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## An evaluation of a weaning index for wild fishers (*Pekania [Martes] pennanti*) in California

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Conservation concern for fishers (*Pekania [Martes] pennanti*) in the Pacific states has highlighted a need to develop cost-effective methods of monitoring reproduction in extant and reintroduced fisher populations. We evaluated the efficacy of nipple size as a predictive index of weaning success for females with known reproductive histories from 3 study areas in California. We captured and radiocollared 91 female fishers on 146 occasions between 2004 and 2011 and measured the width and height of all 4 nipples and quantified reproductive status via radiotelemetry. We classified each radiomarked female into 1 of 3 reproductive classes (nonbreeders, attempted breeders, and current breeders) based on our telemetry observations during the den season prior to capture. We used a modified random forests (RF) procedure to account for repeated measures of individual females sampled in multiple years. Our modified RF procedure correctly classified reproductive class for 130 (89%) and 131 (90%) of our 146 observations using raw and weighted vote totals, respectively. We calculated Cohen's kappa of 0.80 and 0.81 using raw and weighted vote totals, respectively, indicating strong model performance. We conclude that nipple sizes of female fishers measured during a livetrapping effort can be used as a cost-effective index of the weaning rates of adult female fishers.

Key words: fisher, nipple size, *Pekania [Martes] pennanti*, reproduction, teat size, weaning index

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Understanding the proximal influence of habitat, management, and environmental characteristics on reproductive success is critical to linking them to their ultimate effects on population dynamics. The value of this type of data has been demonstrated in the conservation of northern spotted owls (*Strix occidentalis caurina*) in the timber-managed landscapes of the Pacific Northwest (Anthony et al. 2006; Forsman et al. 2011). Fishers (*Pekania [Martes] pennanti*) have been the focus of recent conservation concern in the Pacific states because of range contractions, their association with mature forests, and assumed sensitivity to anthropogenic habitat alteration, particularly extensive logging (Powell and Zielinski 1994; Carroll et al. 1999). The United States Fish and Wildlife

Service concluded in 2004 that listing the West Coast distinct population segment of the fisher under the United States Federal Endangered Species Act was warranted but precluded by higher priority listing actions (United States Department of the Interior Fish and Wildlife Service 2004).

Estimates of fisher vital rates, including reproduction, have been very difficult and costly to obtain (Douglas and Strickland 1987) and may vary widely based on habitat composition and prey availability (Lofroth et al. 2010). Cost- and labor-



intensive radiotelemetry efforts have provided some information on fisher reproductive rates for some landscapes (Arthur and Krohn 1991; Paragi et al. 1994b; York 1996; Aubry and Raley 2006; Weir and Corbould 2008; Matthews et al. 2013). However, radiotelemetry approaches are cost prohibitive for most managers, particularly in the context of long-term population monitoring across large ownerships.

An alternative to direct observation via radiotelemetry is the use of nipple size as an index of reproduction (Paragi 1990; Mech et al. 1993; Brooks and McRoberts 1997; Frost et al. 1999; Dugdale et al. 2011). Female fishers lactate until their kits are weaned at about 10 weeks of age (Powell 1993). However, for welfare reasons, fishers are not captured during the whelping and rearing period. When capturing is resumed after weaning, lactogenesis has ceased. Thus expression of milk and teat palpation is not a pertinent diagnostic. However, teat size also could act as an indicator of reproduction.

Frost et al. (1999) described a generalized pattern of nipple enlargement using measurements taken twice monthly on captive female fishers. Nipple size ( $\text{mm}^2$ ; nipple width times height) for current breeders (fishers that gave birth and weaned at least 1 kit during the current 12-month period) began to increase in February and March, reaching a maximum size (approximately  $70 \text{ mm}^2$ ) in August and September. Nipple size then decreased through November and remained  $< 35 \text{ mm}^2$  until February. Nipple size of former breeders (fishers that weaned at least 1 kit during the previous 12-month period but not in the current 12-month period) ranged between 10 and  $25 \text{ mm}^2$  until giving birth again. Nipple size of nonbreeders remained  $< 10 \text{ mm}^2$  throughout the year.

