Empirical model examining influences of temperature, predation, and density on survival of deposited lake trout eggs

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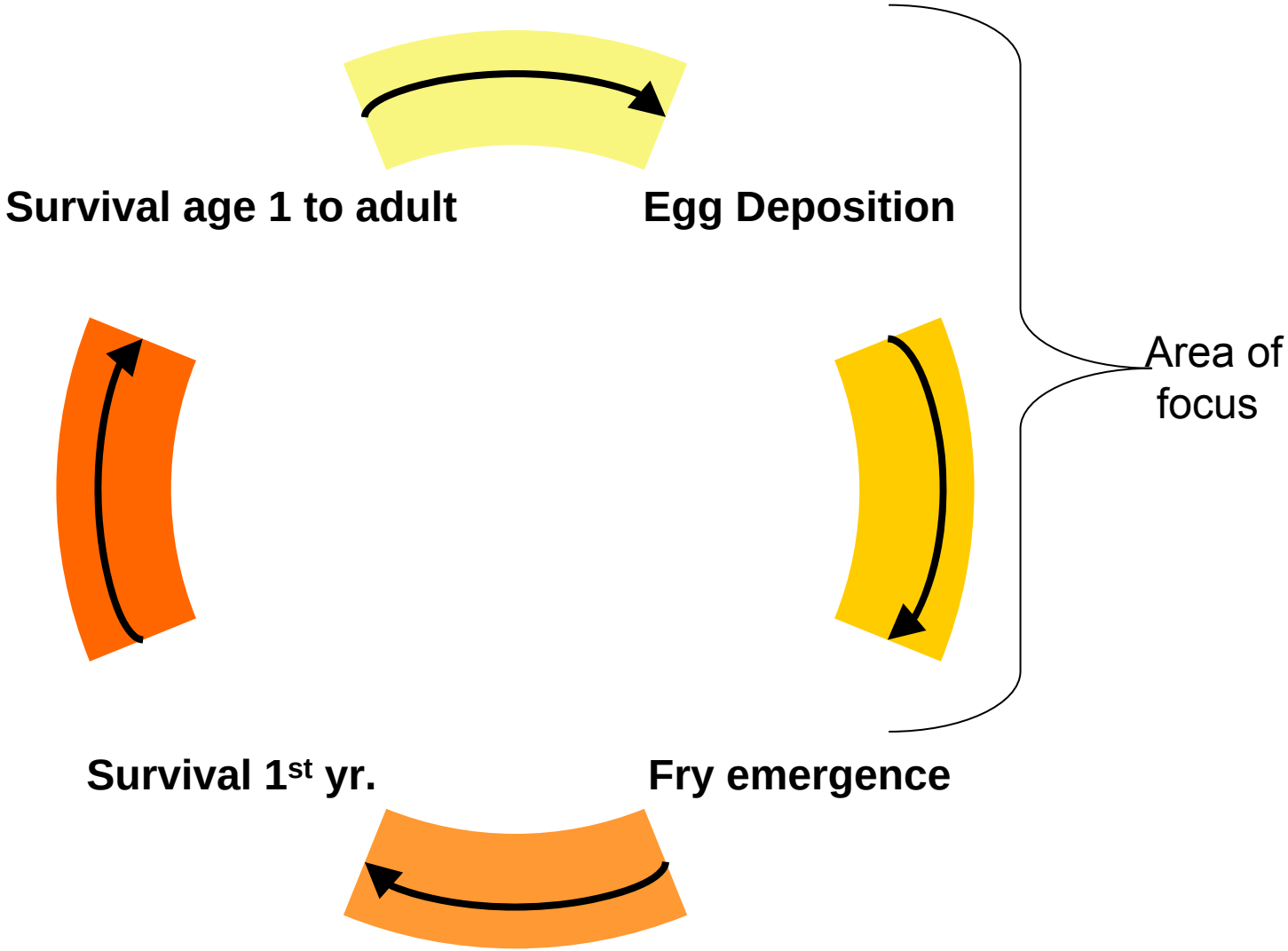
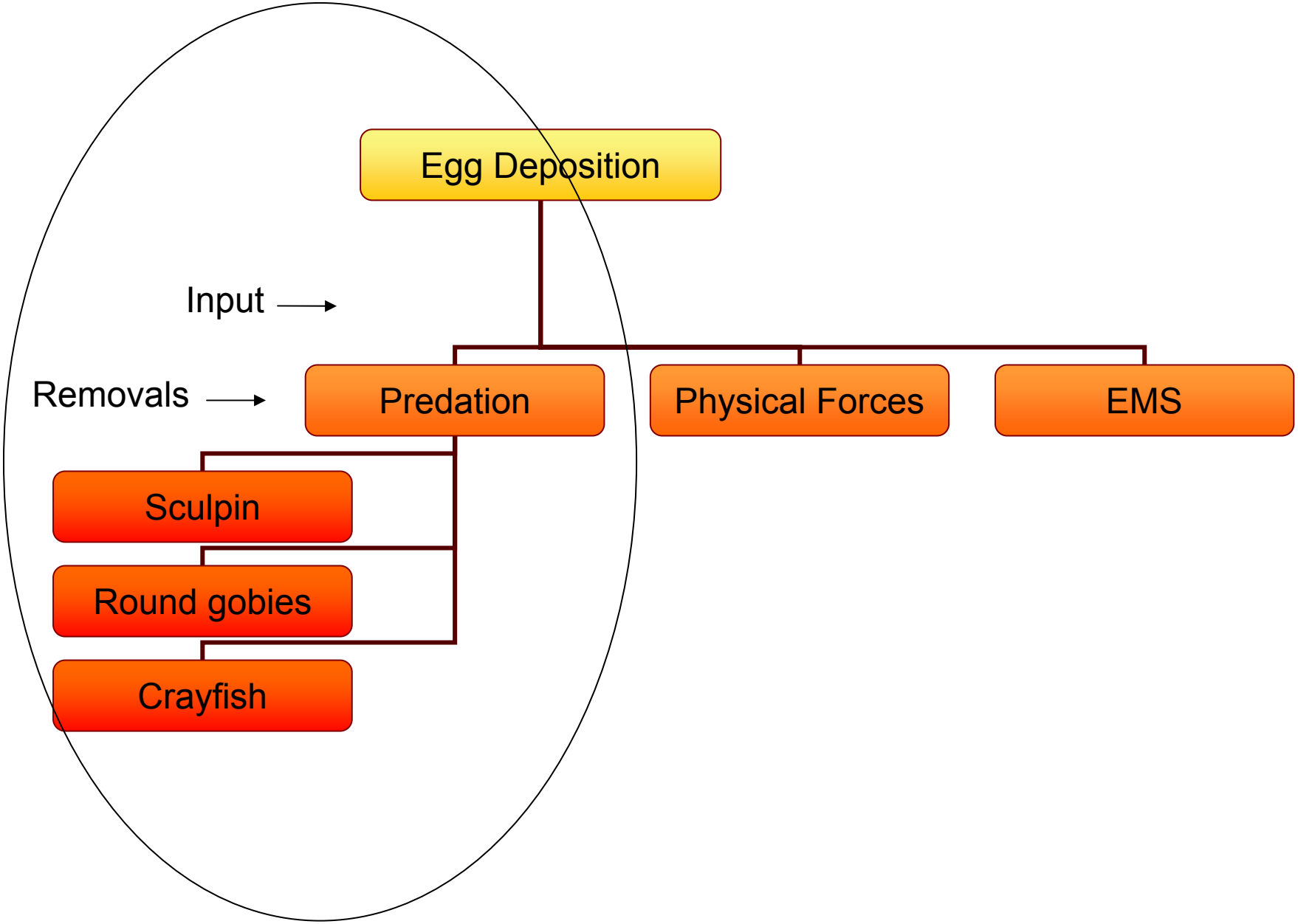
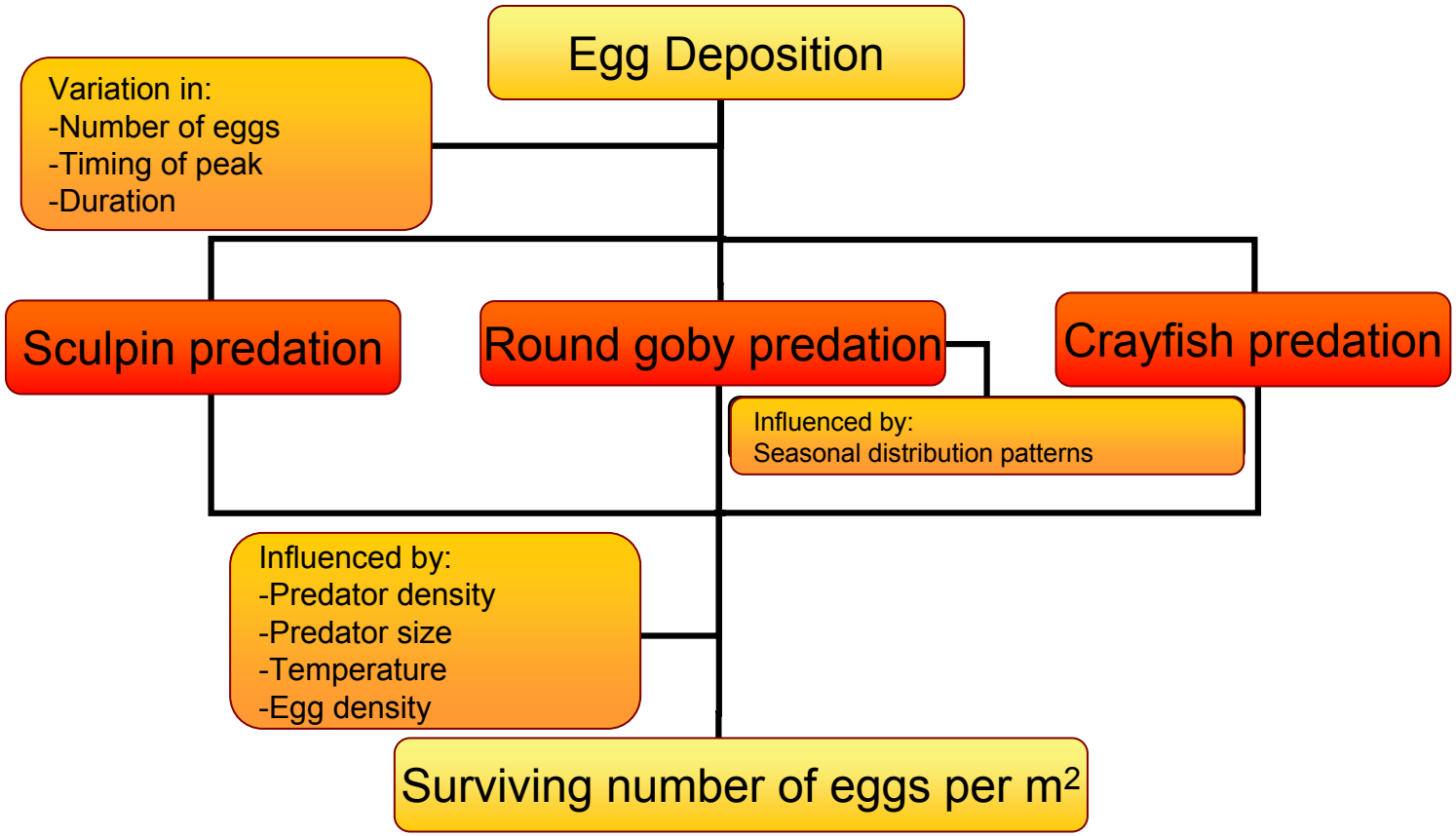

