Study design and sampling intensity for demographic analyses of bear populations

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λ

How many bears – and of what sort – should we follow (and for how long) if our objective is to quantify λ with some specified level of precision?

λ

Demographic projection

- Age-specific vital rates
- Asymptotic
- Information-rich

Empirical (C-MR)

- Population sizes (or estimates of seniority [Pradel approach])
- Real-time
- Information-limited

λ

Demographic projection

- Age-specific vital rates
- Asymptotic
- Information-rich

“After spending *x* dollars monitoring the population for *y* years, and applying the most state-of-the-art demographic methods, we have determined that the population is either going up or it’s going down…”

$\lambda = 1.02\ (0.95 - 1.09)$

- Denial

- Anger

- Bargaining

- Depression

- Acceptance

How are bears are typically studied?

Photo: Courtesy IGBST

Photo: Shannon Podruzny

How are bears are typically studied?

Both photos: Steve Ard

How many bears are typically followed annually?

Study Area/species	Females/yr	Litters/yr	Cubs/yr
Yellowstone (griz)	23.0	5.1	6.8
Montana (griz)	20.4	5.0	10.0
Alaska (griz)	22.8	7.4	11.7
B.C. (griz)	7.9	?	2.9
Alberta (black)	8.6	2.5	3.7
Arkansas (black)	31.1	15.4	3.5
Ontario (black)	35.9	11.9	22.8
Florida (black)	22.8	?	12.5

How many years elapse before estimates of λ are produced?

Study Area/species	Years elapsed	Source:
Yellowstone (griz)	19-20	Schwartz et al. 2006
Montana (griz)	6	Mace et al. 2012
Alaska (griz)	11	Kovach et al. 2006
B.C. (griz)	15	Hovey and McLellan 1996
Alberta (black)	6	Hebblewhite et al. 2003
Arkansas (black)	5-7	Clark and Eastridge 2006
Ontario (black)	11	Obbard and Howe 2008
Florida (black)	4-7	Hostetler et al. 2009

How much uncertainty is typically present in vital rate estimates?

Study Area/species	Adult female survival	Cub survival	Fecundity
Yellowstone (griz)	1.4%*	5.0%	7.8%
Montana (griz)	2.2%	17.6%	12.3%
Alberta (black)	12.7%	16.7%	23.1%
Arkansas (black)	2.2%*	47.3%*	19.8%*

Values are: SE/Mean (%)

* = Process variance only

Doak et al. 2005

$$\mathrm{Var}\left(\ln\hat{\lambda}_s\right) = \sum_i \mathrm{Var}(\hat{v}_i)\left(\frac{\partial \ln \lambda_s}{\partial_{v_i}}\right)^2 + \frac{1}{\lambda_1^4}\sum \mathrm{Var}(\hat{\sigma}_{i,E})\left(\sum_j S_i S_j \rho_{i,j}\sigma_{j,E}\right)^2 + \frac{1}{\lambda_1^4}\sum \mathrm{Var}(\hat{\rho}_{i,j})\left(S_i S_j \sigma_{i,E}\sigma_{j,E}\right)^2 \quad \text{(Eq. A1)}$$

Ecology, 86(5), 2005, pp. 1154–1163

UNDERSTANDING AND PREDICTING THE EFFECTS OF SPARSE DATA ON DEMOGRAPHIC ANALYSES

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Abstract. Demographic models are an increasingly important tool in population biology. However, these models, especially stochastic matrix models, are based upon a multitude of parameters that must usually be estimated with only a few years of data and limited

- Adult females monitored/yr: 10 – 60
- Litters monitored: 15% to 100% of females
- Years considered in estimates: 2 - 20

of demographic predictions: the sampling of small numbers of individuals within each year, so that vital rate estimates made for each transition period are uncertain; and the collection of data over only a small number of years, so estimates of the mean, variance,

of uncertainty around estimates of variance and correlation with limited data. Consequently, we ask: when is the cost of including estimates of variance and correlation in a demographic model worth the benefit? The basic idea behind this question is now well-publicized

Research Article

Growth and Sustainability of Black Bears at White River National Wildlife Refuge, Arkansas