Paragi (1990) concluded that nipple sizes of current-year breeders and nonbreeders were sufficiently distinct to assign reproductive status to unknown individuals in south-central Maine. However, Paragi's (1990) conclusion was based on a mixture of livetrapped individuals and pelt measurements and small sample sizes (nulliparous  $n = 26$ , nonparous  $n = 1$ , parous  $n = 7$ ), and the parous females were captured at 2 distinctly different times in the female reproductive cycle (4 captured in May and 3 between August and December). Frost et al. (1999) found nipple size to be a reliable index for captive and wild fishers in Maine and Massachusetts to distinguish current-year breeders from nonbreeders, but found former breeders may be misclassified as current breeders.

We evaluated nipple size as an index of weaning success for a sample of wild fishers livetrapped in California. We used weaning success, defined as whether a female successfully weaned at least 1 kit, rather than simply gave birth (Paragi 1990). We believe the use of weaning success is more appropriate because it accounts for failure rates of whelping and rearing episodes. Frost and Krohn (1994) found that during a 3-year study, 10 (26%) of 38 kits born in captivity died within a week after birth. On the Hoopa Valley Indian Reservation, we determined that 18 (22%) of 80 whelping and rearing episodes by wild fishers failed prior to weaning (Matthews et al. 2013). The goal of our study was to determine the efficacy of nipple size as an index of weaning success for

wild female fishers from northwestern coastal California and the southern Sierra Nevada of California.

## MATERIALS AND METHODS

We used teat measurements and reproductive history data collected during 3 fisher studies in California. The Hoopa Fisher Project (hereafter, Hoopa) was carried out on the  $366\text{-km}^2$  Hoopa Valley Indian Reservation in northwestern California. The reservation is located within the Klamath Mountains of northwestern California, between 98 and 1,170 m in elevation. The Kings River Fisher Project (hereafter, KRFP) was located east of Shaver Lake in the High Sierra Ranger District of the Sierra National Forest, between 1,067 and 2,134 m in elevation. The Sierra Nevada Adaptive Management Project (hereafter, SNAMP) was located north and northeast of Oakhurst, California, in the Bass Lake District of the Sierra National Forest between 758 and 2,652 m in elevation.

We captured breeding-age and non-breeding-age female fishers from June through March of 2004 through 2011. We used Tomahawk live traps (model 207; Tomahawk Live Trap Company, Tomahawk, Wisconsin) baited with chicken legs and modified with a plywood cubby box (Wilbert 1992; Seglund 1995). Captured fishers were anesthetized with ketamine hydrochloride (40 mg/kg) and diazepam (0.25 mg/kg) and handled using standard protocols (Aubry and Raley 1996; Yaeger 2005). We measured width and height of all 4 nipples on captured fishers using digital calipers and 30-cm plastic rulers (Paragi 1990; Frost et al. 1999). Training of observers was conducted by a single individual across study areas in an attempt to standardize measurements between observers. Along with these 8 direct nipple measurements, we derived 16 additional nipple variables that were evaluated as potential predictors of weaning success (Table 1). Nipple sizes ( $\text{mm}^2$ ) were measured as diameter at base multiplied by height to the nearest one-hundredth of a millimeter. Fishers were equipped with radiocollars (Holohil model MI-2; Holohil Systems Ltd., Carp, Ontario, Canada; or Telonics model MOD80; Telonics Inc., Mesa, Arizona) and tracked to determine weaning success. Following recovery from anesthesia, we released all fishers at their sites of capture. Capture and handling methods used at Hoopa, KRFP, and SNAMP followed guidelines of the American Society of Mammalogists (Sikes et al. 2011) and were approved by the Institutional Animal Care and Use Committees of Humboldt State University (protocol 04104.W.42.A; Hoopa) and University of California Berkeley (protocol R139; SNAMP).

Radiomarked female fishers were monitored 4–7 days per week during 6 (2005–2010) den seasons (March–June) to determine reproductive class. We used ground-based radiotelemetry techniques to estimate locations of female fishers and to chronicle denning behavior (Arthur and Krohn 1991; Paragi et al. 1994b; York 1996; Aubry and Raley 2006). Denning behavior was characterized by a sudden change in behavior from using numerous rest sites per week across the majority of the home range to more restricted movements in a small

**TABLE 1.**—Variables used in a modified random forests machine-learning modeling approach to develop a predictive index of weaning for wild fishers (*Pekania [Martes] pennanti*) in California.