Survival age 1 to adult
Egg Deposition
Area of focus
Survival 1st yr.
Fry emergence


Egg Deposition
Input
Removals
Predation
Physical Forces
EMS
Sculpin
Round gobies
Crayfish


Egg Deposition
Variation in:
-Number of eggs
-Timing of peak
-Duration
Sculpin predation
Round goby predation
Crayfish predation
Influenced by:
Seasonal distribution patterns
Influenced by:
-Predator density
-Predator size
-Temperature
-Egg density
Surviving number of eggs per m2

Explore variation in:

1. Timing and duration of deposition
2. Fall cooling patterns
3. Egg predator species, densities and sizes

Baseline Values:

Spawning

Spawning period= Oct 30 – Dec 22 (53 days)
Egg Density= 2,000 eggs per m^2 for entire period
Peak deposition rate= 266 eggs per m^2 per day

Temperature

Average daily values from four years and six sites in Lake Michigan

Predator size and abundance

Average of 25 Great Lake Sites:

Size

Sculpin and round goby = 55±7 mm
Crayfish = 30±5 mm

Abundance

15 predators per m2 (5 sculpin, 5 round gobies, 5 crayfish)

Egg deposition modeled as a normal distribution:

Daily egg density = μ*exp(-0.5*((day-b)/α)2))

μ = peak density

b = timing of the peak

α = duration of spawning

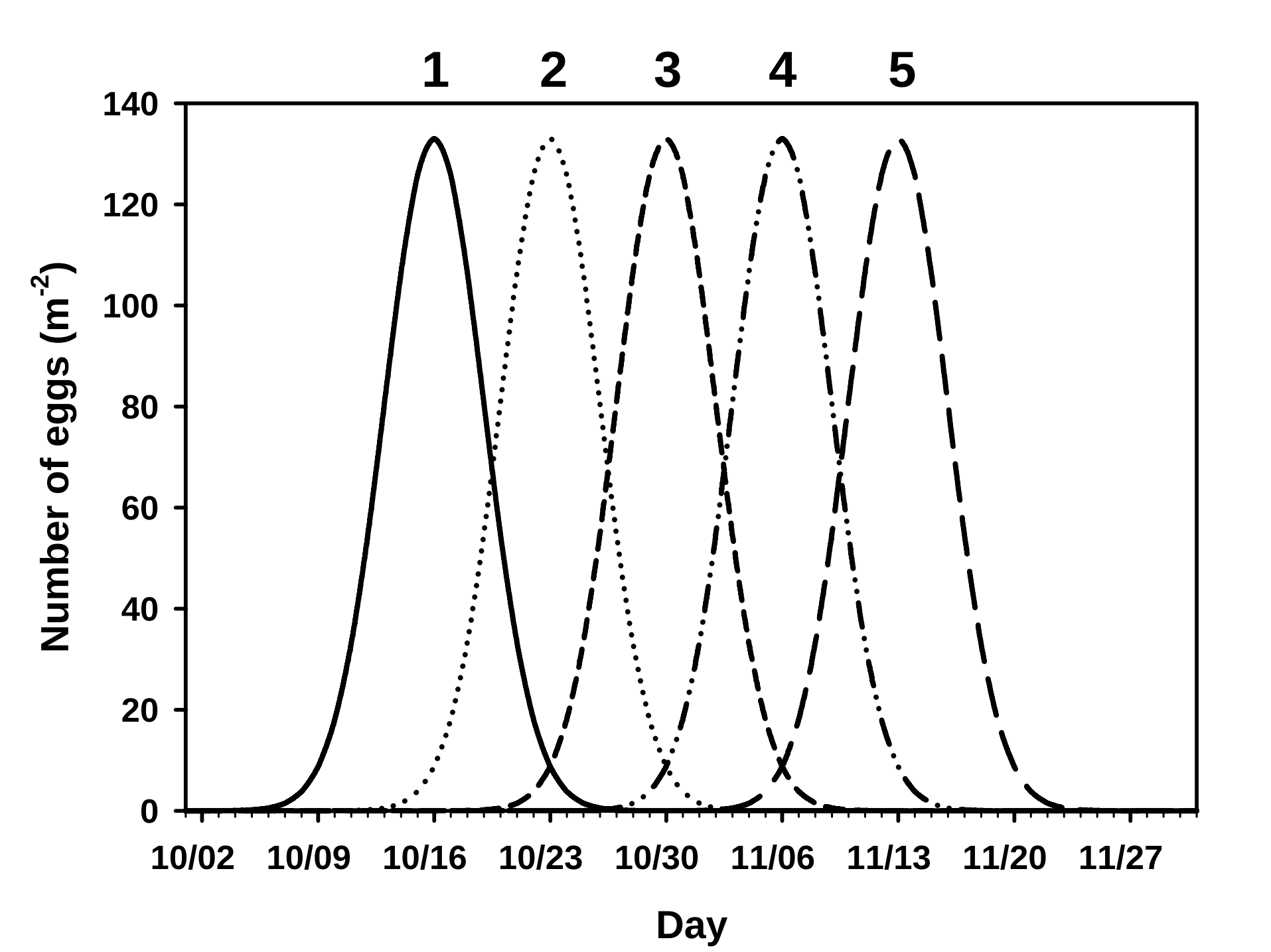
(spawning constrained to occur after Oct. 1)