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Abstract

The black bear (Ursus americanus) population at White River National Wildlife Refuge is isolated and genetically distinct, but hunting occurs adjacent to refuge boundaries and females with cubs are removed annually for a reintroduction project. We trapped and radiotracked bears to determine level of exploitation and compare methods for estimating population growth and sustainability. We captured 260 bears (113 M:147 F), 414 times, from 1998 through 2003. Survival estimates based on radiotracking and mark–recapture indicated that hunting and translocations were significant sources of loss. Based on mark–recapture data (Pradel estimator), the annual population growth rate (λ) averaged 1.066 (SE = 0.077) when translocation removals occurred and averaged 0.961 (SE = 0.155) when both harvest and translocations occurred. Estimates of λ based on a population simulation model (program RISKMAN) averaged 1.061 (SD = 0.104) and 1.100 (SD = 0.111) when no removals occurred, 1.003 (SD = 0.097) and 1.046 (SD = 0.102) when translocations occurred, and 0.973 (SD = 0.096) and 1.006 (SD = 0.099) when both harvest and translocations occurred, depending on the survival rate estimates we used. The probability of population decline by >25% over a 10-year period ranged from 13.8 to 68.8%, given our estimated removal rates. We conclude that hunting and translocation losses are at or exceed the maximum the population is capable of sustaining. Although extinction risks of this important bear population are low over the near term, it should continue to be closely monitored by state and federal agencies. The mark–recapture method we used to estimate λ proved to be a reliable alternative to more costly population modeling methods. (JOURNAL OF WILDLIFE MANAGEMENT 70(4):1094–1101; 2006)

Key words

abundance, black bear, population growth, Pradel model, Ursus americanus, White River,

White River National Wildlife Refuge (NWR) in eastern Arkansas, USA, supports the largest remnant population of black bears in the Mississippi alluvial plain. Land-clearing for agriculture has caused losses of >80% of the bottomland hardwood habitat in the region (Neal 1990). The bear population at White River NWR was thought to have declined to about 25 animals by the 1940s (Dellinger 1942, Holder 1951) but has dramatically increased since that time (Smith 1985, Bowman et al. 1996, White 1996). Bears at White River NWR have a distinct genetic makeup, and issues regarding their taxonomic classifica-

Desha, Monroe, and Phillips counties in eastern Arkansas. This long, narrow refuge varies from 5 to 16 km in width and contains a 145-km portion of the White River, just upstream from its confluence with the Mississippi River (Fig. 1). A network of sloughs and bayous connects more than 350 lakes within the refuge. White River NWR is approximately 65,000 ha in size, with roughly 2,000 ha of permanent water, 62,300 ha of forests, 360 ha of crops, and 400 ha of grassland. Agriculture is the primary use for lands surrounding the refuge, and rice is the major crop followed by soybeans, corn, wheat, and sorghum. Winter and

Study Area

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Black bear (*Ursus americanus*) survival and demography in the Bow Valley of Banff National Park, Alberta

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Abstract

We studied survival and demography of black bears, *Ursus americanus*, in Banff National Park (BNP) from 1994 to 2000 to test the efficacy of National Park protection. We monitored 25 radiocollared bears an average of 1.9 years each for a total of 51.8 bear-years. Eighty-two percent of all mortality ($n=11$) was human-caused, composed of highway mortality (36%), management mortality (27%) and management relocation (18%). Survival was influenced by season and management status. Once bears became a management problem, survival (0.66) was lower than several hunted populations. Adult (0.84) survival was comparable to other unprotected or partly protected populations. Cub (0.64) and yearling (0.67) survival, and reproductive rate ($m_x=0.47$ female cubs/inter-birth interval), was slightly lower than other populations in western North America. We combined survival and reproductive rates in a preliminary post-birth pulse age-class Leslie matrix model and estimated population growth rate as 0.95 (95% simulated C.I. 0.79–1.10). Sensitivity analyses showed λ was most sensitive to changes in adult female survival. Responsible management agencies should reduce adult female highway mortality and the likelihood of becoming a management problem, while continuing monitoring to refine demographic analyses to adequately protect this population.

