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DYNAST: Simulating Wildlife Responses to Forest-Management Strategies

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Abstract.—A computer simulation approach (DYNAST) was used to evaluate effects of three timber-management alternatives on wildlife in a 2700-ha (6700-acre) study area located in the Sierra Nevada, California. Wildlife species selected to evaluate the effects of these alternatives were band-tailed pigeon (*Columba fasciata*), pileated woodpecker (*Dryocopus pileatus*), and mule deer (*Odocoileus hemionus*). Pileated woodpeckers responded most positively to the long-rotation alternative. Responses by band-tailed pigeons and mule deer indicated that either the mixed-rotation or optimal-timber alternative would be the most beneficial.

DYNAST was shown to be a useful tool for displaying the effects of various timber-management schemes. Program outputs were in a format that displayed trade-offs between timber and wildlife production. Because DYNAST simulations have not been tested for accuracy, the outputs should be used with caution. However, DYNAST is flexible, and forest dynamics can be simulated by this model.

The concept of multiple-use, "the balanced allocation of timber, water, range, recreation, wildlife, and other resources found on national forests" (Steen 1976:278), is the basis for integrating numerous resource concerns in National Forest management (Wengert et al. 1979). The DYNamically Analytic Silviculture Technique (DYNAST) (Boyce 1977, 1978; Biesterfeldt and Boyce 1978; Boyce and Cost 1978) was developed for comparing multiple-use resource productions under different management options. DYNAST simulates resource outputs associated with alternative land-management strategies (Boyce 1977). The model operates by combining resource models (e.g., wildlife, erosion, timber production) with models of natural succession for different land types (vegetation cover types, timber cover types, combinations of vegetation cover and slope types, and so on). Alternative timber prescriptions (rotation length for each land type, percent of each land type to be harvested, size of harvest units, and percent of land converted or reverted to another land type) are then developed and linked with DYNAST's successional model to simulate outputs on the areas to be manipulated. The DYNAST model operates through the use of the DYNAMO compiler, which is a FORTRAN source compiler or assembler language (Pugh 1980).

DYNAST outputs can be displayed in both tabular and graphic formats to show changes through time in the production of various benefits for each alternative. Outputs, especially the graphic ones, display trade-offs among the different alternatives. Decision makers then can view the DYNAST products for each alternative and select the option that achieves intended objectives for the land unit.

We selected DYNAST to display trade-offs among management alternatives developed specifically for the winter range of the Downieville (Sierra County) population of mule deer (*Odocoileus hemionus*) on the Tahoe National Forest. The most productive sites in this area are being converted to conifers by regeneration harvest methods that leave only remnant pockets of hardwoods for wildlife or other purposes.

Study area

The study area included 2700 ha (6700 acres) in eastern Yuba and western Sierra counties in the central Sierra Nevada of California. Elevations ranged from 600 to 1400 m (2000–4500 feet). The topography included steep canyons with mostly north- and south-facing slopes. The study area was dominated by mixed stands of conifers and hardwoods; however, small areas of pure hardwoods and conifers existed. Most of the stands were young, i.e., <80 years old. Principal trees were white fir (*Abies concolor*), Douglas-fir (*Pseudotsuga menziesii*), California black oak (*Quercus kelloggii*), and tanoak (*Lithocarpus densiflorus*) (Benson 1983). The study area included portions of the key winter range for the Downieville deer population.

Methods

Study-area characterization

Ten land types (combination of vegetation cover and slope types) and seven successional stages for each land type were defined for the study area, using information from the Tahoe National Forest land-management planning file and timber-type maps. Land types were (1) mixed-conifer on gentle

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slopes (<30%); (2) mixed-conifer on moderate slopes (30–50%); (3) mixed-conifer on steep slopes (>50%); (4) mixed-conifer–hardwood on gentle slopes; (5) mixed-conifer–hardwood on moderate slopes; (6) mixed-conifer–hardwood on steep slopes; (7) commercial hardwood on gentle or moderate slopes; (8) commercial hardwood on steep slopes; (9) noncommercial hardwood on gentle or moderate slopes; and (10) noncommercial hardwood on steep slopes. Habitat (successional) stages were seedling, sapling, small pole, medium pole, large pole, mature timber, and old-growth timber. Duration of successional stages varied by land type.

