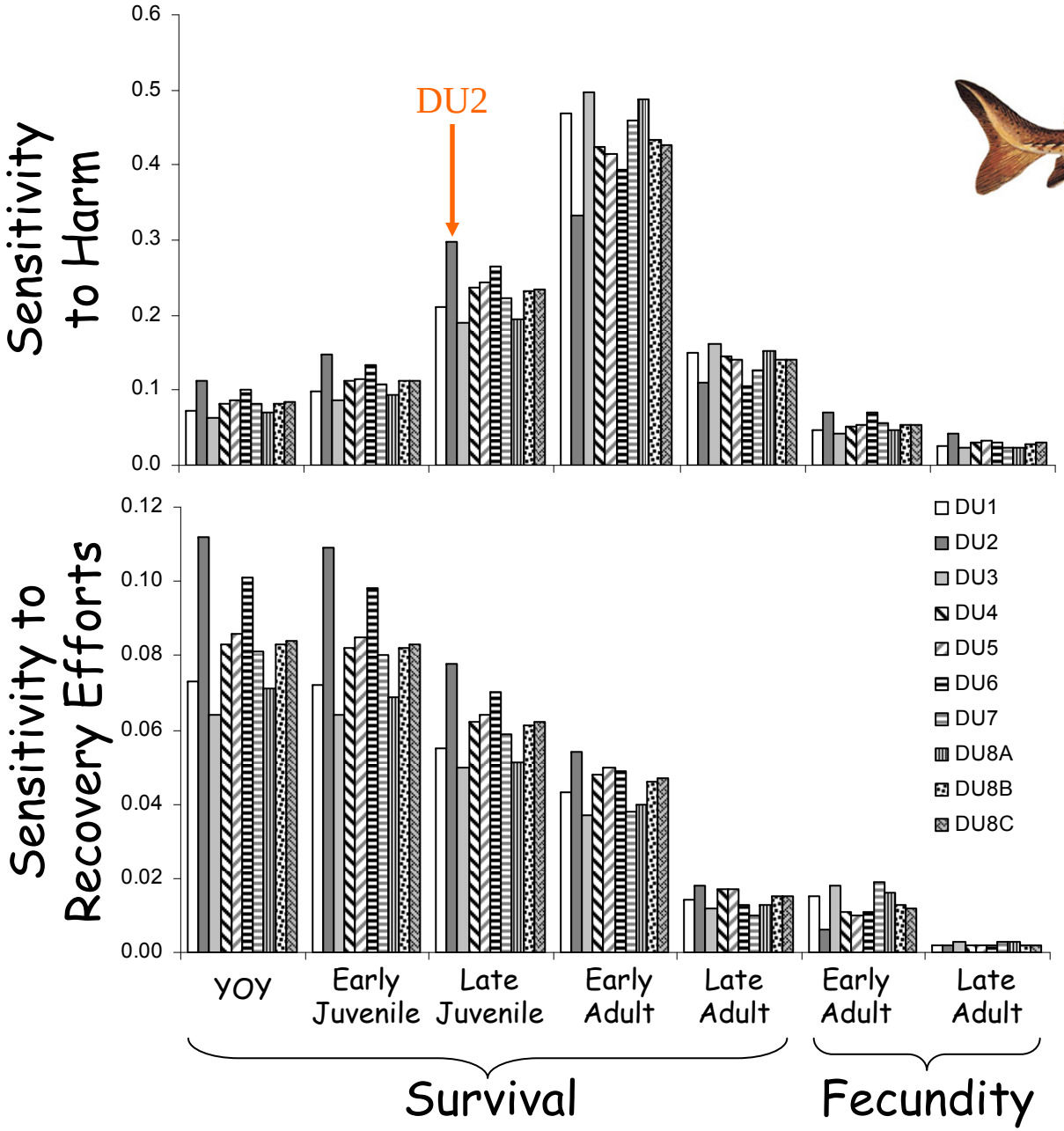
1. YOY
2. Early juvenile
3. Late juvenile
4. Early adult
5. Late adult



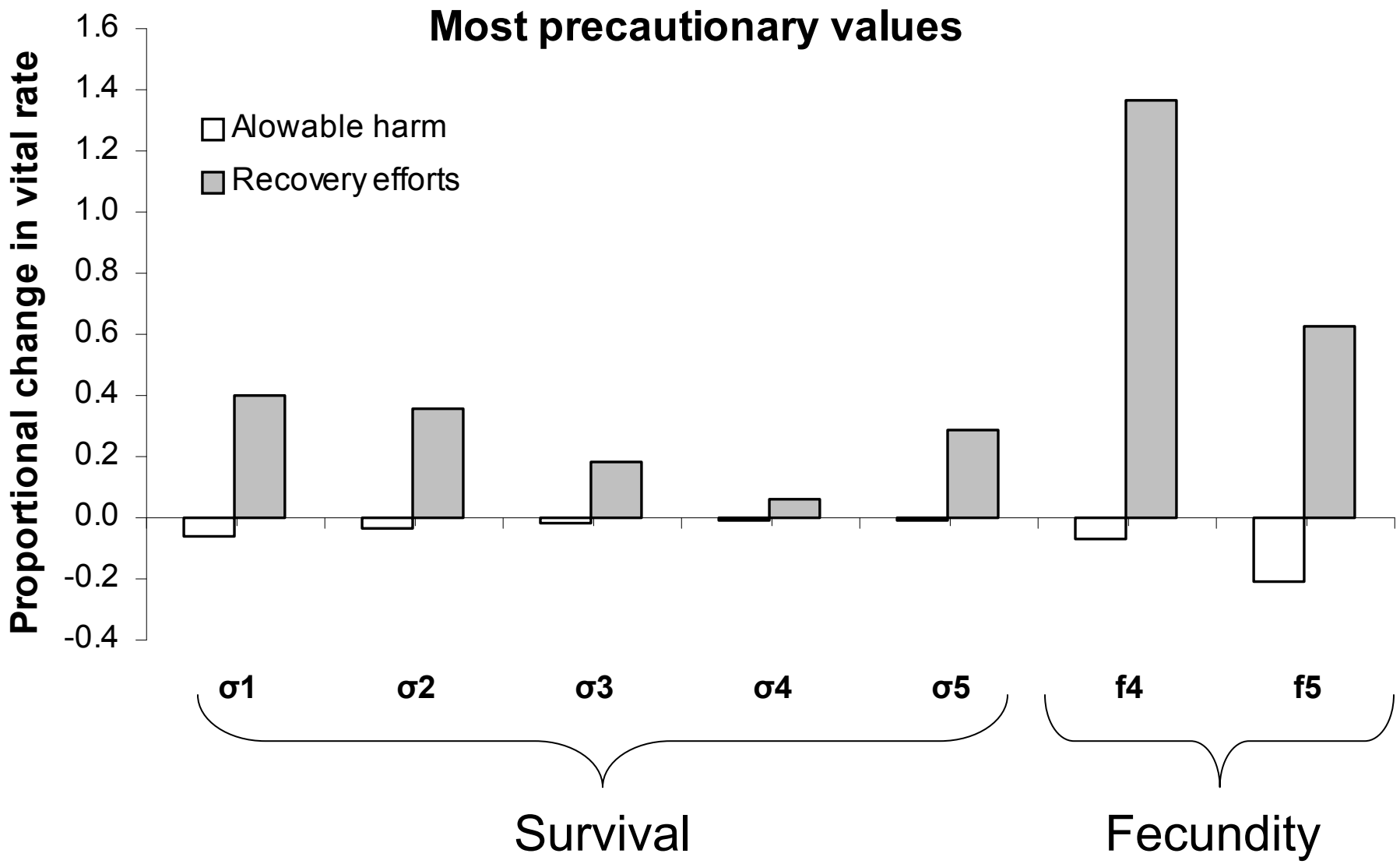
$$\mathbf{A} = \begin{pmatrix} 0 & 0 & 0 & F_4 & F_5 \\ G_1 & P_2 & 0 & 0 & 0 \\ 0 & G_2 & P_3 & 0 & 0 \\ 0 & 0 & G_3 & P_4 & 0 \\ 0 & 0 & 0 & G_4 & P_5 \end{pmatrix}$$