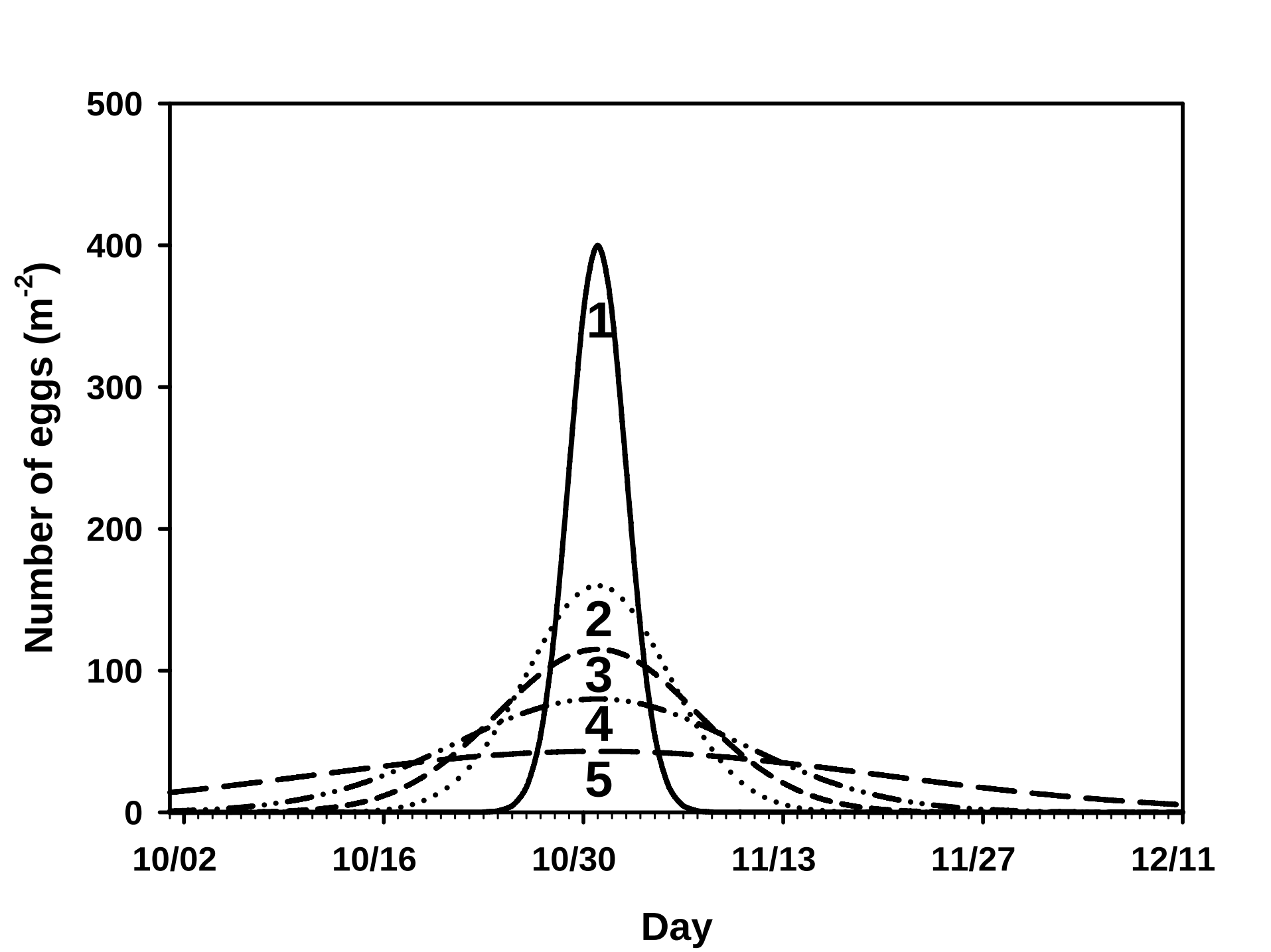
Deposition scenarios

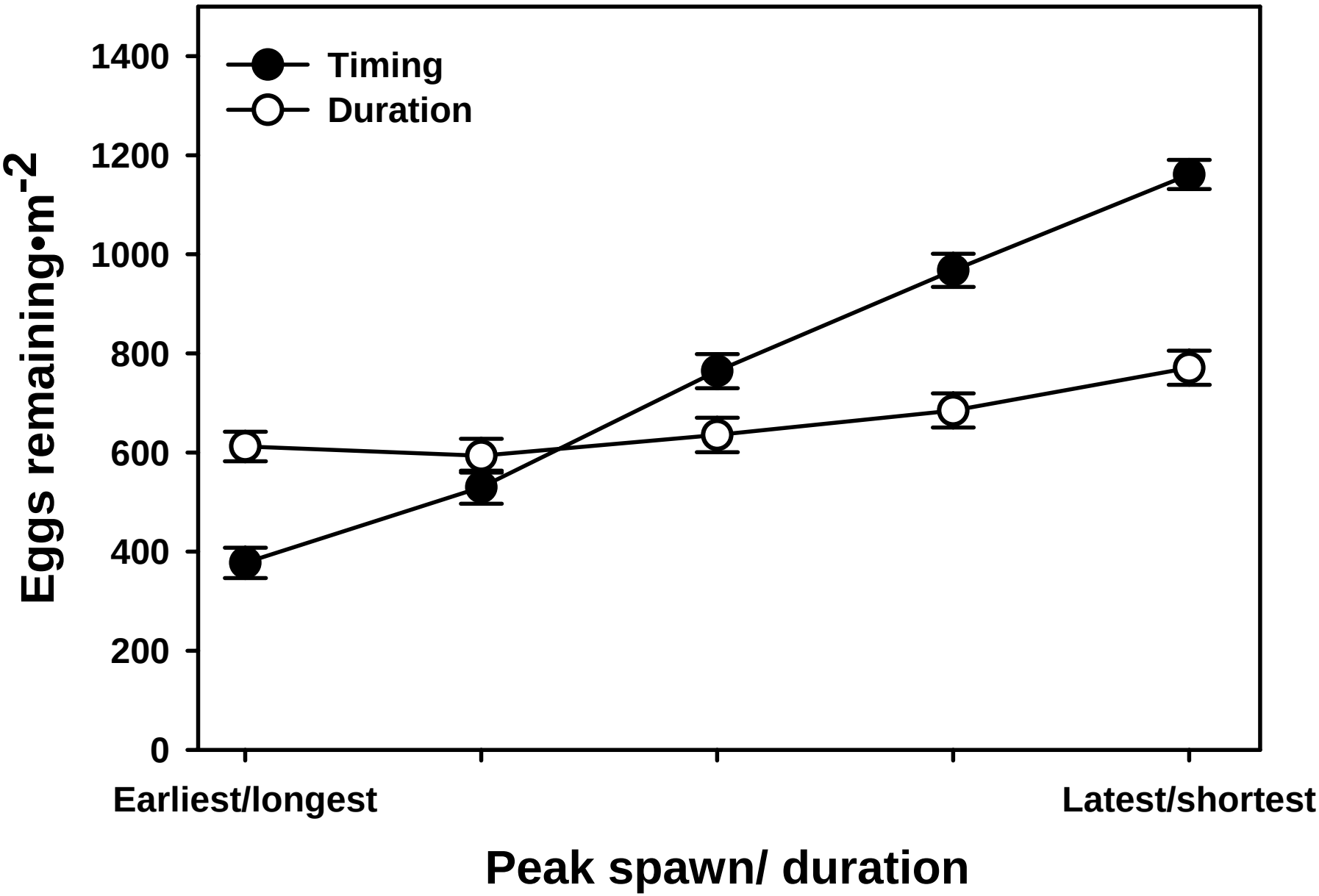
1. Timing 16, 23, 30, 37, 44 days (5 scenarios)