DYNAST simulation model

The DYNAST simulation model operates by moving the acreage of each successional stage within each forested land type through time. The simulation continuously moves all acreages through time, employing user-specified time intervals for successional stages (seven were established for each land type). Time intervals for successional stages vary, depending on the land type being simulated. When the acres of a land type reach the user-specified harvest age or completion of old-growth, they are "potentially" harvested or "die," and that number of acres is returned to the earliest successional stage. Meanwhile, all acres in the remaining younger successional stages are correspondingly "moved up" in age. In this way, the simulation model mimics natural vegetative succession.

The DYNAST simulation conducts potential harvesting in a study area which eventually brings the area to a steady-state or sustained-flow-of-timber condition. One of the ways it accomplishes this is to harvest the acreage of older timber at an accelerated rate, resulting in a peak of timber harvested before the sustained flow of timber is achieved.

DYNAST can operate using either English or metric units for the input and output values. English units were used for this study to facilitate prompt recognition and utilization of study results for resource agency personnel.

Management decisions that control the simulation sequence for DYNAST are rotation length for each land type, percentage of each land type to be harvested, and size range of harvest units. The size of harvest units stipulated for this simulation was expressed in terms of acres. Timber-stand-development information for the Tahoe Forest was used in DYNAST to simulate vegetation succession. Yield tables developed for the Tahoe National Forest Land Management Plan were used for mixed-conifer and mixed-conifer–hardwood land types and for maximum productivity or culmination of mean annual increment (with 10-year thinnings) of these timber types at 110 and 120 years, respectively.

Yield tables did not exist for hardwoods, so we developed them for tanoak and California black oak, using observations and measurements from regulated stands in the Challenge Experimental Forest, Challenge, California (P. McDonald, pers. comm.). Benson developed tables related to best growth, spacing, and hardwood thinning. The yield table for commercial hardwoods assumed that the hardwood land types were managed and the culmination of mean annual increment (with 10-year thinnings) occurred at 80 years of age.

Wildlife models

Initial development of wildlife models was accomplished by selecting those habitat variables that were (1) most critical to each wildlife species; and (2) could be linked to vegetation succession. Wildlife models to interface with DYNAST were constructed using information from the species-habitat matrices in Verner and Boss (1980). Coefficients inferred from the matrices rate the value of each successional stage for feeding, cover, and reproduction.

Models were developed for band-tailed pigeon (*Columba fasciata*), pileated woodpecker (*Dryocopus pileatus*), and mule deer. The values used indicated qualitative habitat suitability and ranged from 0 to 1. A value of 1 indicated that the simulated area had a combination of successional stages that provided the greatest habitat quality for that species; 0 represented the poorest combination of successional stages for that species. This qualitative range of values was used so that the effects on several wildlife species could be simultaneously displayed and compared on the same graph. Barrett and Salwasser (1982) described detailed approaches for building models to interface with DYNAST.