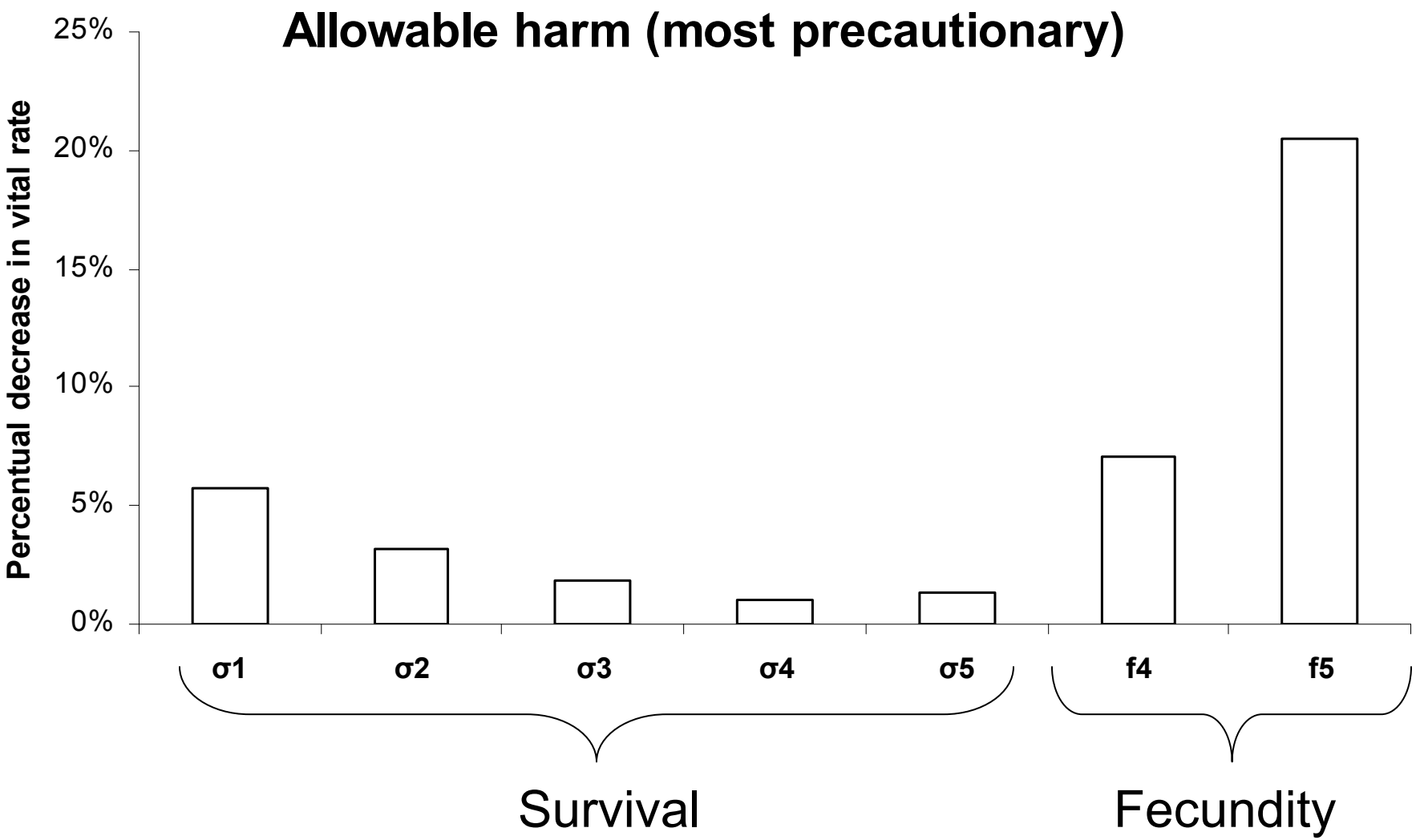
$$\mathbf{A} = \begin{pmatrix} 0 & 0 & f_4\, G_3 & f_4\, P_4 + f_5\, G_4 & f_5\, P_5 \\ \sigma_1\, \gamma_1 & \sigma_2\, (1-\gamma_2) & 0 & 0 & 0 \\ 0 & \sigma_2\, \gamma_2 & \sigma_3\, (1-\gamma_3) & 0 & 0 \\ 0 & 0 & \sigma_3\, \gamma_3 & \sigma_4\, (1-\gamma_4) & 0 \\ 0 & 0 & 0 & \sigma_4\, \gamma_4 & \sigma_5\, (1-\gamma_5) \end{pmatrix}$$