Keywords: Black bear; Demo

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Population Ecology

Grizzly Bear Population Vital Rates and Trend in the Northern Continental Divide Ecosystem, Montana

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ABSTRACT We estimated grizzly bear (*Ursus arctos*) population vital rates and trend for the Northern Continental Divide Ecosystem (NCDE), Montana, between 2004 and 2009 by following radio-collared females and observing their fate and reproductive performance. Our estimates of dependent cub and yearling survival were 0.612 (95% CI = 0.300–0.818) and 0.682 (95% CI = 0.258–0.898). Our estimates of subadult and adult female survival were 0.852 (95% CI = 0.628–0.951) and 0.952 (95% CI = 0.892–0.980). From visual observations, we estimated a mean litter size of 2.00 cubs/litter. Accounting for cub mortality prior to the first observations of litters in spring, our adjusted mean litter size was 2.27 cubs/litter. We estimated the probabilities of females transitioning from one reproductive state to another between years. Using the stable state probability of 0.322 (95% CI = 0.262–0.382) for females with cub litters, our adjusted fecundity estimate (m_x) was 0.367 (95% CI = 0.273–0.461). Using our derived rates, we estimated that the population grew at a mean annual rate of approximately 3% (λ = 1.0306, 95% CI = 0.928–1.102), and 71.5% of 10,000 Monte Carlo simulations produced estimates of λ > 1.0. Our results indicate an increasing population trend of grizzly bears in the NCDE. Coupled with concurrent studies of population size, we estimate that over 1,000 grizzly bears reside in and adjacent to this recovery area. We suggest that monitoring of population trend and other vital rates using radioed females be continued. © 2011 The Wildlife Society.

KEY WORDS grizzly bear, lambda, Montana, mortality, population trend, reproduction, survival, *Ursus arctos*.

The grizzly bear (*Ursus arctos*) occupies wilderness and non-wilderness habitats in the Northern Continental Divide Ecosystem (NCDE) of western Montana, USA. In 1975, this species was listed in the United States as Threatened under the Endangered Species Act because of threats to habitat and populations. At that time, there was limited information on the ecological requirements of the species and its population status. The NCDE supports the largest population of 6 designated recovery areas for the species (U.S. Fish and Wildlife Service 1993) in the lower 48 states and is contiguous with populations to the north in Canada.

Knowledge of population size and trend is useful to develop appropriate management programs for grizzly bears and to judge success of the recovery effort. In the Greater

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Temporal, Spatial, and Environmental Influences on the Demographics of Grizzly Bears in the Greater Yellowstone Ecosystem

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ABSTRACT

During the past 2 decades, the grizzly bear (*Ursus arctos*) population in the Greater Yellowstone Ecosystem (GYE) has increased in numbers and expanded in range. Understanding temporal, environmental, and spatial variables responsible for this change is useful in evaluating what likely influenced grizzly bear demographics in the GYE and where future management efforts might benefit conservation and management. We used recent data from radio-marked bears to estimate reproduction (1983–2002) and survival (1983–2001); these we combined into models to evaluate demographic vigor (lambda [λ]). We explored the influence of an array of individual, temporal, and spatial covariates on demographic vigor.

We identified an important relationship between λ and where a bear resides within the GYE. This potential for a source-sink dynamic in the GYE, coupled with concerns for managing sustainable mortality, reshaped our thinking about how management agencies might approach long-term conservation of the species. Consequently, we assessed the current spatial dynamic of the GYE grizzly bear population. Throughout, we followed the information-theoretic approach. We developed suites of a priori models that included individual, temporal, and spatial covariates that potentially affected reproduction and survival. We selected our best approximating models using Akaike's Information Criterion (AIC) adjusted for small sample sizes and overdispersion (AIC_c or $QAIC_c$, respectively).

We provide recent estimates for reproductive parameters of grizzly bears based on 108 adult (>3 years old) females observed for 329 bear-years. We documented production of 104 litters with cub counts for 102 litters. Mean age of females producing their first litter was 5.81 years and ranged from 4 to 7 years. Proportion of nulliparous females that produced cubs at age 4–7 years was 9.8, 29.4, 56.4, and 100%, respectively. Mean (±SE) litter size ($n=102$) was 2.0 ± 0.1. The proportion of litters of 1, 2, and 3 cubs was 0.18, 0.61, and 0.22, respectively. Mean yearling litter size ($n=57$) was 2.0 ± 0.1. The proportion of litters containing 1, 2, 3, and 4 yearlings was 0.26, 0.51, 0.21, and 0.02, respectively. The proportion of radio-marked females accompanied by cubs varied among years from 0.05 to 0.60; the mean was 0.316 ± 0.03. Reproductive rate was estimated as 0.318 female cubs/female/year. We evaluated the probability of producing a litter of 0–3 cubs relative to a suite of individual and temporal covariates using multinomial logistic regression. Our best models indicated that reproductive output, measured as cubs per litter, was most strongly influenced by indices of population size and whitebark pine (*Pinus albicaulis*) cone production. Our data suggest a possible density-dependent response in reproductive output, although perinatal mortality could have accounted for the correlation.