Alternatives

Three timber-management alternatives were developed to illustrate a range of management options for the study area. The number of acres in different successional stages within each land type varied considerably (e.g., from 0 to 1200 acres). All land types were assumed to be actively managed, and each land type was thinned every 10 years after the acreage for each successional stage reached or was grown up to 40 years of age. Brief descriptions of the timber alternatives are provided below (see Table 49.1 for more detailed information):

1. Long rotation. Potential harvest occurred within each land type whenever the acreage of the successional stages reached 200 years of age. All of the area within each land

Table 49.1. Timber-management alternatives for winter range of Downieville deer population

Alternative	Land type[a]	Rotation (years)	Opening size (acres)
Long rotation	C & HW/C	200	5 ± 1
	CHW	200	5 ± 1
	NHW	290[b]	1 ± 0.1
Mixed rotation (long/short)	C	120	25 ± 15
	HW/C	120/220[c]	25 ± 15
	CHW	200	15 ± 5
	NHW	290[b]	1 ± 0.1
Optimal-timber rotation	C	110	25 ± 15
	HW/C	120	25 ± 15
	CHW	80	10 ± 5
	NHW	290[b]	1 ± 0.1

[a] Land-type codes: C = conifers, HW/C = mixed hardwood and conifers, CHW = commercial hardwoods, NHW = noncommercial hardwoods.
[b] Stands were not managed at 290–300 years but were allowed to undergo natural regeneration.
[c] Year/year denotes that one-half of the land type was managed for each rotation.

type, except noncommercial hardwoods, was harvested when each successional stage reached 200 years of age.

2. Mixed rotation. Two potential harvest ages (120 and 200 years) were applied to the mixed-conifer–hardwood land types. One half of the acreage of each developing successional stage was harvested when it reached 120 years of age. The other half of that acreage was allowed to mature to 200 years of age before it was harvested. Half of the acreage in these land types reached the old-growth stage, and the other half was harvested near the optimal productivity level, i.e., near culmination of mean annual increment. Mixed-conifer land types were harvested when each successional stage reached 120 years of age, whereas commercial hardwood land types were harvested when the successional stages reached 200 years.
3. Optimal timber. Potential harvest of the land types occurred when each successional stage approached culmination of mean annual increment, which is as follows: mixed-conifer land types = 110 years; mixed-conifer–hardwood land types = 120 years; commercial hardwood land types = 80 years.

Each alternative made four additional assumptions: (1) reforestation was successful within a reasonable amount of time (<5 years); (2) control of competing growth (e.g., shrubs, forbs, and grasses) was largely ineffective; (3) removal of snags and dead material on the ground was minimal; and (4) no site conversions occurred.

Results

Annual timber-output levels for all alternatives were similar, approaching 14,000 m^3 (500,000 ft^3) for the study area 200 years after initial harvest. Although timber production was comparable among the three alternatives after 200 years, the time required to reach peak production and the total volume of timber produced through the simulation run varied considerably. Because much of the study area was dominated by young timber, little timber was produced early in the simulation; thus a lag period occurred before the timber harvest reached its maximum under each option. Maximal timber output appeared to depend on a combination of rotation age and number of land types harvested. Peak production was greater when more land types were managed and the rotation length closely approached the culmination of mean annual increment (point at which the rate of tree growth begins to decline) for each land type. The optimal-timber alternative produced the most timber of the three options because the timber-rotation lengths for mixed-conifer, mixed-conifer–hardwood, and commercial hardwood land types were at or near culmination of mean annual increment (see Table 49.1 and 49.2).

Wildlife responses to the three alternatives (Table 49.2) differed by the habitat quality, time necessary to reach greatest habitat quality, and long-term stability of the response curve (after curve reached the maximum habitat quality). Band-tailed pigeon habitat reached the highest point of habitat quality (i.e., 0.45–0.50) in the shortest time (i.e., approximately 60 years) under the mixed-rotation (Fig. 49.2) and optimal-timber (Fig. 49.1) alternatives. Both the mixed-rotation (Fig. 49.2) and optimal-timber (Fig. 49.1) response curves also showed the greatest stability—that is, the highest point of habitat quality was reached in a relatively short time, and thereafter the curve remained relatively stable (habitat quality = 0.45).