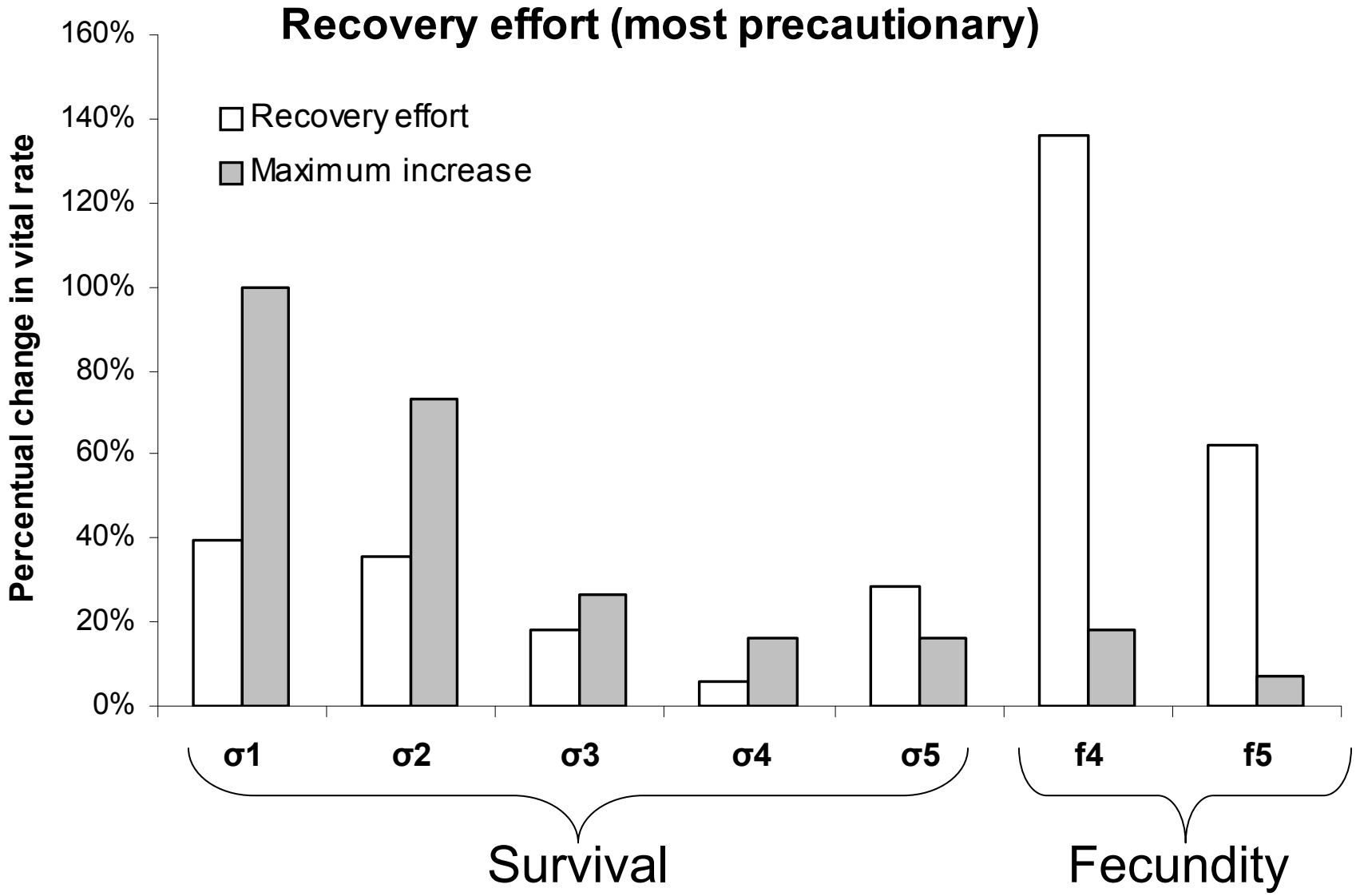
Allowable harm and Recovery Efforts



λ designation	λ max	Λ
0.887	1.150	1.007
0.887	1.103	0.993
0.887	1.173	1.013
0.887	1.118	0.997
0.887	1.109	0.994
1.000	1.103	1.033
1.000	1.139	1.044
0.933	1.117	1.014
0.933	1.112	1.012
0.933	1.095	1.007


Most precautionary values
Proportional change in vital rate
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
-0.2
-0.4
Alowable harm
Recovery efforts
σ1
σ2
σ3
σ4
σ5
f4
f5
Survival
Fecundity


Allowable harm (most precautionary)
Percentual decrease in vital rate
25%
20%
15%
10%
5%
0%
σ1
σ2
σ3
σ4
σ5
f4
f5
Survival
Fecundity

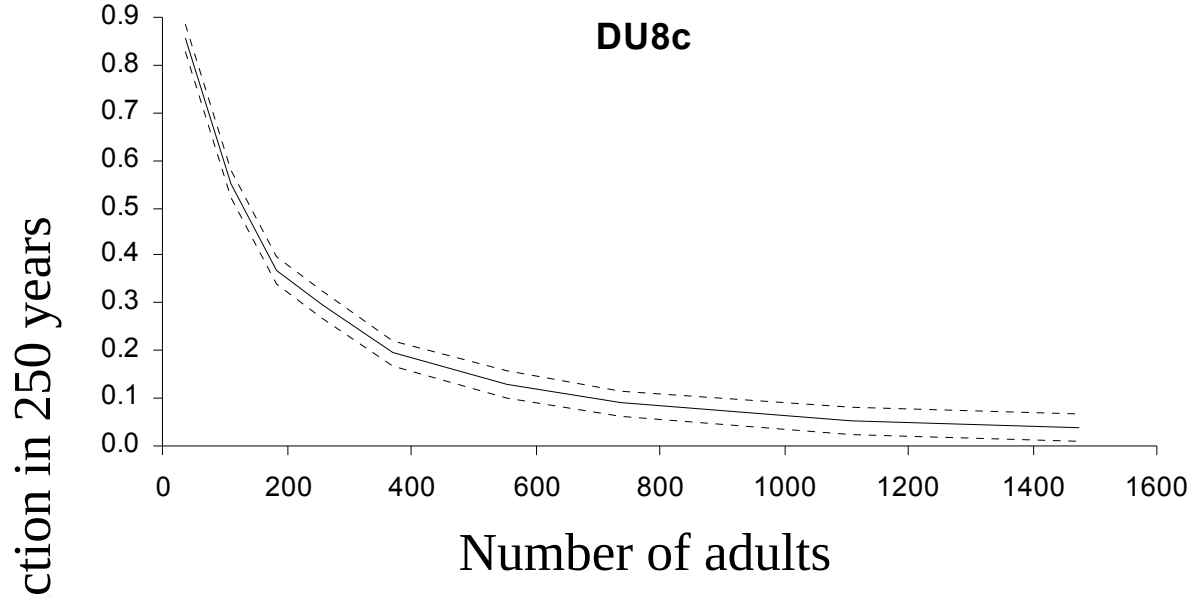

Recovery effort (most precautionary)
Recovery effort
Maximum increase
Percentual change in vital rate
160%
140%
120%
100%
80%
60%
40%
20%
0%
σ1
σ2
σ3
σ4
σ5
f4
f5
Survival
Fecundity

Allowable fishing mortality
4.0%
3.5%
3.0%
2.5%
2.0%
1.5%
1.0%
0.5%
0.0%
Late juvenile
Early adult
Late adult
Composite
60
70
80
90
100
110
120
Minimum legal size (cm)

