# The Effectiveness of Tetracycline as a Marker to Estimate Black Bear Numbers in Oregon

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**Abstract:** We tested the feasibility of using tetracycline-laced baits to mark black bears (*Ursus americanus*) in southwest Oregon, recapture marked bears through sport harvest and non-hunting mortality, and then estimate the population size using a modified Lincoln-Peterson model (Garshelis and Visser 1997). We deployed 2830 baits during (1999-2004) and marked 1081 bears. We detected 101 marks (86 teeth) from 1817 bear teeth voluntarily returned by hunters and taken on damage or road-killed. Annual population estimates ranged from 3286 to 10509 bears with a 6-year mean of 7229 bears. (Wildlife Technical Report 001-2008)

**Key words:** black bear, mark-recapture, Oregon, population size, tetracycline, tooth samples, *Ursus americanus*.

Obtaining accurate population estimates for black bear (*Ursus americanus*) is important when implementing adaptive management principles in harvest strategies. Most state and provincial black bear population estimates are based on known harvest rates or extrapolation from small mark-recapture studies (Garshelis and Hristienko 2006). Neither of these methods produce reliable estimates for large geographical areas. Tetracycline is an ingestible biomarker that can be easily deployed over large areas at relatively low costs. Tetracycline binds to serum calcium, which is then incorporated into developing bones and teeth. A detectable mark is specific to the annuli laid down in the year tetracycline was consumed. Although it is eventually remodeled out of bones, the mark remains permanent in teeth. Garshelis and Visser (1997) used tetracycline to mark black bears in Minnesota and Michigan and then recaptured the marks through mandatory check-in of harvested bears. Oregon had no mandatory reporting system for bear harvest during this study. Voluntary tooth returns were used to monitor population trends. We applied a similar technique (with voluntary check-in) to the entire southwest region of Oregon from 1999-2004.

# **STUDY AREA**

The 31,216 km<sup>2</sup> study area encompasses 3 physiographic regions; the Coast Range, the Klamath Mountains (Siskiyou Mountains Province), and the West Cascades (Fig. 1). The study area has 24,325 km<sup>2</sup> of land covered by forests (MRLC Regional Land Cover Characterization Project 1999) that are considered bear habitat by the Oregon Department of Fish and Wildlife (ODFW).

The northern and western portions of the study area are dominated by mesic temperate forests comprised mostly of conifers, whereas the warmer and drier southern interior

valleys are a mosaic of oak (*Quercus spp.*) woodlands, coniferous forests, grasslands, chaparral, and riparian forests (Franklin and Dyrness 1988). All of ODFW's Tioga, Melrose, Dixon, Sixes, Powers, Evans Creek, Rogue, Chetco and Applegate Wildlife Management Units (WMU) fall within the study area as well as the Douglas county portion of the Indigo WMU.

The Cascades crest provides a high degree of geographical closure on the northeast side (ODFW, unpublished data) of the study area and the Pacific Ocean provided total geographical closure on the west side. Although the northern and southern edges of the study area allowed bear immigration and emigration, logistics prevented us from estimating closure violations.



**Figure 1.** Physiographic regions (Franklin and Dyrness 1988) of the tetracycline marking study area in southwest Oregon 1999-2004.

## **METHODS**

#### **Bait Production and Deployment**

We constructed baits by rolling a slice of bacon around 500-mg gel capsules of tetracycline and placing 9 of these in a bolus of bacon totaling 0.45 kg. We then stuffed the bolus in a polymesh bag (Pacific Packaging and Shipping Supply, Salem, Oregon) and tied it shut with 20.51 cm rebar ties. At deployment sites, baits were dipped in a

calling lure comprised of a mixture of used commercial kitchen cooking grease and Liquid Smoke® (4 l cooking grease to 206 ml of Liquid Smoke).

Each year during mid-June we placed tetracycline-laced bacon baits systematically throughout the study area. In 1999, we placed baits at the intersection of grid lines 8.4 km apart superimposed on the study area. During 2000-2004, we used GPS units (Garmin, Olathe, Kansas) to place baits 4.86 km apart along rural roads. This distance was maintained to minimize multiple bait consumption. We nailed baits approximately 2.4 m high on tree trunks with smooth bark, 10-30 m from the edge of roads. We revisited baits 10-20 days after deployment to determine the number baits consumed by bears. We assumed that each bait consumed equaled a marked bear as long as corroborating evidence such as claw marks or bent nails were evident. Baits not consumed were collected and disposed of in bear-proof landfills.