Variable
Directly measured variables
Right anterior height
Right anterior diameter
Left anterior height
Left anterior diameter
Right posterior height
Right posterior diameter
Left posterior height
Left posterior diameter
Calculated variables
Average anterior height
Average anterior diameter
Average anterior diameter × height
Maximum anterior diameter × height
Average posterior height
Average posterior diameter
Average posterior diameter × height
Maximum posterior diameter × height
Right anterior height – right posterior height
Right anterior diameter – right posterior diameter
Left anterior height – left posterior height
Left anterior diameter – left posterior diameter
Average anterior height – average posterior height
Average anterior diameter – average posterior diameter
(Average anterior diameter × height) – (average posterior diameter × height)
(Maximum anterior diameter × height) – (maximum posterior diameter × height)

portion of the home range and repeated use of the same structure while inactive (Aubry and Raley 2006). We assumed that a female weaned at least 1 kit if she exhibited denning behavior for at least 10 weeks (Powell 1993).

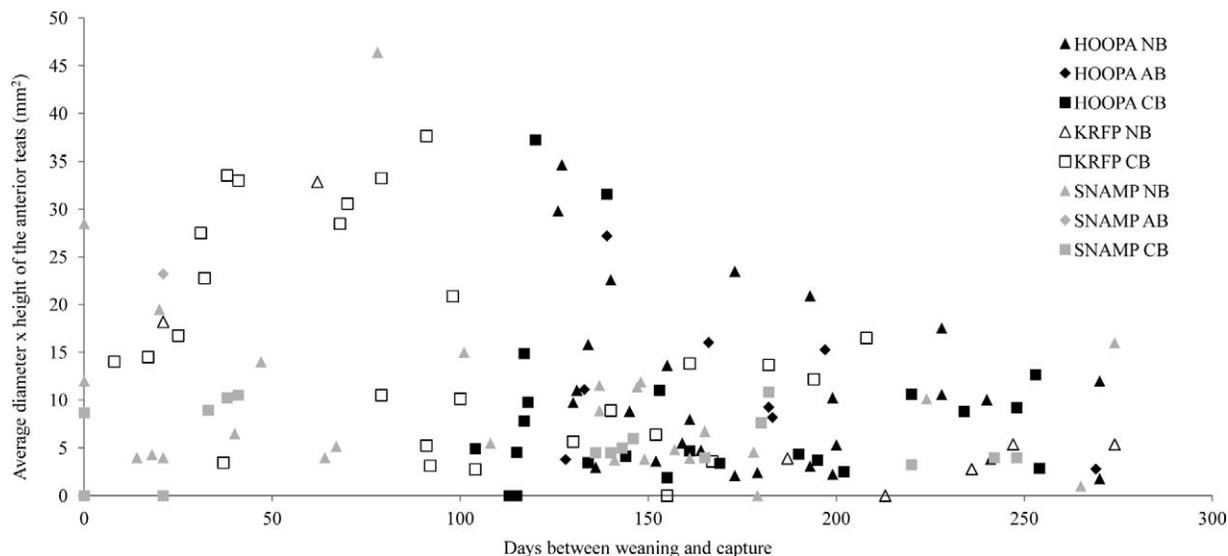
We classified each radiomarked female into 1 of 3 reproductive classes based on our telemetry observations during the den season prior to capture. Classes were nonbreeder: females that did not exhibit denning behavior; attempted breeder: females that exhibited denning behavior but failed to exhibit behavior until weaning; and current breeder: females that exhibited denning behavior until weaning. Nulliparous females (including females not old enough to have bred and adult females that had not previously given birth) and females that bred at least once previously but not in the current season were classified as nonbreeders. Although separation of these states into separate classes has important implications, such differentiation was not possible because estimates of fisher ages and complete reproductive histories were unavailable for our samples. We calculated the number of days between weaning and capture date to account for reductions in nipple size postweaning (Frost et al. 1999). We calculated a weaning date for each study area by adding 10 weeks to the average parturition date for each area (Powell 1993).

We used a machine-learning approach based on random forests (RF—Breiman 2001) to generate a predictive model of

female fisher reproductive class using measurements of nipple size. Random forests is a model-averaging technique based on classification and regression trees. RF builds a large set of trees (the “forest”) from subsets of both the observations and the explanatory variables. Individual trees are built by recursive partitioning of the training data such that the groupings of observations within each partition (or node) become more and more homogenous (Breiman et al. 1984). At each node, the algorithm searches through the variables 1 by 1, and finds the value of each variable yielding the most homogenous groupings of training observations, referred to as the best split. Then it compares the best single-variable splits and selects the best of the best to partition the observations into 2 child nodes. The algorithm recursively partitions each node until each child node is homogenous and assigned to a class. To classify an observation from a test data set, a classification or “vote” is made by each of the trees in the forest for the observation based on the measured explanatory variables. The forest then sums the number of votes across the classes (nonbreeder, attempted breeder, and current breeder) for each observation. The forest then chooses the class for each observation with the most votes. For example, if 7 trees in a 10-tree forest classified an observation based on the measured explanatory variables into class X, 2 trees into class Y, and 1 tree into class Z, the forest would classify the observation into class X.