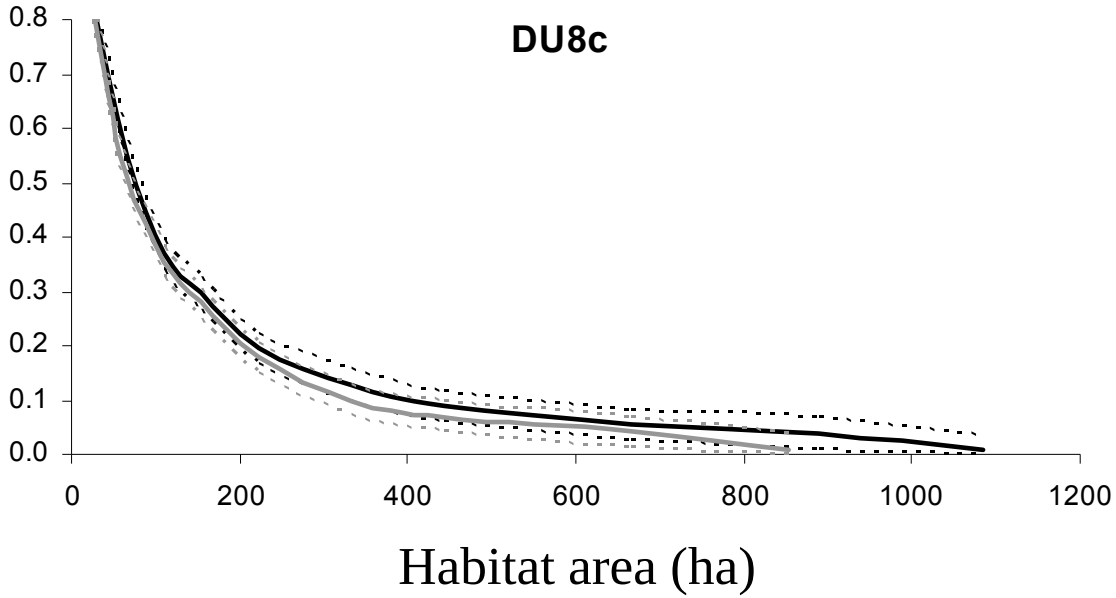
Abundance Recovery Targets

Two approaches

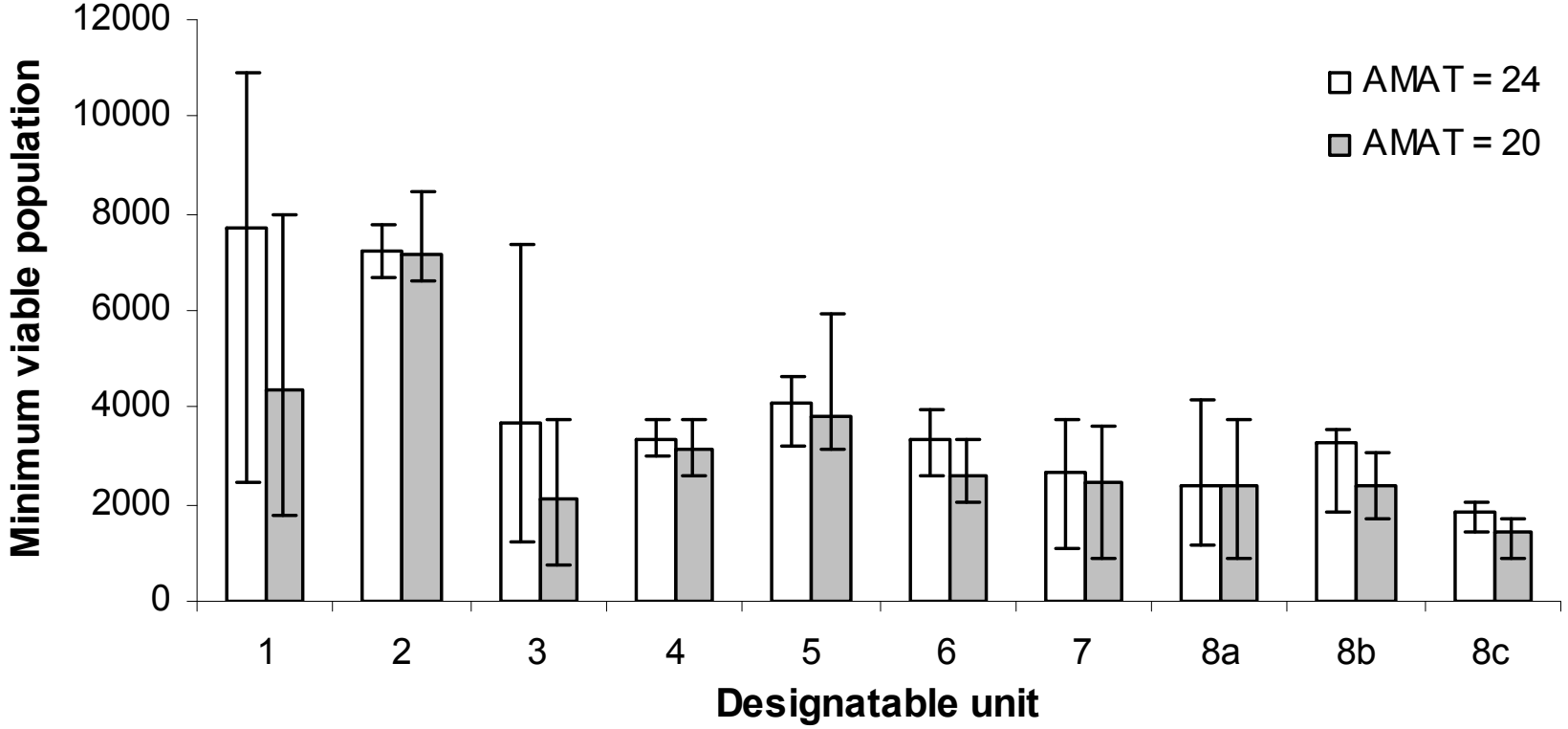
- Metanalysis (Reed et al. 2003)
  - Population growth
  - 99% probability of persistence over 40 generations
  - No catastrophes
- RAMAS
  - Equilibrium dynamics
  - 99% probability of persistence over 250 years
  - Includes catastrophes