#### **Tooth Collection**

ODFW did not have a mandatory reporting process for black bear harvest during the study. Hunters were given a tooth envelope at the time of tag purchase or mailed a tooth envelope with a letter asking them to voluntarily submit a premolar tooth if successful. Less than 30% of black bear hunters statewide had cooperated with this program for 3 years prior to the initiation of this study (Oregon Department of Fish and Wildlife 1999a). We attempted to increase cooperation in southwest Oregon by establishing a network of check-in stations (vendors) in 1999 to aid in the collection of teeth. We trained vendors in tooth extraction techniques and supplied them with the necessary equipment. We paid vendors \$5.00 for each bear they checked. We printed information about vendor locations, along with general information about the study, in the Oregon Big Game Synopsis every year of the study. We also mailed this information individually to hunters purchasing a bear tag. In addition, numerous press releases and articles in local newspapers described the study and requested hunter participation in the tooth return process.

#### **Mark Detection**

Bear teeth we collected were sent to Matson's Laboratory, LLC (Milltown, MT) for screening of tetracycline marks and age determination. Prior to the initial marking in 1999, we screened 150 bear teeth collected from southwest Oregon in 1998 for "background noise" (bears marked by consuming livestock or bees treated with tetracycline). We did not include marked teeth from bears that were captured for research until they were harvested. If harvested bears were marked in more than 1 year, we included the mark as a recapture for each year they had been marked.

We estimated cooperation with tooth submission in our study area by dividing the total number of hunter-submitted bear teeth by the bear harvest estimated through phone surveys (ODFW 1999b, 2000, 2001, 2002, 2004). We demonstrated relative density of bears in 1999 by using the Universal Transverse Mercator (UTM) coordinates of locations where bears were marked as points in a fixed kernel home range utilization distribution (Worton 1989). An ad hoc smoothing parameter was incorporated in the Animal Movement Extension program (Hooge and Eichenlaub 1997) within ArcView (Version 3.2 with Spatial Analyst, ESRI, Redlands, California). Harvested bears that were not available for marking (because of age) in the year estimates were produced were

removed from that year's population estimate. Population estimates did not include cubs-of-the-year because they were not likely to ingest baits (Garshelis and Visser 1997). We calculated population estimates using the Lincoln-Petersen estimator modified by Chapman (Chapman 1951) and 95% confidence intervals for the estimate by multiplying the standard error by 2 (Bailey 1951). Population estimates and cooperation rates were estimated from June 16 to June 15 of the following year. All other analyses were based on the calendar year.

To determine if bears were ingesting more than 1 bait during a marking session we utilized data from another project that was ongoing in the study area (Immell and Anthony 2008). In that study we were able to determine the maximum distance moved by an individual bear during the 3-week baiting session we utilized for the tetracycline marking project.

## RESULTS

#### **Bait Production and Deployment**

The percentage of baits consumed by bears varied between years. Bears consumed 16 % of baits deployed in 1999. When we reduced bait spacing to 4.8 km, bears consumed an average of 35% of the baits for the last 5 years of the study (Table 1). Claw marks on bait trees consistently produced the best confirmation that a bear had consumed the bait.

**Table 1.** Number of tetracycline-laced baits deployed, number of bears marked, percent marking success, number of marks returned and cumulative tooth returns in the southwest Oregon study area 1999-2004.

Year	# baits deployed	# Bears marked	% marking success	# marks returned	Cumulative tooth returns	
1999	410	67	16	20	1303	
2000	342	109	32	29	1054	
2001	658	207	31	22	924	
2002	660	256	39	15	763	
2003	629	232	37	13	519	
2004	531	210	39	3	272	

Density of bears marked with tetracycline was not uniform across the study area (Fig. 2). The ecotone created along the southern borders of the Klamath Mountain and Coast Range physiographic regions had the highest density of marked bears followed by the areas north and east of Coos Bay in the Coast Range physiographic region. Areas west and south of Medford in the Klamath Mountains physiographic region had similar densities as areas near Coos Bay. The Western Cascades physiographic region had the lowest density of marked bears.