We modified the RF procedure to account for repeated measures of individual females sampled multiple years. We used a generalized linear model to account for the apparent relationship between reductions in nipple size and the number of days between weaning and capture (Fig. 1). The goal of the generalized linear model was to estimate a regression model that could be applied to control for changes in nipple length over time. We used a bootstrap sampling procedure (or “bagging”) to generate training and test data sets and a random subset of 12 of the 24 variables for the construction and error assessment for each of 1,000 trees. Each training data set included all the observations of females measured only once and a randomly selected observation of each female measured in multiple years. In addition, each test data set included a randomly selected observation of each female measured in multiple years that was not included in the training data set.

We calculated correct classification rates for each of our 1,000 trees using its training and test data sets. We classified all observations using the 1,000 raw vote totals and weighted vote totals based on a chance-corrected measure of prediction (Cohen’s kappa statistic [ $\kappa$ ]) because of dissimilar group sizes (Cohen 1960). Cohen’s kappa provides a metric for how well our predictions match our original observations. A kappa statistic of 1 indicates perfect agreement and 0 suggests performance no better than random. A kappa statistic that was much lower than the correct classification rate suggested that the correct classification rate, and hence group predictability, was inflated and that much of the classification power was due simply to chance. Kappa values exceeding 0.4 are generally associated with strong model performance (Landis and Koch



**FIG. 1.**—Female fisher (*Pekania [Martes] pennanti*) nipple size (mm<sup>2</sup>, measured as average of diameter at base multiplied by height of anterior nipples) and days elapsed between weaning and capture of 3 reproductive classes on 3 study areas in California between 2005 and 2011. Reproductive classes were nonbreeder (NB): females that did not exhibit denning behavior during the previous den season; attempted breeder (AB): females that exhibited denning behavior but failed to exhibit behavior until weaning during the previous den season; and current breeder (CB): females that exhibited denning behavior until weaning during the previous den season. The study areas were the Hoopa Valley Indian Reservation (Hoopa) and southern (Kings River Fisher Project [KRFP]) and northern (Sierra Nevada Adaptive Management Project [SNAMP]) portions of the Sierra National Forest.

1977). We tallied the number of correctly predicted and incorrectly predicted observations in each class based on raw and chance-corrected votes in confusion matrices. We also calculated model and chance-corrected correct classification rates of all observations from all classes.

Accurate predictions of the proportion of females in each reproductive class annually is often more important to managers than the accurate assignment of a single individual to a reproductive class. We calculated the observed and predicted proportions of females that were current breeders annually for each study area. The proportion of current breeders could be used by managers as a component of a long-term population-monitoring program, particularly to evaluate the impacts of anthropogenic, landscape-level change.

All statistical analyses were conducted using software packages *vegan* (Oksanen et al. 2012), *rpart* (Therneau et al. 2011), and *randomForest* (Liaw and Wiener 2002), in addition to custom functions (K. McGarigal, B. Compton, and J. Finn, University of Massachusetts, Amherst, pers. comm.) in program R version 2.14.1 (R Development Core Team 2012). We provided a comma-separated-values-formatted data file (Supporting Information S1, DOI: 10.1644/12-MAMM-A-249.S1), our complete R script (Supporting Information S2, DOI: 10.1644/12-MAMM-A-249.S2), an R object containing our 1,000 classification and regression tree results (Supporting Information S3, DOI: 10.1644/12-MAMM-A-249.S3; recognizing the R code will generate a different, but similar, object containing 1,000 classification and regression trees each time the script is run), and 4 custom R functions (Supporting Information S4–S7, DOI: 10.1644/

12-MAMM-A-249.S4 through 10.1644/12-MAMM-A-249.S7). Thus, biologists interested in using our approach for their own data can download the supplements, enter their data, and predict the breeding status of their individuals.