We analyzed survival of cubs and yearlings using radiotelemetry of 48 unique female bears observed with 65 litters containing 137 dependent young. We documented 42 deaths: 32 cubs, 5 yearlings, and 5 that could have died as a cub or yearling. Using a nest survival estimator coded in Program MARK, our best model indicated that cub and yearling survival were most affected by residency in the GYE. Survival was highest for cubs and yearlings living outside Yellowstone National Park (YNP) but within the U.S. Fish and Wildlife Service (USFWS) Grizzly Bear Recovery Zone (RZ). Cubs and yearlings living inside YNP had lower survival rates, and those living outside the RZ had the lowest survival rates. Survival rates were negatively related to a population index, suggesting density dependence. Survival improved with higher whitebark pine seed production, greater winter severity, larger litter size, and higher female (mother's) age. We tested theories of sexually selective infanticide, but results were equivocal.

We investigated factors influencing survival of subadult and adult grizzly bears using data from 323 radio-marked bears monitored for 5,988 months. Telemetry records were converted into monthly encounter histories, and survival was estimated using known fate data type in Program

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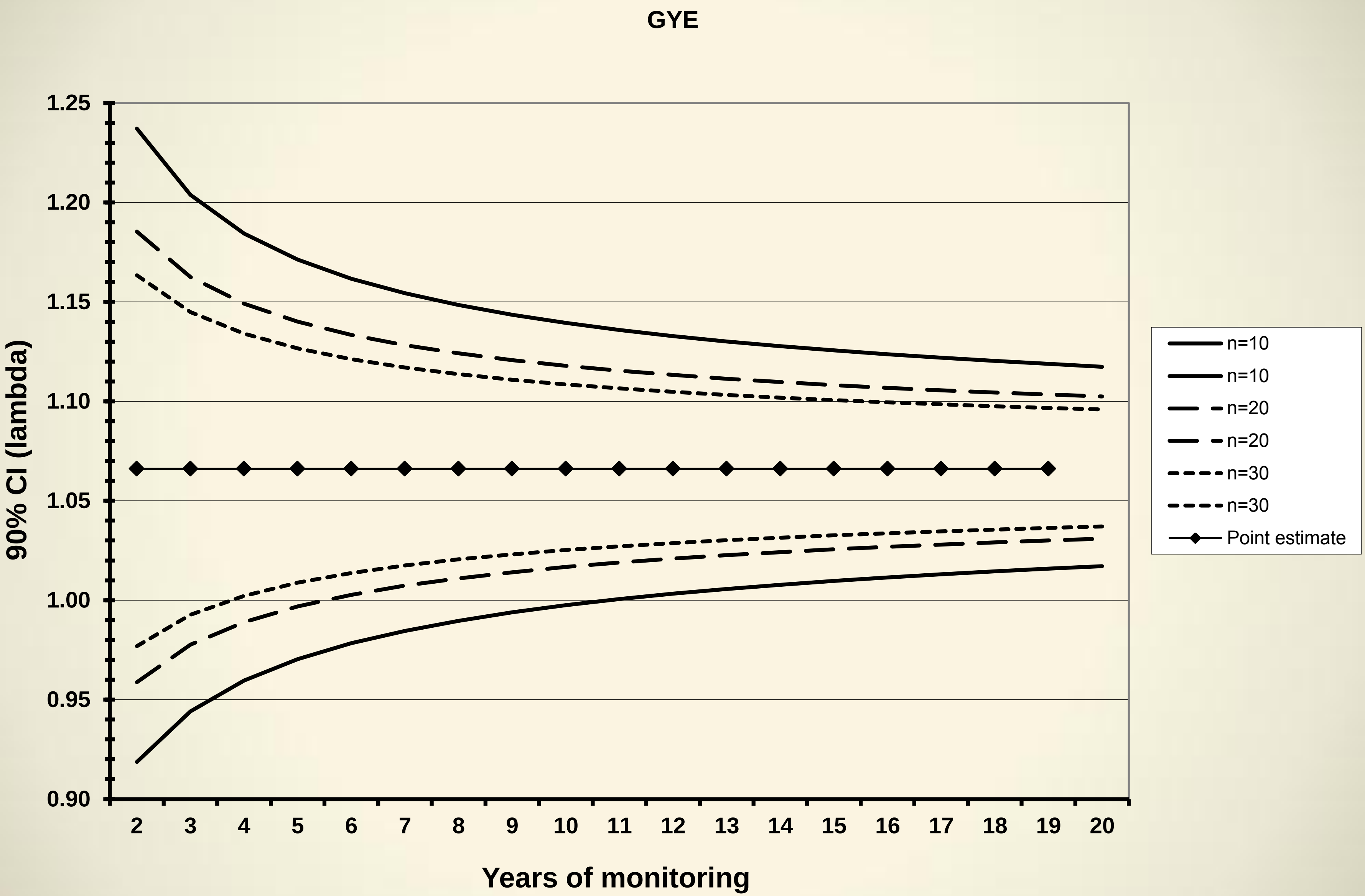
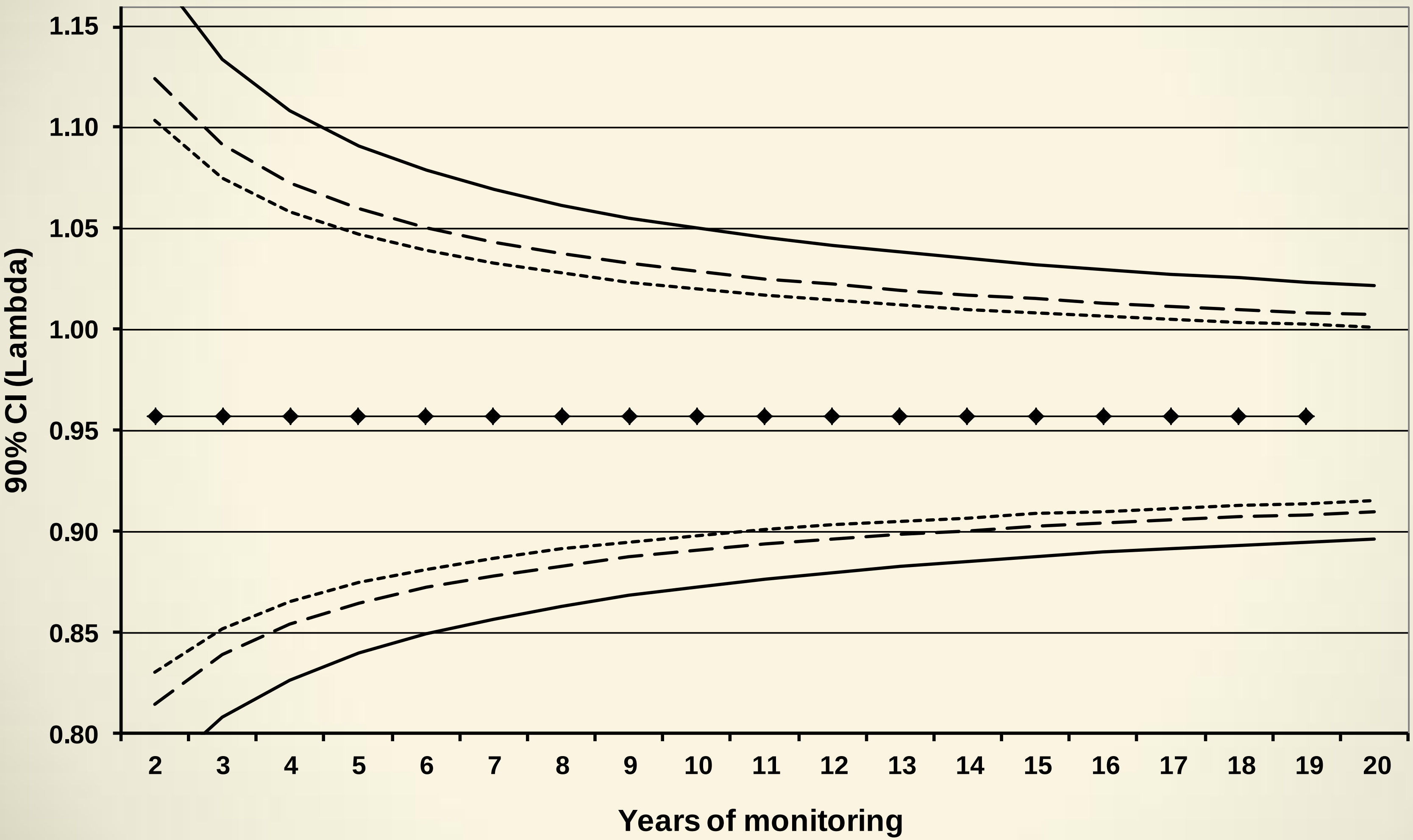
e 5. Patterns of precipitation, elevation, and soils produce predictable patterns of vegetation. Lower elevations feature g