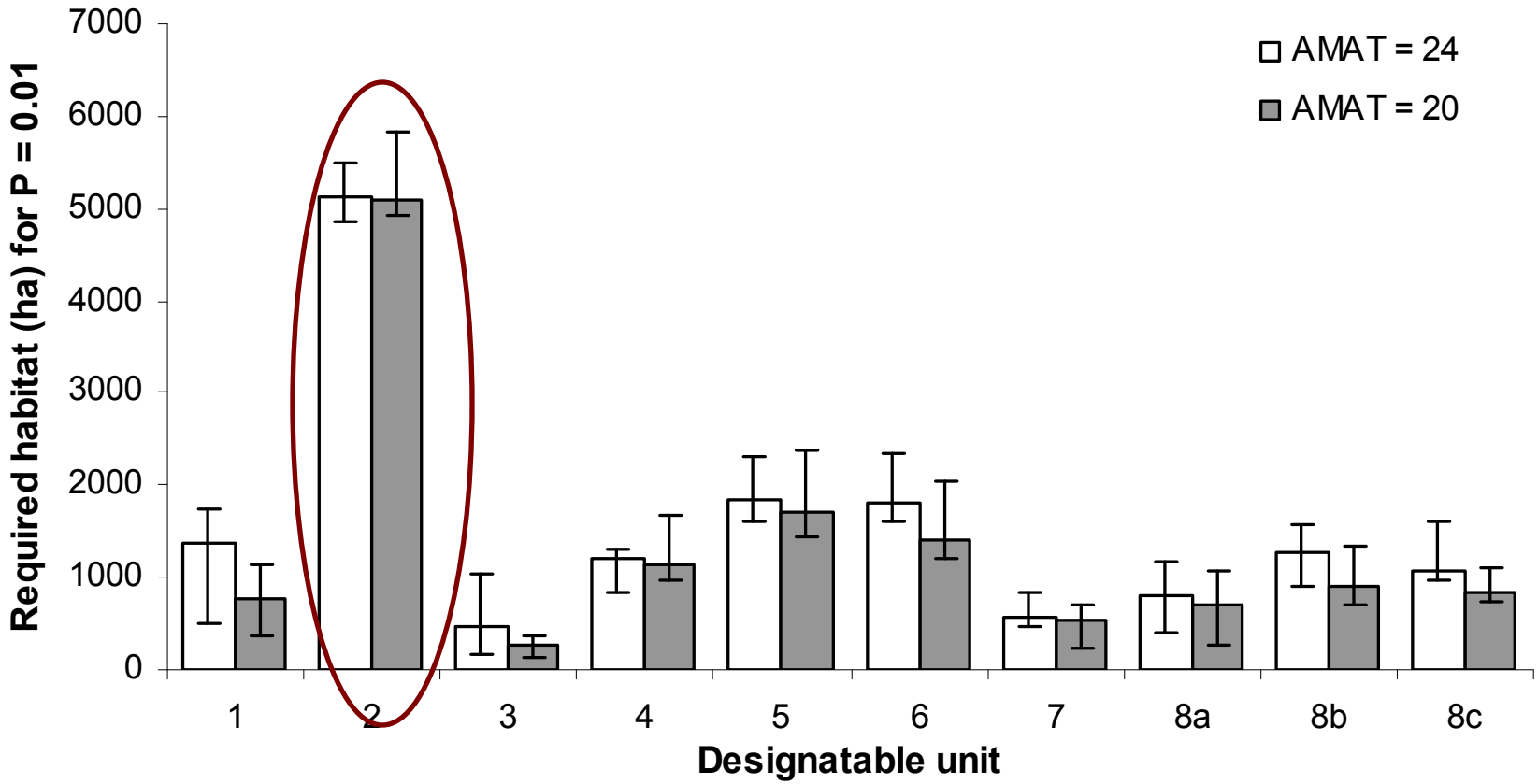
Lake sturgeon



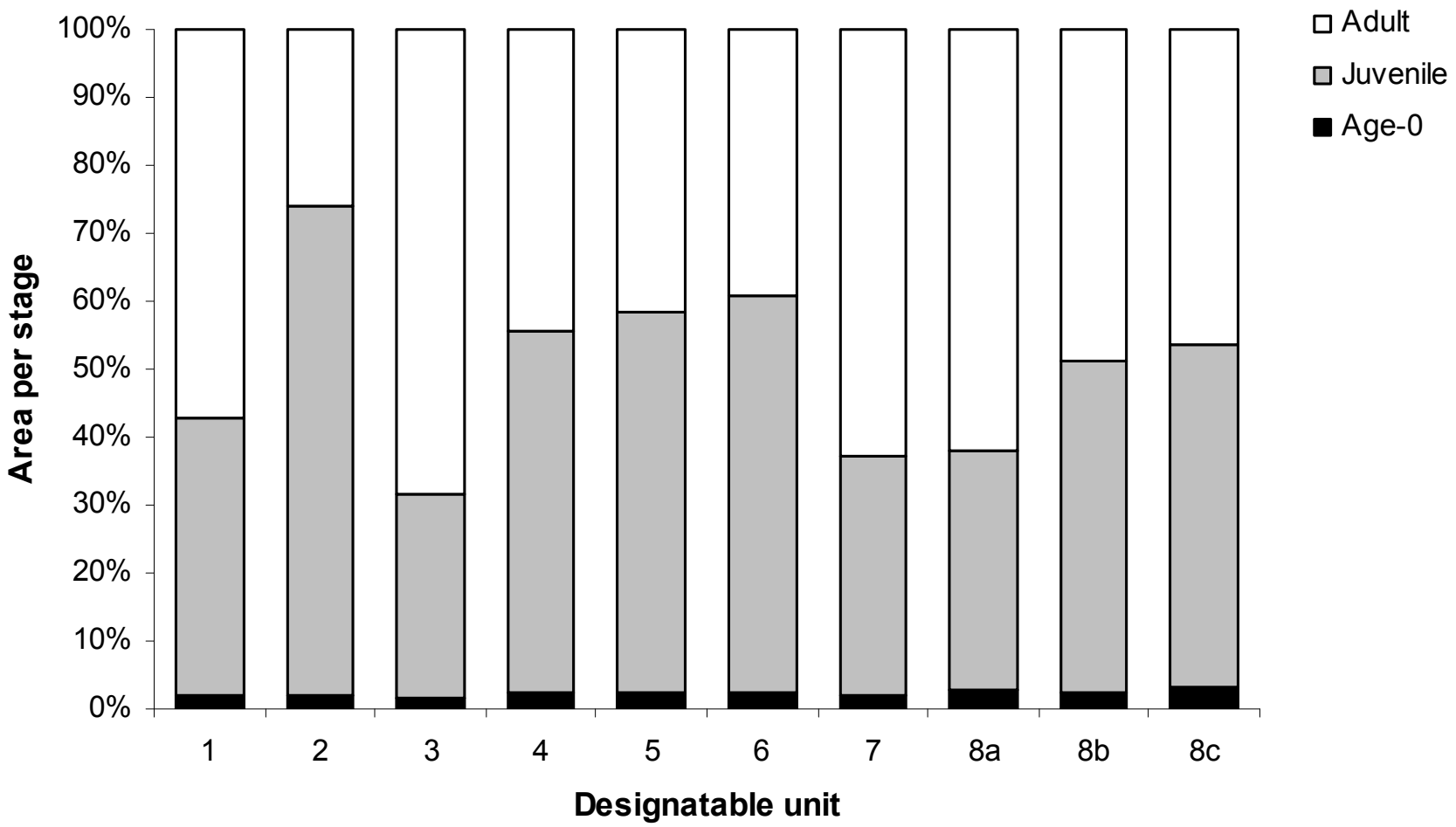
MVP = 99% probability of persistence over 250 years



Required habitat for all life stages



Area allocation per life stage



Recovery targets

DU	Metanalysis		RAMAS	
	W_{opt}	W_{max}	T_{mat} = 24	T_{mat} = 20
1	7 831	10 388	7 675 (2 465 - 10 937)	4 335 (1 746 - 8 000)
2	8 866	11 199	7 240 (6 680 - 7 800)	7 170 (6 616 - 8 483)
3	7 380	10 024	3 683 (1 204 - 7 330)	2 112 (746 - 3 760)
4	8 531	10 930	3 369 (2 968 - 3768)	3 170 (2 610 - 3 730)
5	8 735	11 090	4 093 (3 225 - 4 625)	3 813 (3 115 - 5 915)
6	8 869	11 199	3 345 (2 560 - 3 960)	2 625 (2 050 - 3 308)
7	8 067	10 570	2 672 (1 108 - 3 745)	2 459 (858 - 3 620)
8a	8 543	10 947	2 416 (1 150 - 4 150)	2 380 (916 - 3 780)
8b	8 655	11 036	3 297 (1 872 - 3 515)	2 382 (1 694 - 3 082)
8c	9 059	11 346	1 810 (1 440 - 2 062)	1 423 (884 - 1 703)