## RESULTS

Reproductive history and nipple measurements during the subsequent livetrapping effort were collected from 91 individual female fishers on 146 occasions across the 3 study areas between 2004 and 2011 (Table 2; Fig. 1). We measured the nipples of 46 current breeder individuals on 69 occasions, 8 attempted breeder individuals on 10 occasions, and 53 nonbreeder individuals on 67 occasions (Table 2). We detected a similar general relationship between nipple size and days postweaning for breeders and nonbreeders as found by Frost et al. (1999; Fig. 1). The generalized linear model describing the apparent relationship between nipple size and days between weaning and capture did not reduce the variance or improve RF performance, and thus was not considered further.

The RF procedures produced Cohen's kappa statistics indicating strong model performance for the training data sets and most of the test data sets. Our null and model mean percent correct classification rates for the training data sets in the 1,000 trees were 52% (range 47–57%) and 89% (range 82–96%), respectively. The training data sets yielded a mean Cohen's  $\kappa$  = 0.80 (range 0.66–0.92). The null and model mean percent correct classification rates for the test data sets classified by the 1,000 trees were 56% (range 45–74%) and 72% (range 50–92%), respectively. The classification power of test data sets

**TABLE 2.**—Counts of individual fishers (*Pekania [Martes] pennanti*) and occasions observed in each reproductive class across 3 study areas in California between 2004 and 2011. Reproductive classes were nonbreeder (NB): females that did not exhibit denning behavior during the previous den season; attempted breeder (AB): females that exhibited denning behavior but failed to exhibit behavior until weaning during the previous den season; and current breeder (CB): females that exhibited denning behavior until weaning during the previous den season. The study areas were the Hoopa Valley Indian Reservation (Hoopa) and southern (Kings River Fisher Project [KRFP]) and northern (Sierra Nevada Adaptive Management Project [SNAMP]) portions of the Sierra National Forest.

Class	Hoopa		KRFP		SNAMP		Totals	
	Individuals	Occasions	Individuals	Occasions	Individuals	Occasions	Individuals	Occasions
NB	22	28	7	8	23	31	52	67
AB	6	8	0	0	2	2	8	10
CB	13	24	20	28	13	17	46	69
Totals <sup>a</sup>	35	60	24	36	32	50	91	146

<sup>a</sup> Tallies of individuals for each class on a study area do not sum to the total individuals for each study area because some individuals were observed in different classes in different years.

ranged widely, with some kappa values very near the correct classification rate and others much lower ( $\bar{\kappa} = 0.51$ , range 0.12–0.86).

Our modified RF algorithm, adjusted to control for repeated measures of individual females, correctly classified reproductive class for 130 (89%) and 131 (90%) of our 146 observations using raw and weighted vote totals, with  $\kappa = 0.80$  and  $0.81$ , respectively (Table 3). Nonbreeders were most accurately classified, followed closely by current breeders. Attempted breeders were least accurately classified. The mean difference between our annual observed and predicted proportions on each study area using raw vote totals was 6.6% (range 0–33%; Fig. 2).

For illustrative purposes, we identified our classification tree with the highest percent correct classification rate from the forest of 1,000 trees based on weighted (Cohen’s kappa statistic) vote totals (Fig. 3). This tree correctly classified reproductive class for 127 (87%) of our 146 observations using weighted vote totals and  $\kappa = 0.77$  (Table 4). We caution against the use of this single tree for predictive purposes and recommend the use of the full RF model.

**TABLE 3.**—Confusion matrix from the modified random forests analysis using weighted vote totals (a chance-corrected measure of prediction using Cohen’s kappa) of the association of nipple size and reproductive class for 146 observations of 91 female fishers across 3 study areas in California between 2004 and 2011. Reproductive classes were nonbreeder (NB): females that did not exhibit denning behavior during the previous den season; attempted breeder (AB): females that exhibited denning behavior but failed to exhibit behavior until weaning during the previous den season; and current breeder (CB): females that exhibited denning behavior until weaning during the previous den season. Classification based on raw vote totals misclassified 1 additional nonbreeder as a current breeder. Otherwise, raw and weighted vote classifications were the same.