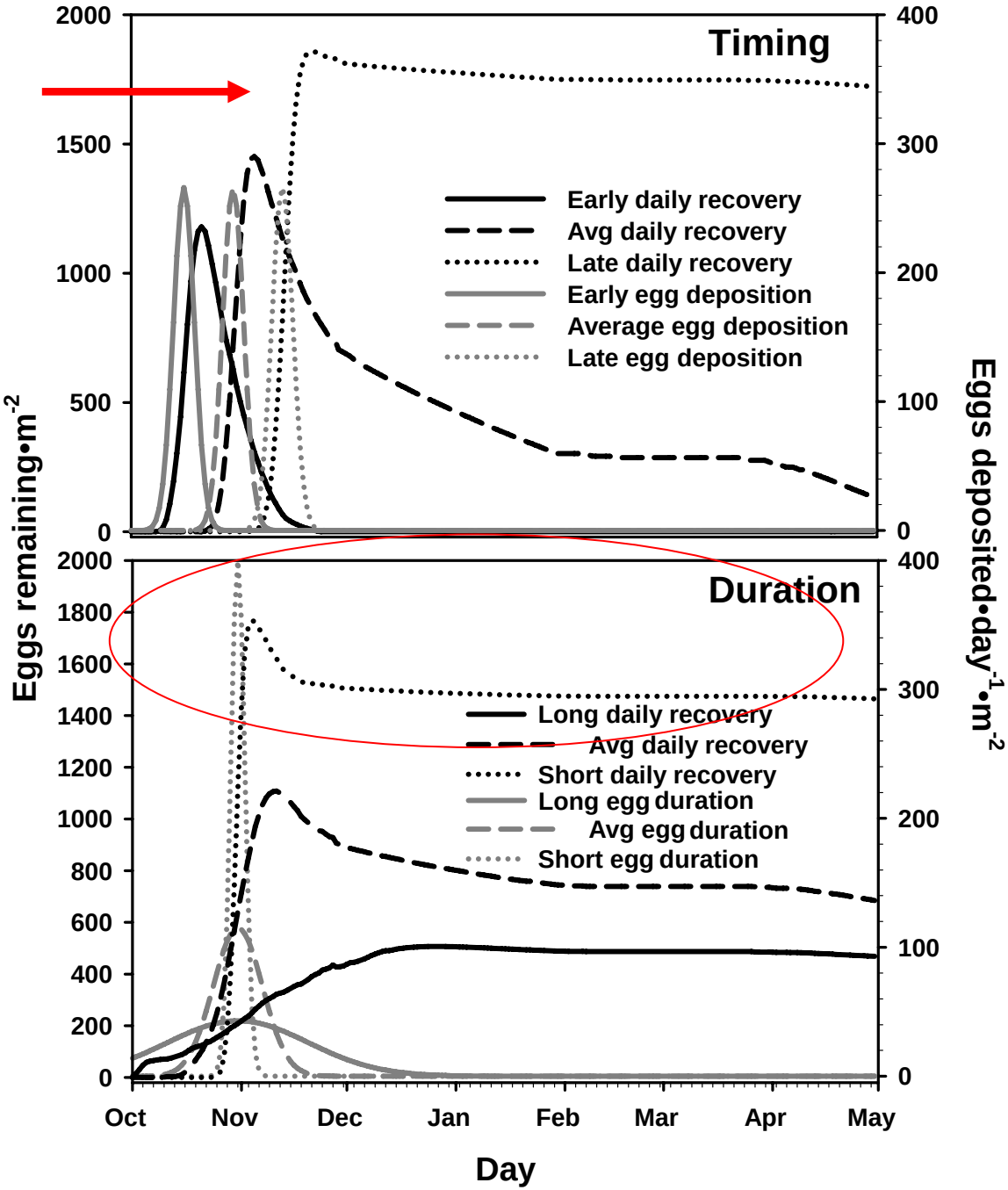
2. Duration α = 2, 5, 7, 10, 20 (5 scenarios)

(egg density held constant)