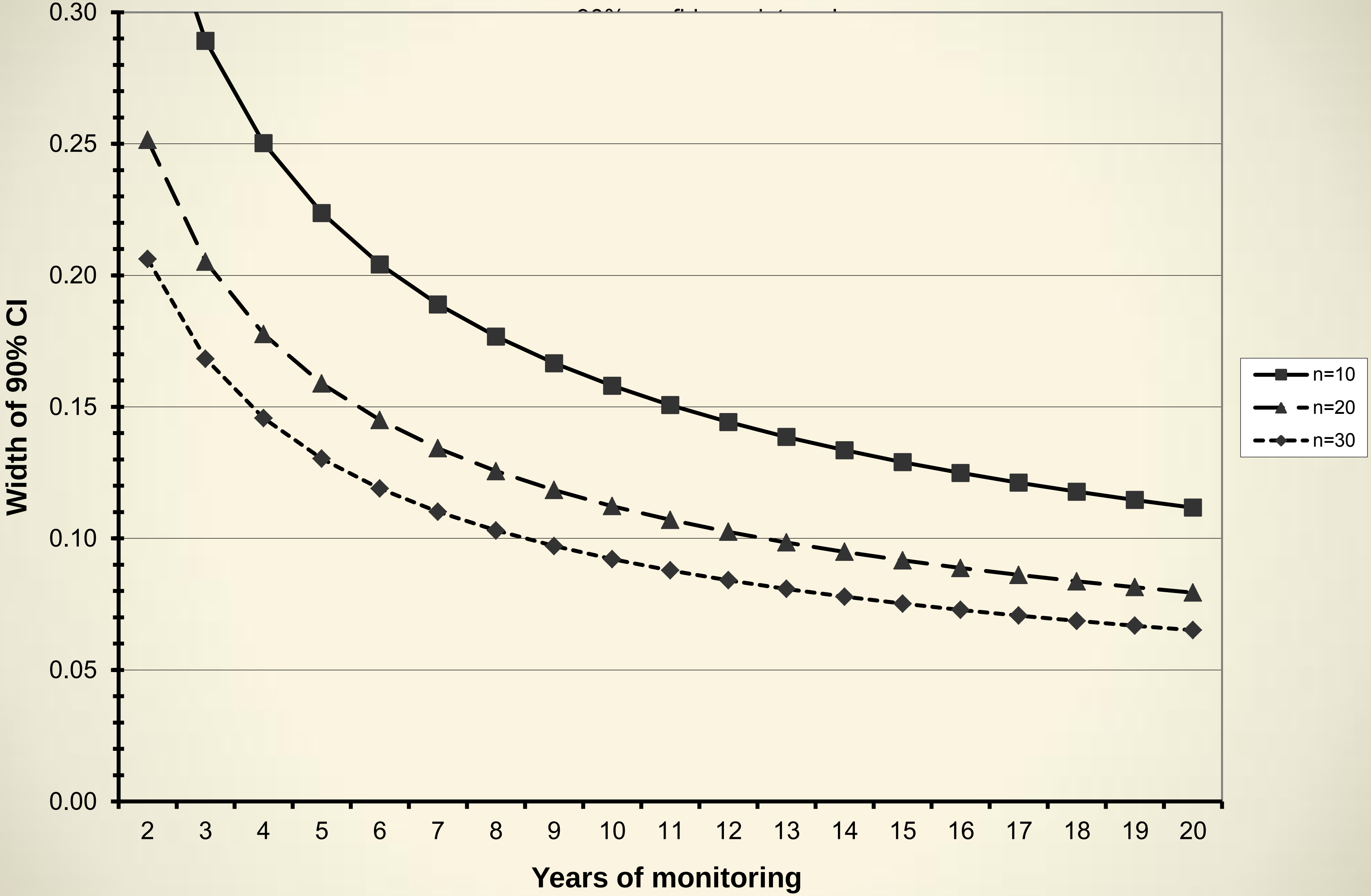
Lemons…



GYE
1.25
1.20
1.15
1.10
1.05
1.00
0.95
0.90
90% CI (lambda)
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
Years of monitoring
n=10
n=10
n=20
n=20
n=30
n=30
Point estimate