Observed	Predicted			Class correct classification rate
	NB	AB	CB	
NB	66	0	1	0.99
AB	4	2	4	0.20
CB	6	0	63	0.91

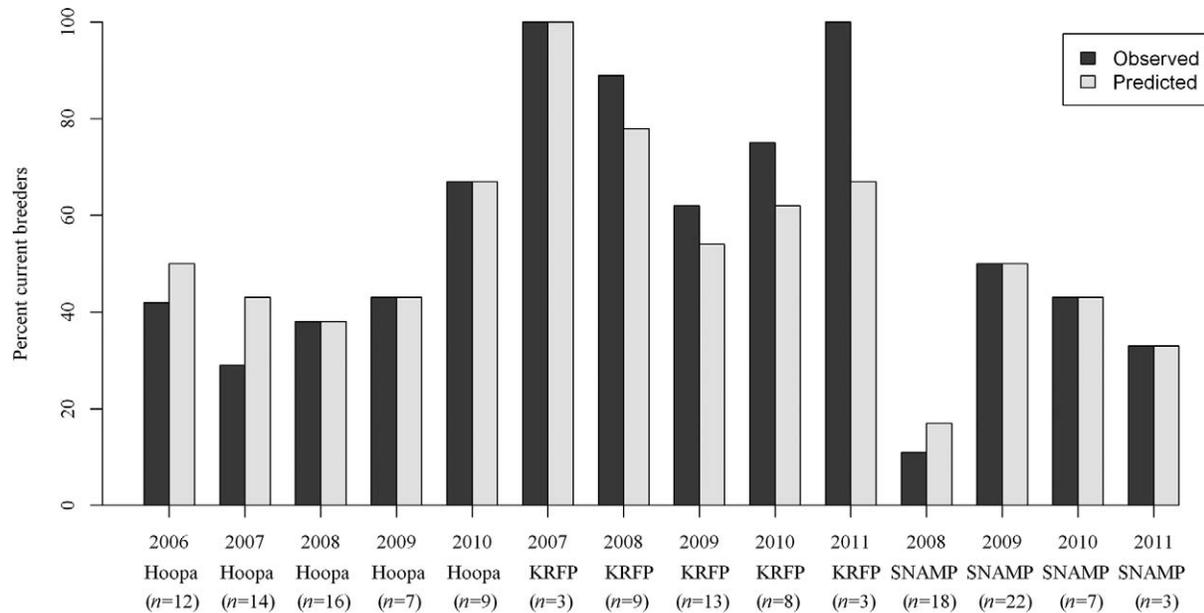
### DISCUSSION

Our results indicate that nipple sizes measured during a livetrapping season are useful in distinguishing reproductive status of wild female fishers. Our modified RF algorithm provides an empirical predictive model of reproductive status based on weaning rates. This index could be used as an element of a mark–recapture–based population-monitoring program to assess the impacts of forest management projects on reproduction, the success of fisher translocation projects, the persistence of existing fisher populations, and the habitat parameters related to fisher reproduction.

We acknowledge that this assessment was conducted with low group sample sizes, particularly for attempted breeders ( $n = 10$ ), and with repeated measures of some individuals. We recognize that a larger sample might help to increase correct classification rates and allow for alternate modeling frameworks, such as mixed effects modeling. However, challenges in classifying some individuals (e.g., distinguish females with late litter failures that go through nearly the same developmental time as successful females) would remain.

We suspect that potential errors in our observed classification of reproductive status may have influenced our classification rates and introduced sources of chance error that may have decreased the precision of our estimates. Our determination of reproductive class was based on behavior observed during the den season. In some cases, females may have exhibited what we interpreted to be denning behavior but were merely avoiding males in the relative safety of tree cavities during the mating season and never birthed kits. Thus at the close of the mating season, these females resumed normal behavior patterns, which we interpreted as a rearing failure and classified these as attempted breeders rather than nonbreeders.

In other cases, a female may have exhibited denning behavior early in the den season but failed to exhibit denning behavior until weaning, although she may have successfully weaned a kit(s). Hypothetically, females with smaller litters may choose to move the litter more frequently than those with larger litters, thus giving the impression the female failed during the rearing period and was using multiple rest sites rather than continuing to den. In these cases we would have



**FIG. 2.**—Annual observed (radiotelemetry observations) and predicted (random forests model of nipple measurements) percentages of female fishers that exhibited denning behavior until weaning during the den season prior to nipple measurements being taken on 3 study areas in California between 2005 and 2011. Study areas were the Hoopa Valley Indian Reservation (Hoopa), Kings River Fisher Project (KRFP), and the Sierra Nevada Adaptive Management Project (SNAMP). Sample sizes were all animals sampled in the given year on the given study area. The mean difference between our annual observed and predicted proportions on each study area was 6.6% (range 0–33%).