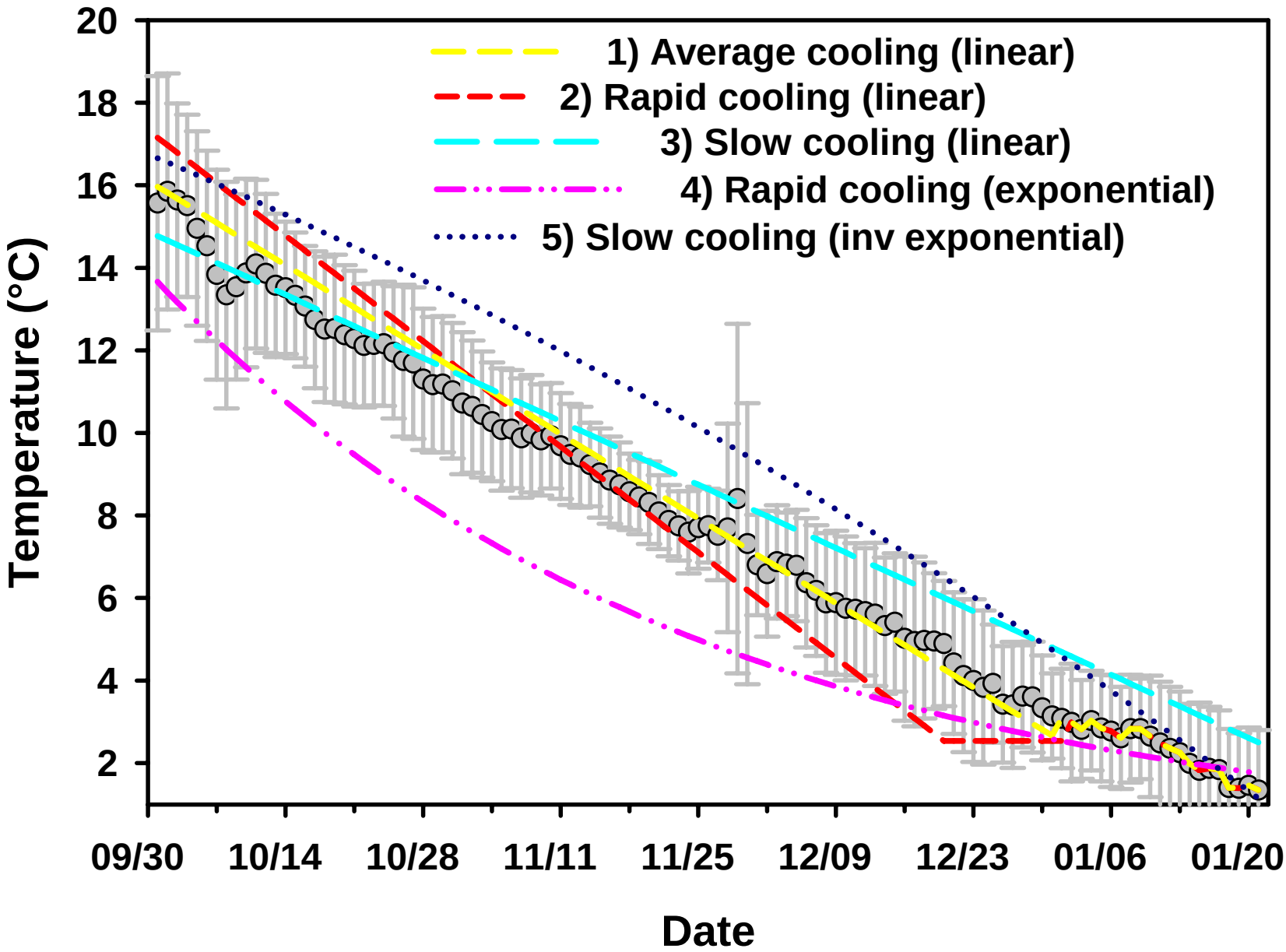

1
2
3
4
5
140
120
100
80
60
40
20
0
Number of eggs (m-2)
10/02
10/09
10/16
10/23
10/30
11/06
11/13
11/20
11/27
Day

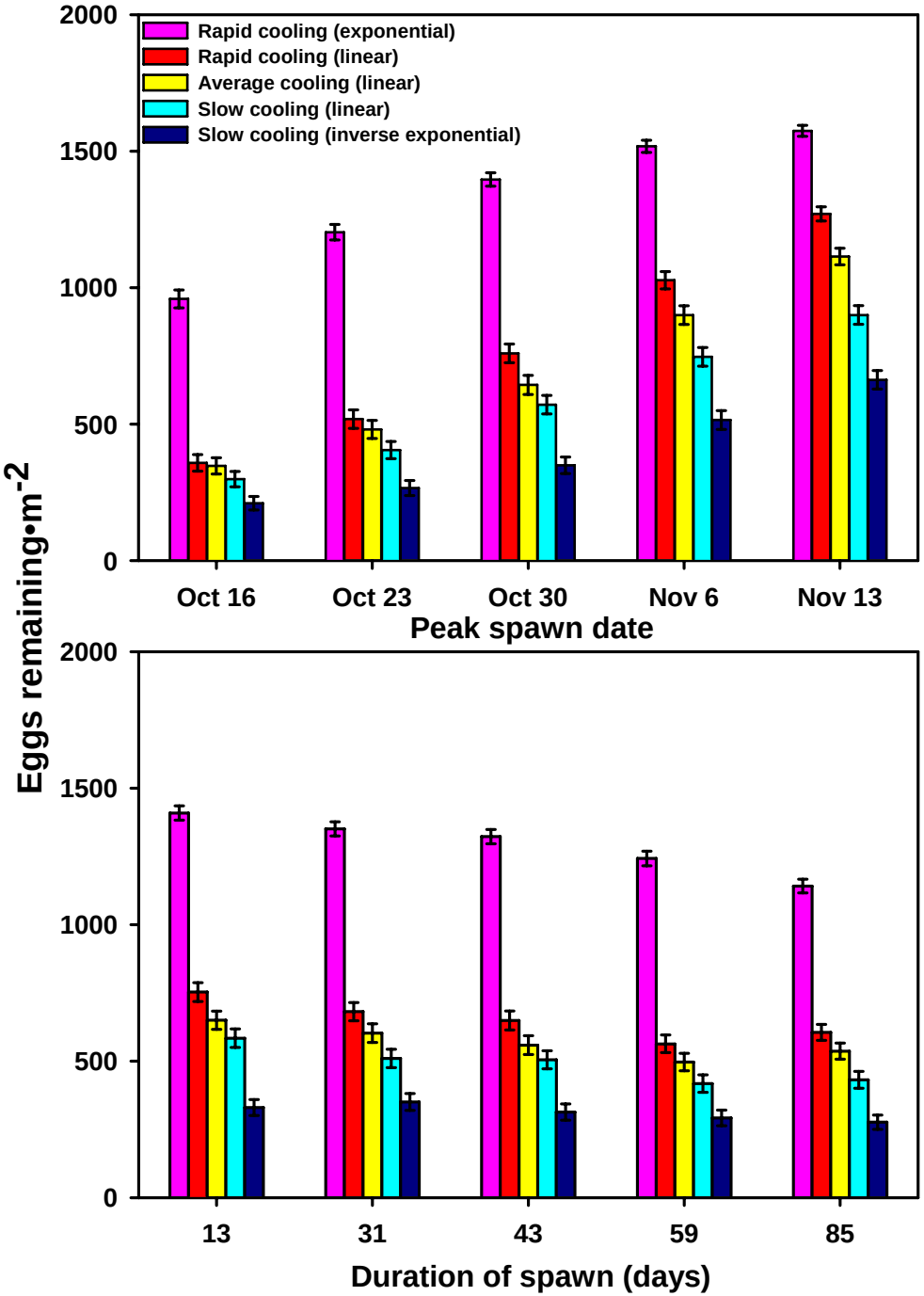

500
400
300
200
100
0
Number of eggs (m-2)
1
2
3
4
5
10/02
10/16
10/30
11/13
11/27
12/11
Day