Hebblewhite black bears




Width of 90% CI
Years of monitoring
0.30
0.25
0.20
0.15
0.10
0.05
0.00
2
3
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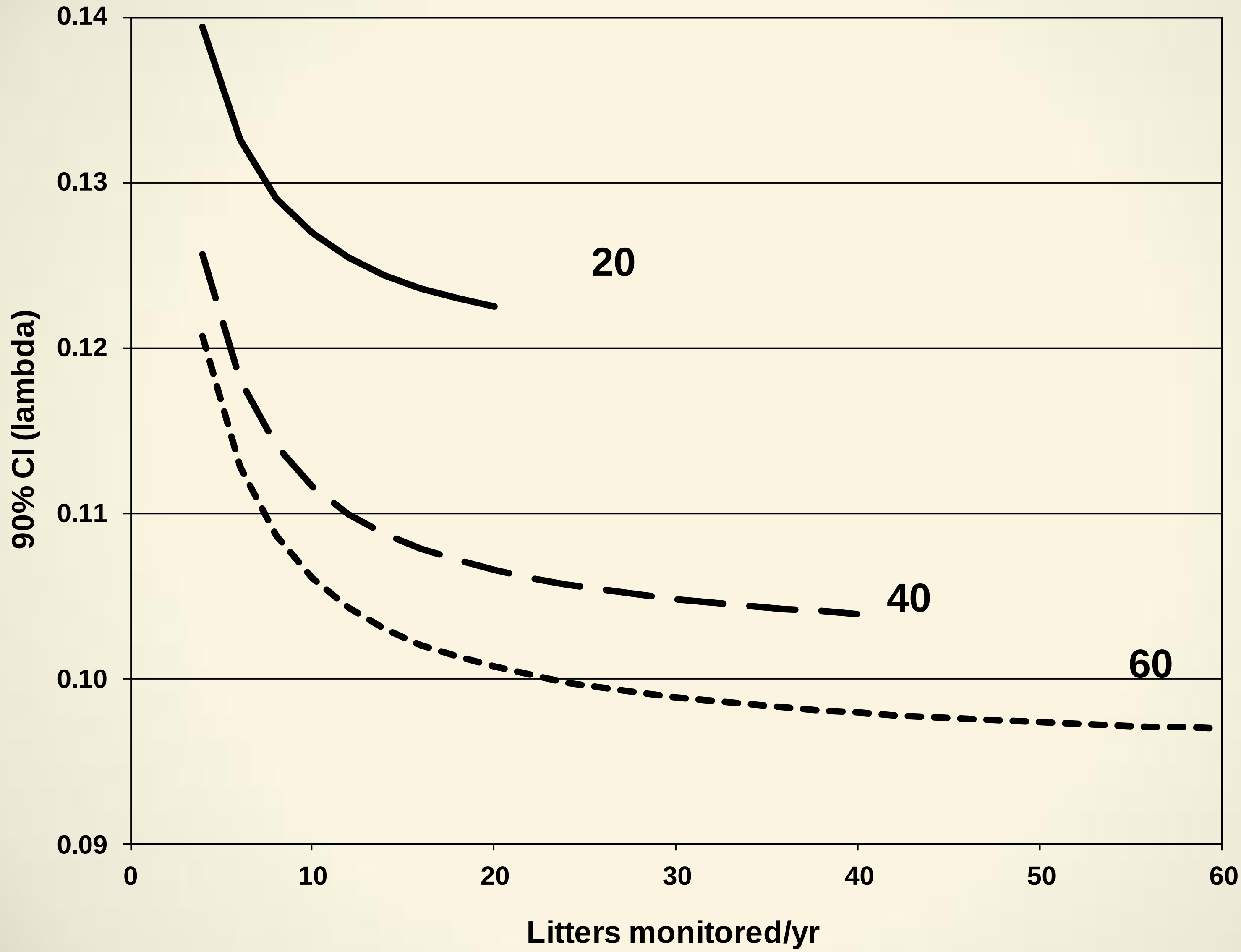
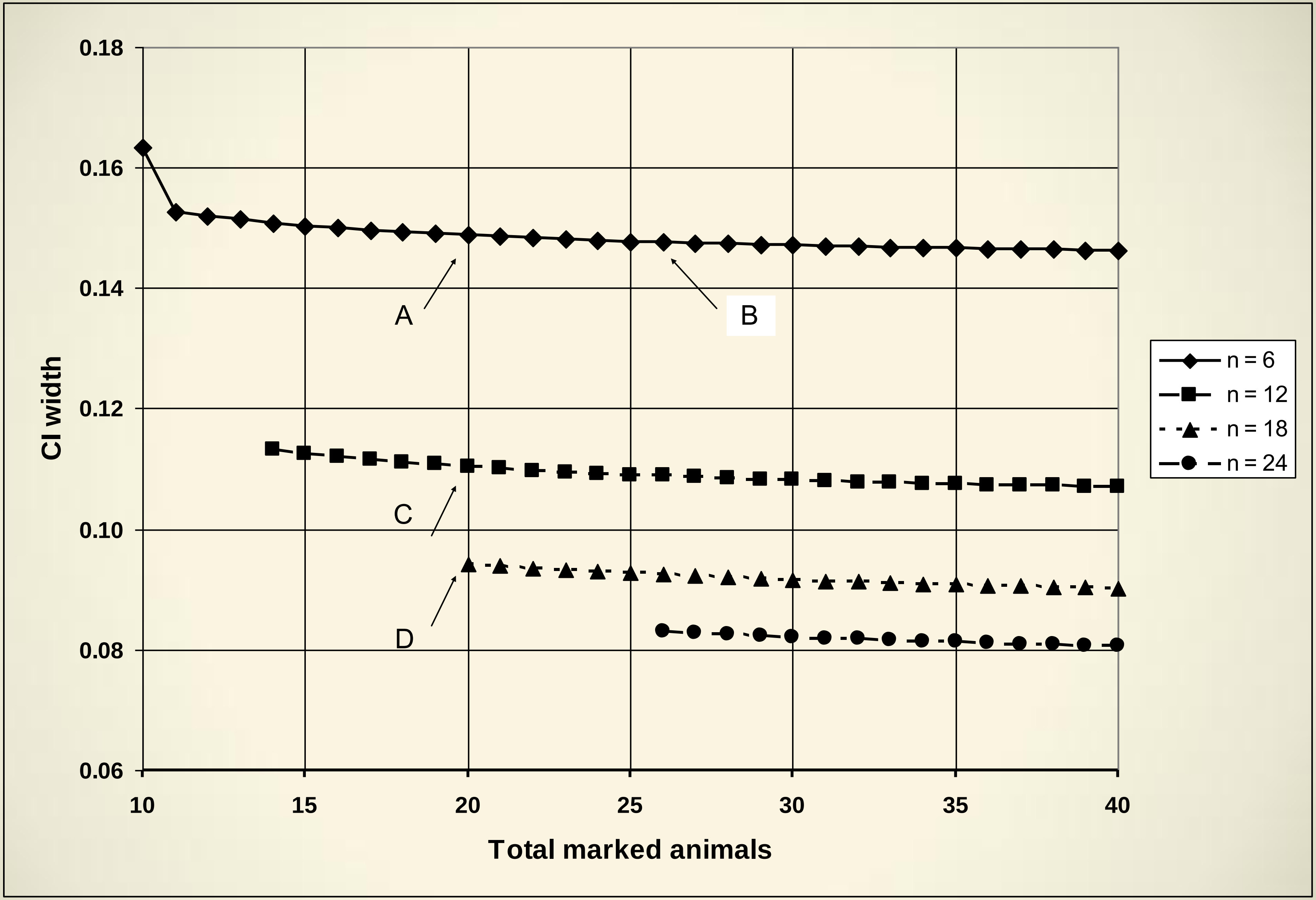
20
n=10
n=20
n=30

Lemonade…



0.14
0.13
0.12
0.11
0.10
0.09
90% CI (lambda)
0
10
20
30
40
50
60
Litters monitored/yr
20
40
60


0.18
0.16
0.14
0.12
0.10
0.08
0.06
CI width
10
15
20
25
30
35
40
Total marked animals
A
B
C
D
n = 6
n = 12
n = 18
n = 24

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