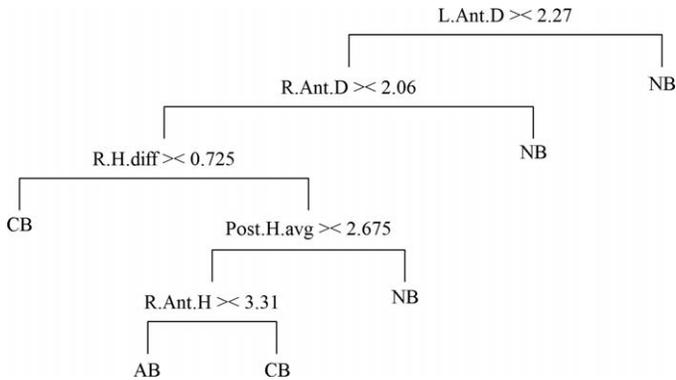
misclassified a current breeder as an attempted breeder. Also, we suspect that litter size and den site selection could play a role in misclassification of breeding females. Larger litters place more energetic demands on the female and thus the need to invest more time in securing prey away from the den as compared to a female with a smaller litter (Paragi et al. 1994a), potentially leading us to classify her as a female without kits. Additionally, larger litters might provide a thermoregulatory benefit in the kits keeping each other warm, rather than depending on the adult female to do so, enabling the adult female to spend more time away from the den securing prey. Den site selection might provide similar thermoregulatory benefits with respect to solar exposure and other microclimatic variables, allowing the female more time away from the den. Despite these potential shortcomings, examination of our data suggests that nipple size of female fishers can be used to accurately index the weaning rates of female fishers.

Litter size also might have influenced our correct classification rates by introducing a source of variation in nipple size within each reproductive class. An attempted breeder that failed late in the den season with a litter  $\geq 2$  might have larger nipples than a current breeder with a litter of 1. This variation could lead to an increase in the misclassification of attempted breeders with larger litters as current breeders and current breeders with smaller litters as attempted breeders.

The relatively high correct classification rate for nonbreeders was probably influenced by the group being composed mostly of younger females that we suspect were nulliparous. Twenty-eight (42%) of the 67 nonbreeder observations were of known nulliparous females (based on cementum annuli estimates and

known births from Hoopa). Thirty-six (54%) of the 67 observations were of suspected nulliparous females (based on morphology and dental wear–based estimates of age from KRFP and SNAMP). Three (4%) of the 67 observations were of 3 SNAMP adult females that were either nulliparous or nonparous (bred a previous season, but not during the season observed). A more complete assessment of this index would include a sample of nipple measurements of confirmed nonparous females. At our study areas, we did not have data on known nonparous females; once females attempted to den as an adult, they attempted to den each subsequent year. In our sample, 20 adult female fishers classified as breeders (current breeder or attempted breeder) were classified as breeders on 27 occasions during subsequent den seasons, and never as a nonbreeder.

Nipple size of female fishers measured during a livetrapping season can be used as an index of the weaning rates of adult female fishers. This index could prove useful for managers hoping to model fisher reproduction and the influence of habitat and other covariates on weaning success, particularly in timber-managed landscapes occupied by extant or reintroduced fisher populations. However, the high misclassification rate of attempted breeders, particularly attempted breeders predicted as current breeders, could introduce bias to an analysis with low sample sizes addressing habitat-mediated effects on successful and failed breeding attempts. As a conceptual example, a measure of habitat quality (e.g., abundance of a key prey population) differs where females raise kits to weaning versus where female breeding attempts fail. Misclassification of attempted breeders as current breeders results in prey



**FIG. 3.**—The classification tree with the highest percent correct classification rate from the forest of 1,000 trees based on weighted (a chance-corrected measure of prediction using Cohen’s kappa) vote totals of the association of nipple size and reproductive class for 146 observations of 91 female fishers across 3 study areas in California between 2004 and 2011. At each split an observation is classified to the right when the value for the observation is less than the split value. This tree correctly classified reproductive class for 127 (87%) of our 146 observations using weighted vote totals and  $\kappa = 0.77$ . Variables selected include the diameter of the left anterior nipple (L.Ant.D), the diameter of the right anterior nipple (R.Ant.D.), the difference in height between the right anterior and posterior nipples (R.H.diff), the average height of the posterior nipples (Post.H.avg), and the height of the right anterior nipple (R.Ant.H). Reproductive classes were nonbreeder (NB): females that did not exhibit denning behavior during the previous den season; attempted breeder (AB): females that exhibited denning behavior but failed to exhibit behavior until weaning during the previous den season; and current breeder (CB): females that exhibited denning behavior until weaning during the previous den season. This single tree is provided for illustrative purposes. We caution against the use of this single tree for predictive purposes and recommend the use of the full Random Forest model.