A posteriori analysis of variance

Analysis	DU	Tukey-	Kramer	HSD		Mean	Group
MVP	2	A				7332	1
	1	A	B			5860	1
	5		B	C		4131	2
	4		B	C		3269	2
	3		B	C		3139	2
	6		B	C		2975	2
	8b			C		2640	3
	8a			C		2465	3
	7			C		2410	3
	8c			C		1554	3
Area	**Level**					**Mean**	
	2	A				5221	1
	5		B			1886	2
	6		B	C		1731	2
	4			C	D	1193	3
	8b			C	D	1118	3
	8c			C	D	E	1056	3
	1				D	E	974	4
	8a				D	E	743	4
	7				D	E	557	4
	3					E	403	4

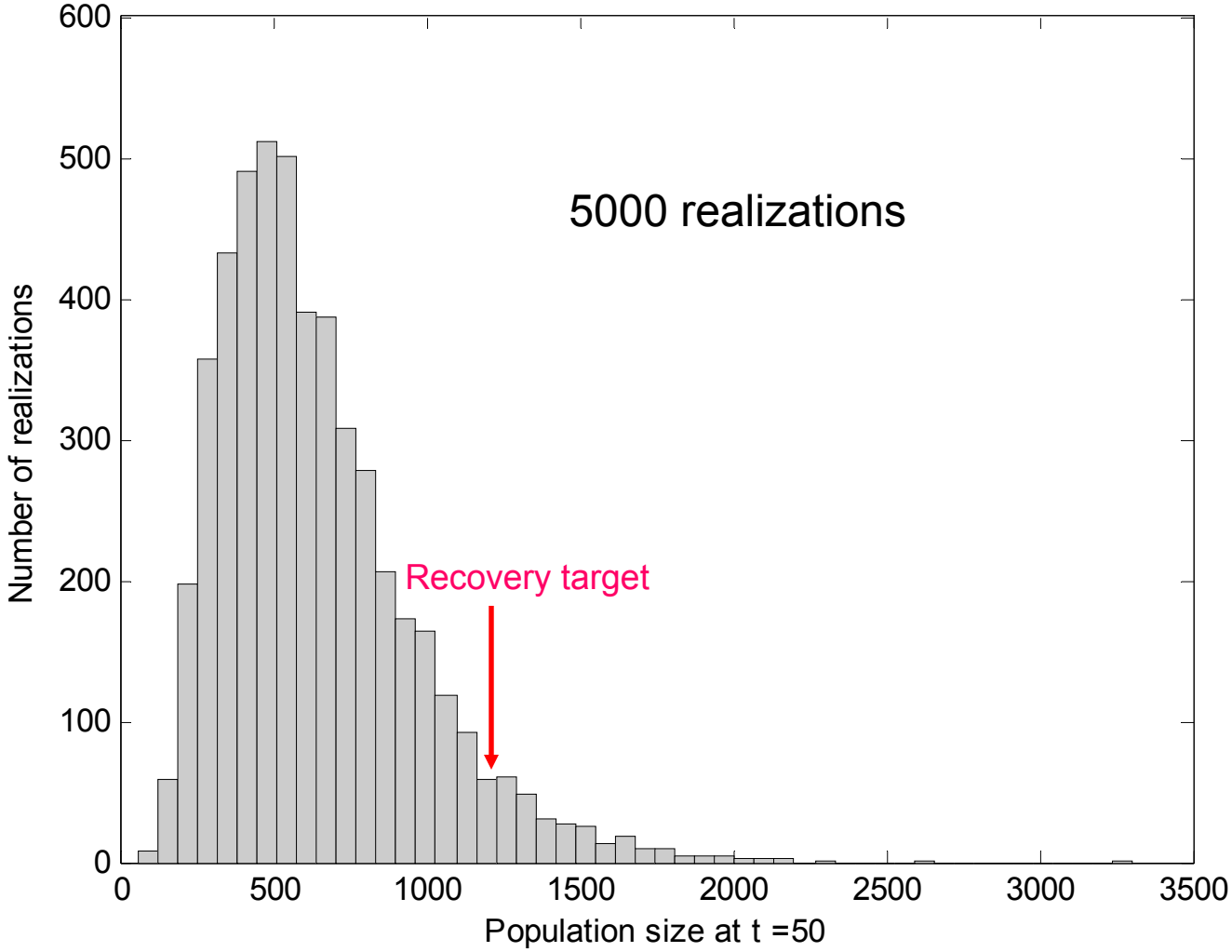
Precautionary estimates

DU	Region	ASF	Required habitat ha
1	Western Hudson Bay	586	974
2	Saskatchewan River	586	974
3	Nelson River Mainstem	413	974
4	Red-Assinibine River – Lake Winnipeg	413	1 193
5	Winnipeg/English Rivers	413	1 886
6	Lake of the woods - Rainy River	413	1 886
7	Southern Hudson Bay and James Bay	264	974
8a	Lakes Erie, Ontario, Huron	264	974
8b	North Lake Superior	264	1 193
8c	St. Lawrence River	264	1 193