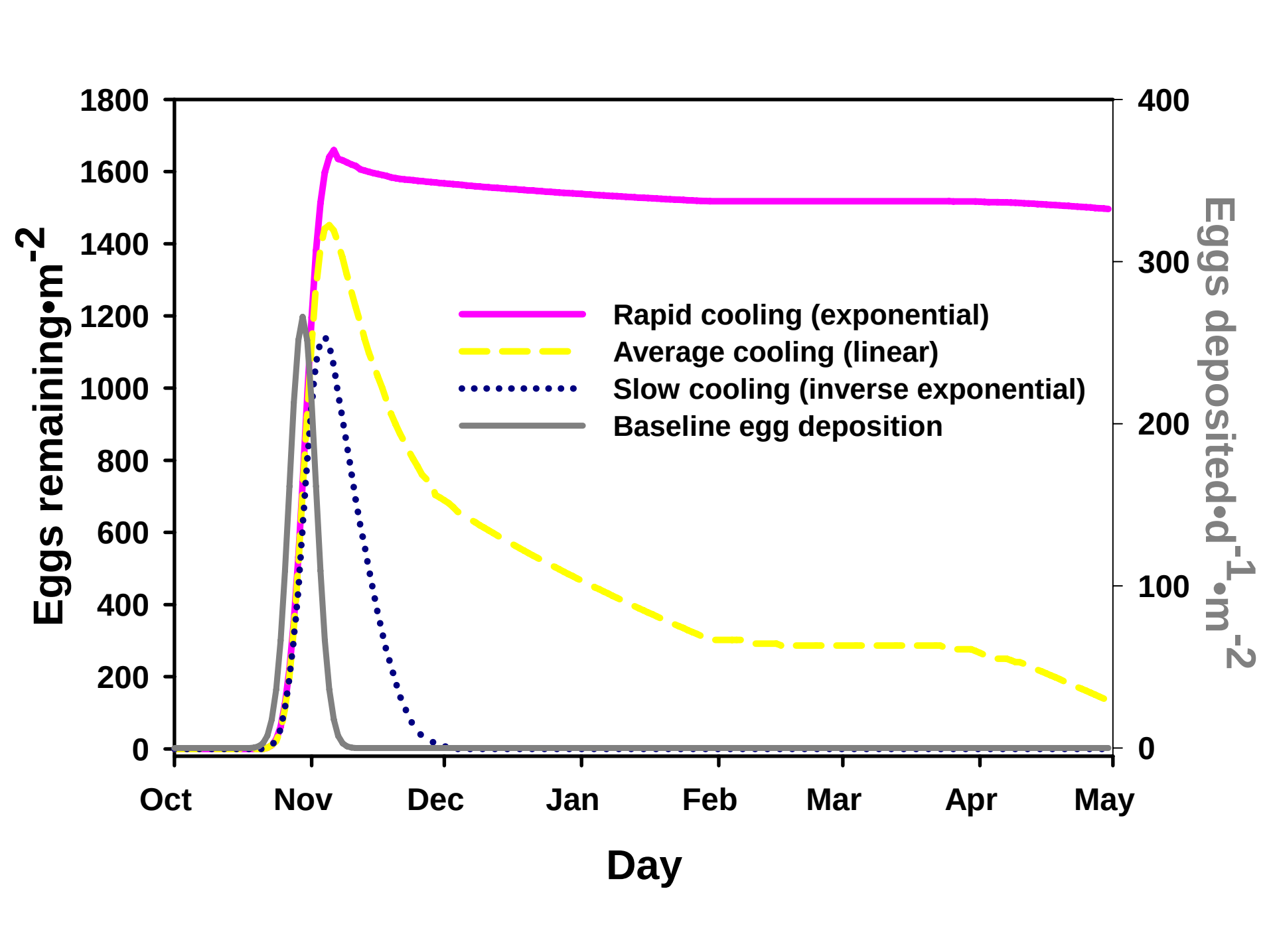

Timing
Duration
1400
1200
1000
800
600
400
200
0
Eggs remaining•m-2
Earliest/longest
Latest/shortest
Peak spawn/ duration


Timing
Early daily recovery
Avg daily recovery
Late daily recovery
Early egg deposition
Average egg deposition
Late egg deposition
Duration
Long daily recovery
Avg daily recovery
Short daily recovery
Long egg duration
Avg egg duration
Short egg duration
Eggs remaining•m-2
Eggs deposited•day-1•m-2
Day
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
0
500
1000
1500
2000
100
200
300
400
600
800
1200
1400
1600
1800

Cooling Scenarios

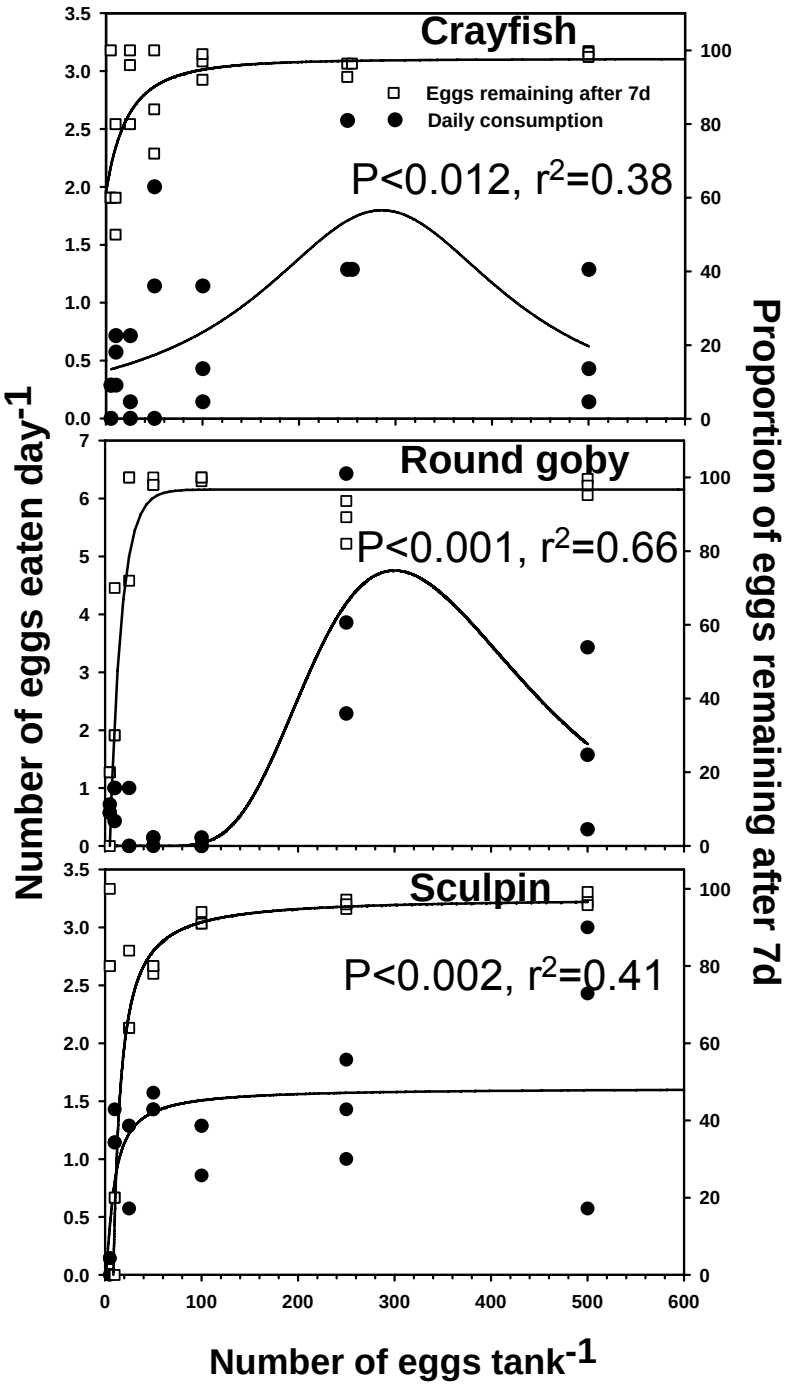



Rapid cooling (exponential)
Rapid cooling (linear)
Average cooling (linear)
Slow cooling (linear)
Slow cooling (inverse exponential)
Eggs remaining•m-2
2000
1500
1000
500
0
Oct 16
Oct 23
Oct 30
Nov 6
Nov 13
Peak spawn date
13
31
43
59
85
Duration of spawn (days)


1800
1600
1400
1200
1000
800
600
400
200
0
Eggs remaining•m-2
400
300
200
100
0
Eggs deposited•d-1•m-2
Rapid cooling (exponential)
Average cooling (linear)
Slow cooling (inverse exponential)
Baseline egg deposition
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Day

Egg density Response:

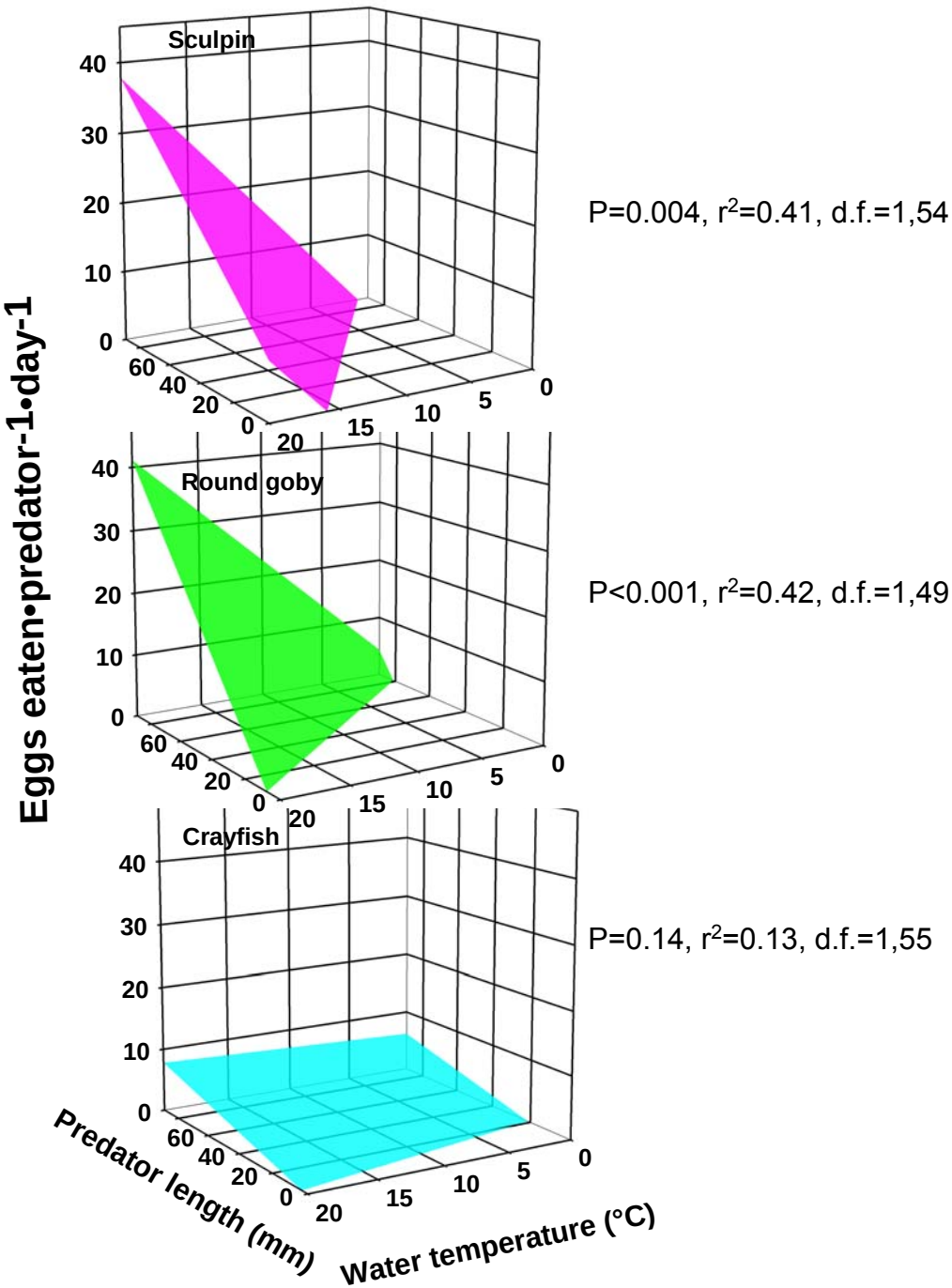
(Fitzsimons et al. 2006, Journal of Great Lakes Research)