abundance values supporting failed breeding attempts being incorrectly assigned to the current breeder group. The problem of misclassification and the potential biases in parameter estimation are well documented for mark–recapture (Lebreton and Pradel 2002) and occupancy modeling (Nichols et al. 2007). Our model suffers from a similar problem, albeit with only one of the classes.

Despite this potential bias, this index provides less costly estimates of fisher reproduction compared to radiotelemetry-based approaches, with some cost of precision (90% of our 146 observations correctly classified). Use of the index does require a livetrapping program, which can be cost prohibitive for some managers. A potential cost-effective extension of the index would make use of data collected from remote cameras rather than livetrapping.

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**TABLE 4.**—Confusion matrix from the classification tree with the largest percent correct classification rate from the forest of 1,000 trees based on weighted (a chance-corrected measure of prediction using Cohen’s kappa) vote totals of the association of nipple size and reproductive class for 146 observations of 91 female fishers across 3 study areas in California between 2004 and 2011. Reproductive classes were nonbreeder (NB): females that did not exhibit denning behavior during the previous den season; attempted breeder (AB): females that exhibited denning behavior but failed to exhibit behavior until weaning during the previous den season; and current breeder (CB): females that exhibited denning behavior until weaning during the previous den season. Correct classification results from this single tree are provided for illustrative purposes. We caution against the use of this single tree for predictive purposes and recommend the use of the full random forests model.

Observed	Predicted			Class correct classification rate
	NB	AB	CB	
NB	63	0	4	0.94
AB	1	5	4	0.50
CB	5	5	59	0.86

M. W. Kotschwar, S. D. LaPoint, P. Lincoln, D. V. Masters, D. McCovey, K. T. Mellon, K. M. Moriarty, C. H. Myers, M. D. Palumbo, K. A. Penderson, A. J. Pole, R. V. Schlexer, S. H. Van Arb, S. M. Wadham, and G. M. Wengert. Funding support for the KRFP was provided by the United States Department of Agriculture Forest Service Region 5. The KRFP is particularly thankful for field assistance from J. Banazack, D. Drynan, G. Colligan, J. Garner, R. Green, N. Hebert, Z. Miller, B. Nichols, S. Rossler, T. Smith, and G. Watts. Funding support for the SNAMP fisher research was provided under a cooperative agreement with the United States Department of Agriculture Forest Service. More than 40 research technicians, volunteers, and pilots have provided invaluable assistance trapping, handling, and locating fishers during the study. The SNAMP research is particularly thankful for long-term support from R. Barrett, J. Litton, C. O’Brien, and A. Otto. We also thank *Journal of Mammalogy* reviewers R. D. Weir and K. M. Slauson as well as M. J. Jordan for their comments on this manuscript.

**SUPPORTING INFORMATION**

**SUPPORTING INFORMATION S1.**—Comma-separated-values–formatted data file, referred to as teats.csv in R script.

Found at DOI: 10.1644/12-MAMM-A-249.S1

**SUPPORTING INFORMATION S2.**—Complete R script.

Found at DOI: 10.1644/12-MAMM-A-249.S2

**SUPPORTING INFORMATION S3.**—R object containing our 1,000 classification and regression tree results.

Found at DOI: 10.1644/12-MAMM-A-249.S3

**SUPPORTING INFORMATION S4.**—Custom R function 1, referred to as biostats.R in R script.

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**SUPPORTING INFORMATION S5.**—Custom R function 2, referred to as cartwareJTF.R in R script.

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**SUPPORTING INFORMATION S6.**—Custom R function 3, referred to as Fisher\_cart\_Functions.r in R script.

Found at DOI: 10.1644/12-MAMM-A-249.S6

**SUPPORTING INFORMATION S7.**—Custom R function 4, referred to as gini.r in R script.

Found at DOI: 10.1644/12-MAMM-A-249.S7

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