Lotic x 2

Long-Term Projections: Recovery Timeframes

Long-term projections in a stochastic environment

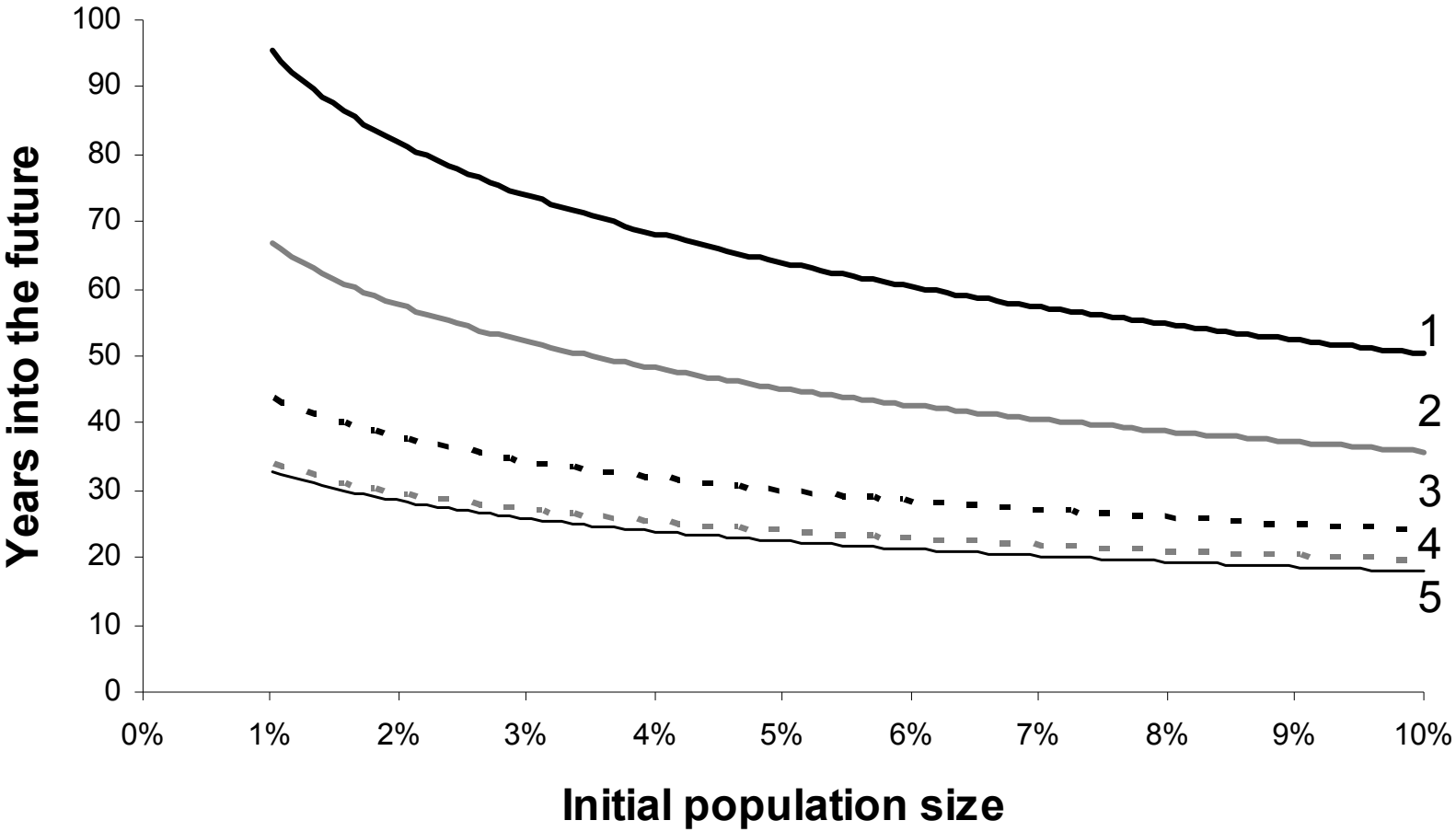


Management strategies

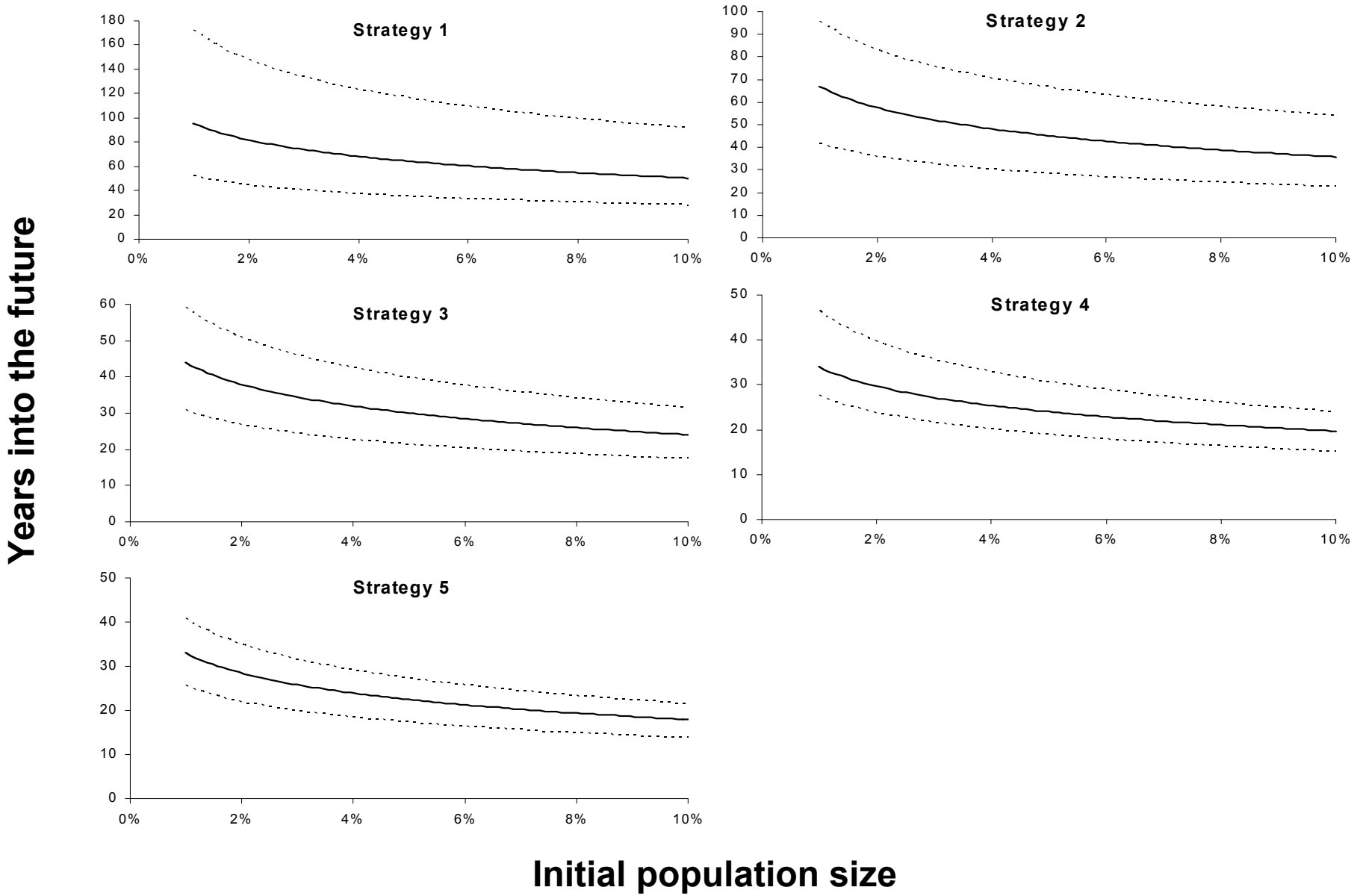
	Survival						
Strategy	YOY	Early juvenile	Late juvenile	Early adult	Late adult	Fecundity	Implementation
1				Maximization			Closing fishery for early adults
							+
2			10% increase	Maximization			Restrictions in mortality of late juveniles
							+
3	20% increase	20% increase	10% increase	Maximization			Habitat rehabilitation + stocking
							+
4	20% increase	20% increase	10% increase	Maximization	Maximization		Closing fishery for late adults
							+
5	20% increase	20% increase	10% increase	Maximization	Maximization	20% increase	Improving fish passage