#### **Tooth Collection**

Twenty-three vendors assisted in collecting bear teeth. The estimated cooperation rate for tooth returns was 63%, 53%, 44% and 38% for 1999-2002 respectively (Table 2). No surveys were completed in 2004 to estimate 2003 compliance. Surveys completed in 2005 indicated compliance dropped even further in 2004 to 32%.



**Figure 2.** Isopleths indicating relative densities of marked bears throughout southwest Oregon in 1999. Dark shading indicates highest densities and light shading indicates lowest densities.

#### **Mark Detection**

We detected 125 marks in 107 teeth examined from fall 1999 to spring 2005. Nine marks from the teeth of 8 research bears that were still alive at the end of this study were censored from the analysis. Although we detected no tetracycline marks in the 150 teeth we screened prior to study initiation, after screening more teeth we discovered and censored 14 marks that were laid down in cementum prior to the initiation of this study in 1999 (background marks). The total number of marks used for population estimates was 101 (Table 3).

Because relatively few bears had background marks, it's probable that screening 150 teeth was insufficient for detecting background noise. However, we used the known number of background marks we later detected to develop a correction factor for

	Number of teeth						
	Reported harvest		Estimated harvest	Return rate (cooperation)	Damage and other		
Year <sup>a</sup>	Fall	Spring	Total				
1999/2000	222	34	256	404	63%	164	
2000/2001	148	31	179	335	53%	131	
2001/2002	135	23	158	357	44%	106	
2002/2003	164	24	188	499	38%	118	
2003/2004	104	23	127	N/A <sup>b</sup>	N/A <sup>b</sup>	105	
2004/2005	107	59	166	182 <sup>c</sup>	32% <sup>c</sup>	124	

**Table 2.** Reported harvest, estimated harvest based on phone surveys, bear tooth return rates and number of teeth submitted from bears taken on damage in the southwest Oregon study area 1999-2005.

<sup>a</sup>Harvest and damage years run from June 16 to June 15.

<sup>b</sup>Bear harvest surveys were not completed in this year.

<sup>c</sup>Spring harvest only.

recaptured marks. The correction factor was calculated by dividing the number of marks made prior to project initiation (n = 14) by the total number of marks detected (n = 125) prior to censoring 23. Thus, the total number of marks detected in each year was reduced by 11% to account for background marks.

Bears killed on damage permits accounted for 37% of the recaptured marks. Bears harvested during spring and fall hunting seasons accounted for 55% of the marks and the remaining 8% (censored) of the marks came from bears captured for research.

Sixteen returned marks were females and 70 were male. Twelve of these bears were marked in multiple years. The mean age of bears at marking was 4.35 years (SE = .28, n = 94). Two females appeared to have been marked as cubs, however Harshyne et al. (1998) reported a 8.1% error rate in cementum analysis in Pennsylvania so the age of these 2 bears could have been incorrect. It's also possible that they could have been marked as cubs through ingestion of tetracycline-treated livestock or domestic bees.

Because marks in teeth of bears consuming multiple baits in the same year cannot be reliably distinguished during lab analysis (Garshelis and Visser 1997), we developed a correction factor for multiple marking. Using bear movement data (Immell and Anthony 2008) we determined that the mean maximum distance moved during bait deployment periods was 5.7 km for males and 2.7 km for females. The pooled mean maximum distance moved for both sexes was 4.7 km. In that study, 27% of bears (40% of males, 10% of females) moved greater than 4.8 km during a single hair snare baiting session. Therefore, we reduced the estimated number of tetracycline marked bears by 27% in all years except the first year (Table 3).

#### **Population Estimation**

The mean population estimate for all 6 years was 7229 bears. Although the estimates we obtained indicated an increasing population, some fluctuations occurred (Fig. 3).

Population estimates increased from 1999-2002 and then decreased in 2003. The 2004 estimate, although preliminary, was the highest estimate within the 6 years. However,

**Table 3.** Number of bears marked, double marking adjustment, number of marks returned, adjusted number of marks, population estimates and 95% confidence intervals (CI) for bears in southwest Oregon 1999-2004.