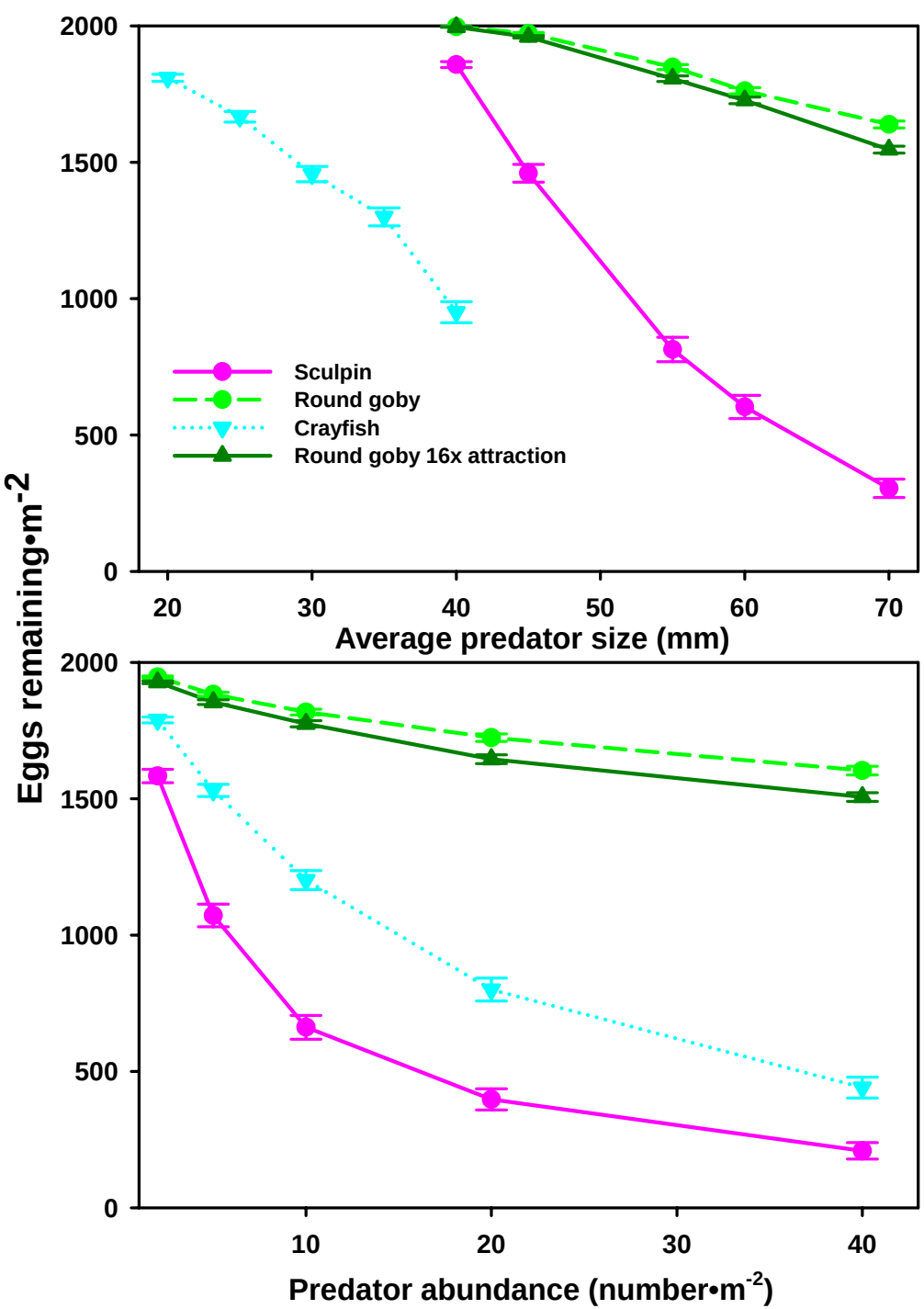


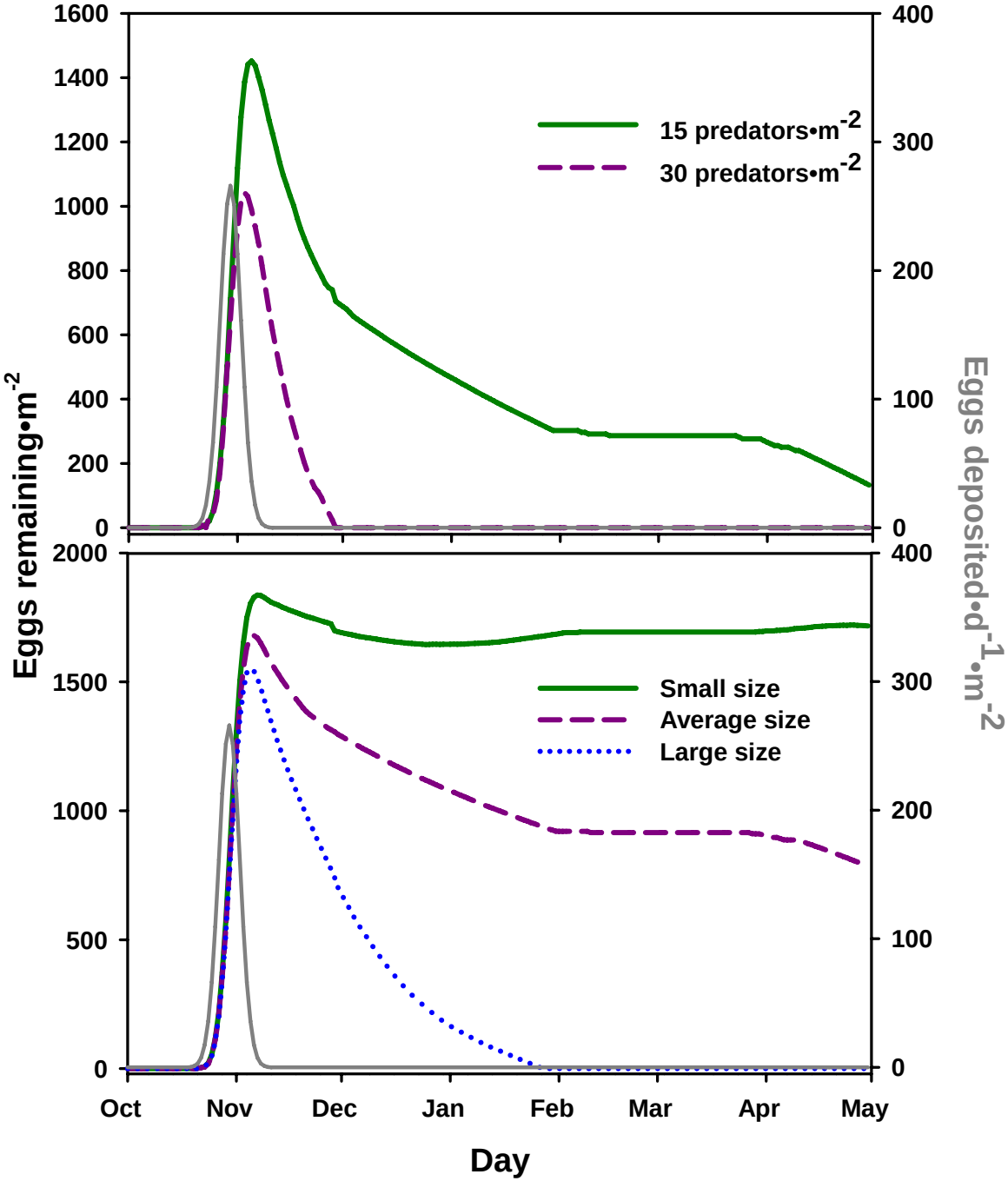
Predator scenarios

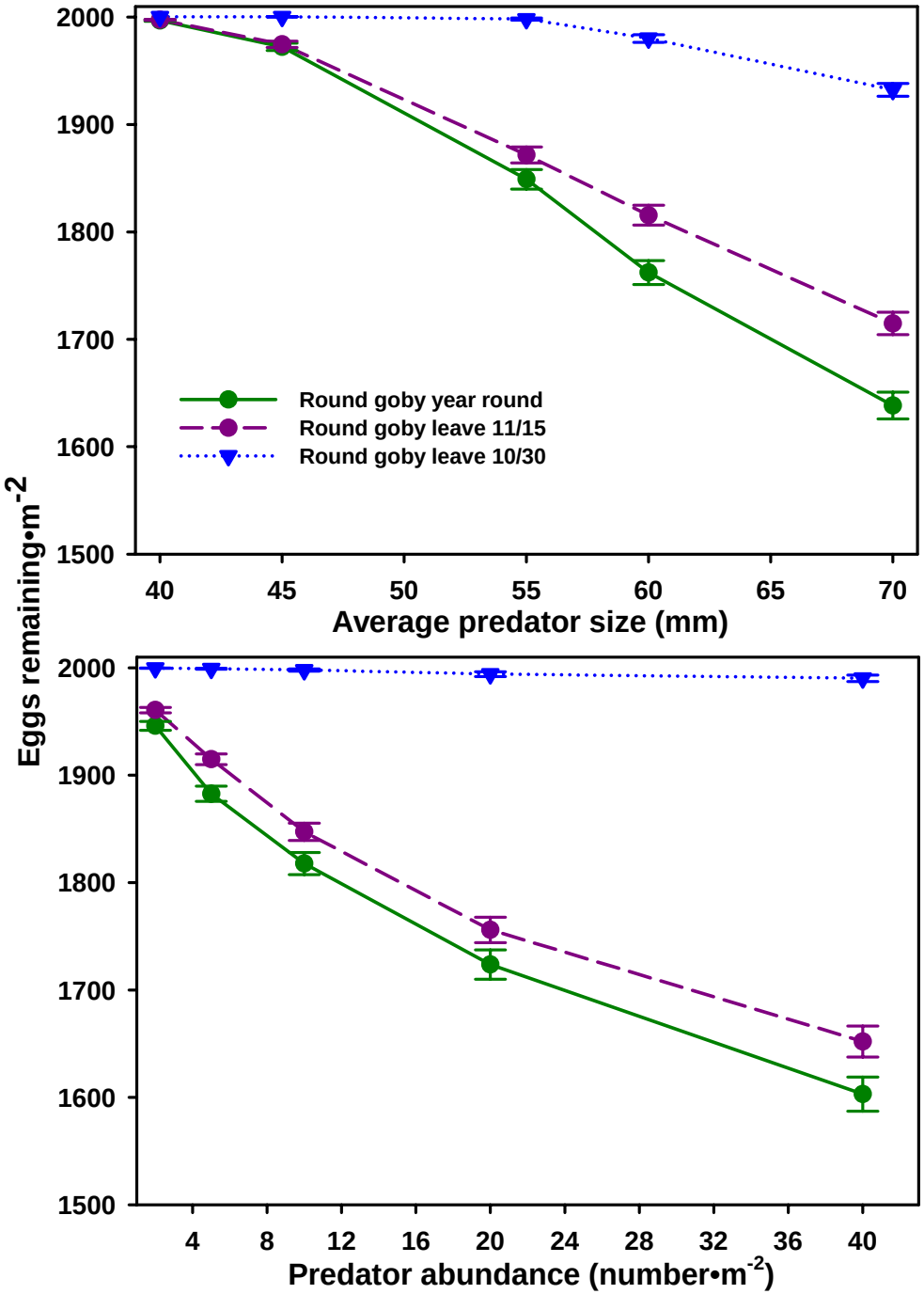
1. Size
   - Sculpin (40, 45, 55, 60, and 70 mm)
   - Round goby (40, 45, 55, 60, 70 mm)
   - Crayfish (20, 25, 30, 35, 40 mm)

2. Abundance
   - Sculpin (2, 5, 10, 20, and 40 m^{-2})
   - Round goby (2, 5, 10, 20, 40 m^{-2})
   - Crayfish (2, 5, 10, 20, 40 m^{-2})


Sculpin
Round goby
Crayfish
Eggs eaten•predator-1•day-1
Predator length (mm)
Water temperature (°C)
0
10
20
30
40
60
40
20
0
20
15
10
5
0
P=0.004, r2=0.41, d.f.=1,54
P<0.001, r2=0.42, d.f.=1,49
P=0.14, r2=0.13, d.f.=1,55


Eggs remaining•m-2
2000
1500
1000
500
0
20
30
40
50
60
70
Average predator size (mm)
Sculpin
Round goby
Crayfish
Round goby 16x attraction
10
20
30
40
Predator abundance (number•m-2)


Eggs remaining•m-2
Eggs deposited•d-1•m-2
15 predators•m-2
30 predators•m-2
Small size
Average size
Large size
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Day


Eggs remaining•m-2
2000
1900
1800
1700
1600
1500
40
45
50
55
60
65
70
Average predator size (mm)
Round goby year round
Round goby leave 11/15
Round goby leave 10/30
2000
1900
1800
1700
1600
1500
4
8
12
16
20
24
28
32
36
40
Predator abundance (number•m-2)

Predator simulation summary points:

1. Spawning late during a compacted period of deposition is best for survival of lake trout eggs.

2. Rapid fall cooling is best for egg survival.

3. Crayfish are least effective predator in the lab.

4. Attraction (16x) had only a minimal effect on predation losses to round goby.

5. Can use tool to determine probability of survival given measured environmental conditions.