In progress: development of a stand-alone application

Recovery timeframes



Sensitivity to spawning periodicity



Distribution targets

* Independent treatment of catastrophes

* Minimum number of populations

* Spatial attributes are still undetermined

Probability of persistence of a group of populations

$$P_m = 1 - (1 - P_k + P_z)^n$$

No habitat constraints

$$P_m = 1 - \left(1 - \prod_{i=1}^{n} P_{s,i}\right)^n$$

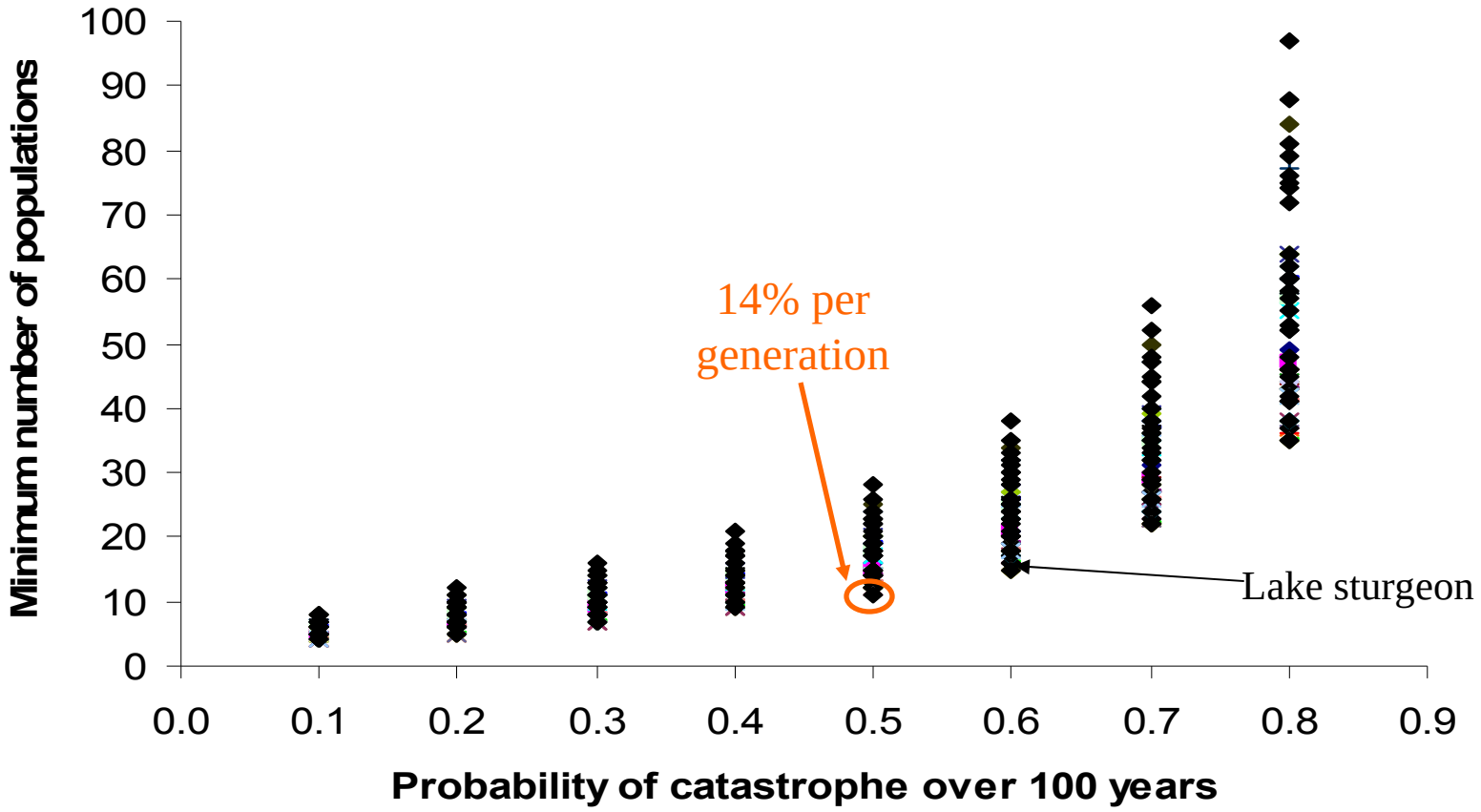
Habitat constraints

P_k = probability of persistence at MVP

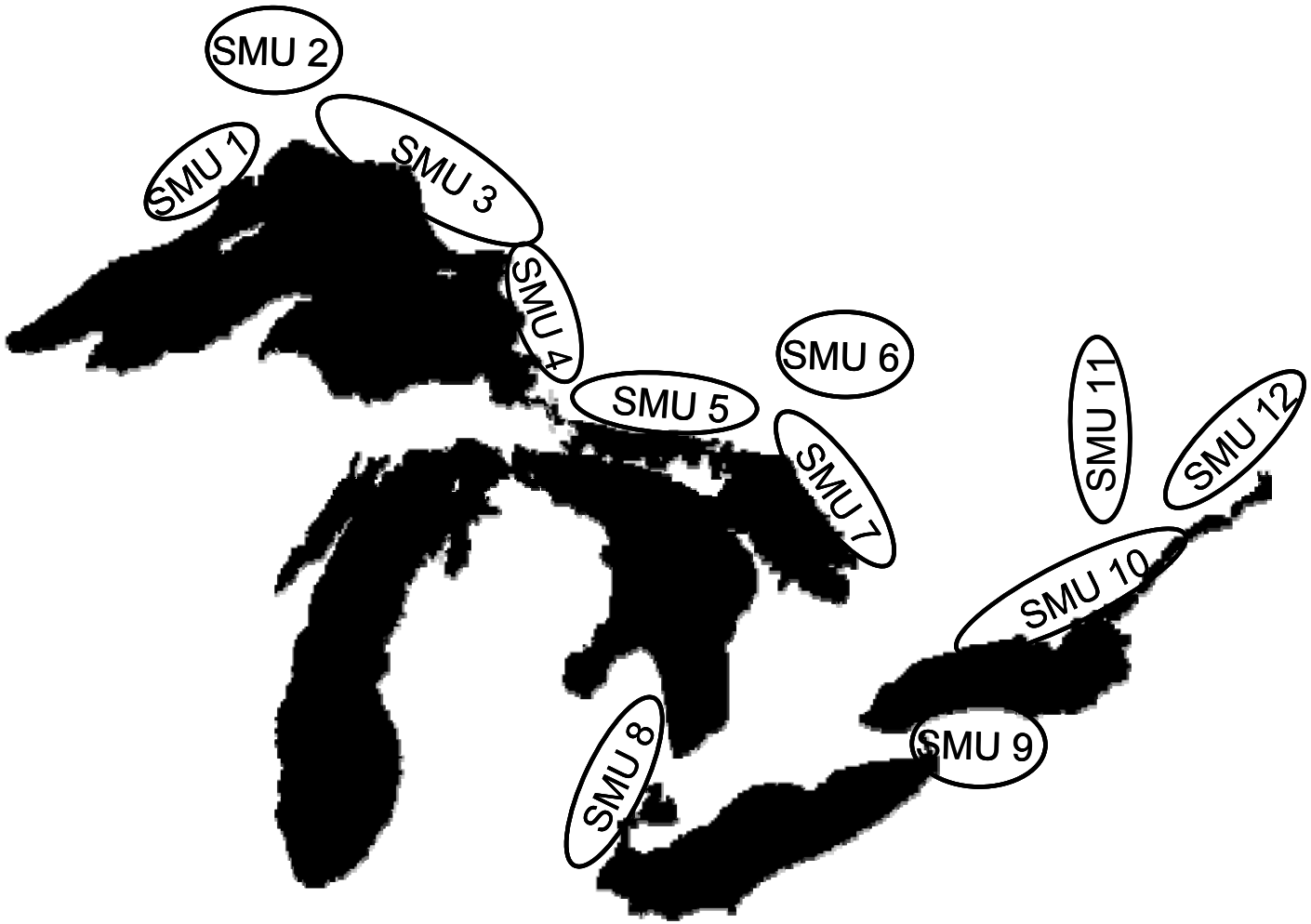
P_z = probability of catastrophe

P_s = probability of persistence at carrying capacity

Freshwater fishes at risk in Canada



Sturgeon Management Units (DU8)



Acknowledgements

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