Year	# of bears marked	Double marking adjustment	# marks returned	Adjusted # marks	Population estimate	95% CI
1999	67	67 <sup>a</sup>	20	17	4926	± 2474
2000	109	80	29	25	3286	±1332
2001	207	151	22	19	7030	±3334
2002	256	187	14	13	10259	±6034
2003	232	169	13	11	7366	±4756
2004	210	153	3	3	10509	$\pm 15928$

<sup>a</sup>No adjustment was made because baits were spaced further apart than the mean distance moved by bears in a concurrent study (Immell and Anthony 2008).

there is generally a 2-year lag between marking and receiving lab results, thus the 2004 estimate was based on few tooth returns.

Using hair snares, Immell and Anthony (2008) estimated bear density at 20.5 bears/100  $\text{km}^2$  in the Western Cascades physiographic region. This area is believed to have the lowest bear densities within the tetracycline study area. Applying that density estimate across the 24,325  $\text{km}^2$  of forested habitat within our study area we estimated 4986 bears within the study area. This estimate is similar to the 1999 tetracycline-based estimate (Table 3).

# DISCUSSION

Our black bear population estimates showed annual variation. The doubling of the population point estimate between 1999 and 2002 was not biologically possible. Negatively-biased estimates are produced if the number of marked bears found in tooth returns is diluted through background marking. Conversely, inflated population estimates are produced when the number of bears initially marked is over-estimated. This can occur in 2 ways: if baits are consumed by non-target species but reported as consumed by bears, or if a single bear takes multiple baits and each bait taken is reported as a unique mark. In the pilot year of the study, biologists with bear experience were used for bait deployment and determination of species marked. In addition baits were spaced such that the number of bears taking more than 1 bait was minimized. In subsequent years, however, the increased number of baits deployed required more personnel hours than biologists could provide. Therefore, volunteers with little or no experience with bears were used and these personnel may have incorrectly reported the species consuming baits.



**Figure 3.** Bear population estimates with corresponding upper and lower 95% confidence intervals for bears in the southwest Oregon study area 1999-2004.

Lab results indicated only 2 bears had consumed more than 1 bait during a single marking session. Garshelis and Visser (1997) noted that multiple marking events were not reliably detected in bear teeth, and hair snare results (Immell and Anthony 2008) indicated 27% of bears consumed multiple baits spaced more than 4.8 kms apart. A more appropriate spacing between baits may be obtained by taking the average maximum distance bears moved (Immell and Anthony 2008) and adding a buffer of ½ that distance. For future black bear population estimates in Oregon using tetracycline baits we recommend that adjacent baits be separated by 7 km.

Our data indicated declines in the percent of successful hunters checking bear teeth between 1999-2004, with a high of 63% cooperation in 1999 to a low of 32% in 2004. Although the ratio of marked to unmarked bears in the sample of teeth returned from those hunters should remain consistent, the decline in the percent of cooperating hunters has 2 effects on population estimates. A lower percent of cooperating hunters can cause a negative bias in population estimates. Although the bias may be relatively small, it may become compounded by the fact that the Lincoln-Peterson estimator may already underestimate populations (Garshelis and Visser 1997). Also, low cooperation in tooth returns (smaller sample size) increase confidence intervals associated with the population estimates. Attempts to increase voluntary hunter cooperation for returning bear teeth were initially successful, but waned after the first year of the project. We observed similar results when a mandatory reporting system was instituted during a bear research project in the Cascades of western Oregon (ODFW, unpublished data). Vendor check stations are a viable option, however the vast majority of teeth collected by vendors were from taxidermists, where bears were probably "checked-in" for reasons other than reporting a harvest. This probably biased tooth returns we received towards adult males and under-sampled females. Although it is unknown what effect this may have on population estimates since the gender of bears were not determined at the time of marking, it may lead to complacency when examining the sex ratio of the harvest.

# MANAGEMENT IMPLICATIONS

Mandatory check-in of harvested black bears is vital for accurate population estimates and is the only feasible method to obtain a sufficient sample of teeth. In addition, care must be taken when marking bears to insure bait consumption is accurately attributed to bears. If volunteers are used to collect bait consumption data, they should be adequately trained prior to bait deployment. Lastly, spacing of baits should maximize the number of bears marked while minimizing double-marking.

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