Table 49.2. Relative value of each alternative for each modeled resource

Resource	Alternatives[a] Long rotation	Mixed rotation (long/short)	Optimal-timber rotation
Timber production	3	2	1
Band-tailed pigeon	3	1.5	1.5
Pileated woodpecker	1	2	3
Mule deer	3	1.5	1.5

Note: Table values based on our interpretation of the resource responses to each alternative when simulation reached steady-state conditions (approximately 200 years).
[a]Values represent the desirability of the alternative for the resource: 1 = high, 2 = moderate, 3 = low.

Pileated woodpecker habitat reached the highest point of habitat quality (i.e., 1) under all three alternatives (Figs. 49.1, 49.2, and 49.3) in a short period of time, approximately 40 years. The long-rotation alternative (Fig. 49.3), however, provided the highest habitat quality (i.e., 1) from year 40 through the remainder of the rotation; hence, it was the most stable of the three alternatives. Both the mixed-rotation (Fig. 49.2) and optimal-timber (Fig. 49.1) alternatives showed a decline in habitat quality from age 40 to approximately 0.80 and 0.75, respectively, by year 200.

Mule deer habitat quality reached the highest point (0.75) under all three alternatives (Figs. 49.1, 49.2 and 49.3); however, the time required to attain that point varied among alternatives. The mixed-rotation (Fig. 49.2) and optimal-timber (Fig. 49.1) alternatives required a relatively short time to reach the highest point of habitat quality (50 and 60

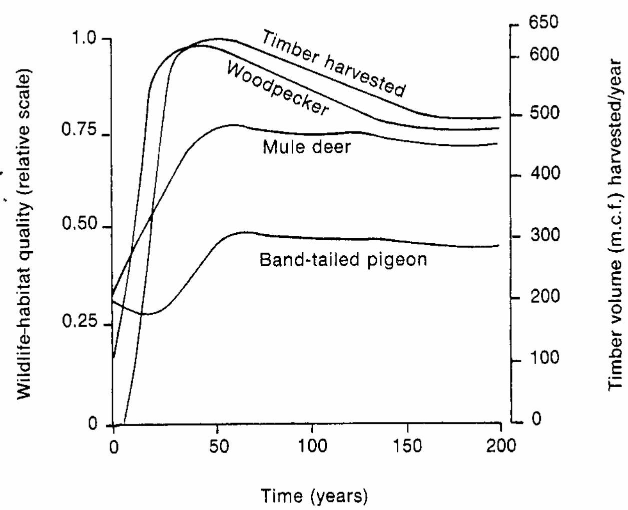

Figure 49.1. Wildlife-species and timber-harvest responses to the optimal-timber rotation DYNAST simulation. Timber-management information for this alternative provided in Table 49.1 (m.c.f. = thousands of cubic feet of harvested timber).

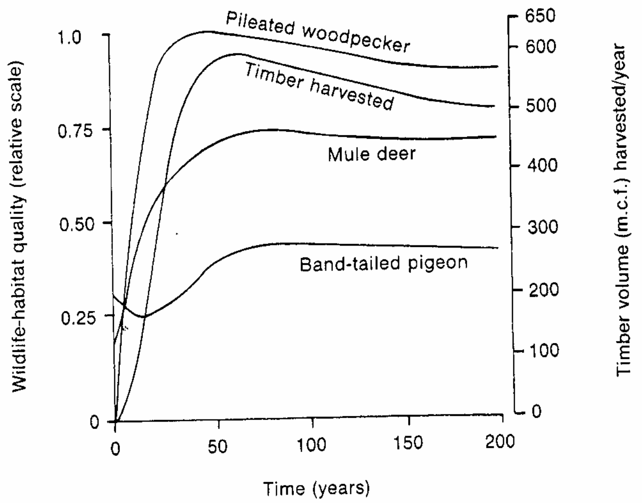

Figure 49.2. Wildlife-species and timber-harvest responses to the mixed (long/short) rotation DYNAST simulation. Timber-management information for this alternative provided in Table 49.1 (m.c.f. = thousands of cubic feet of harvested timber).

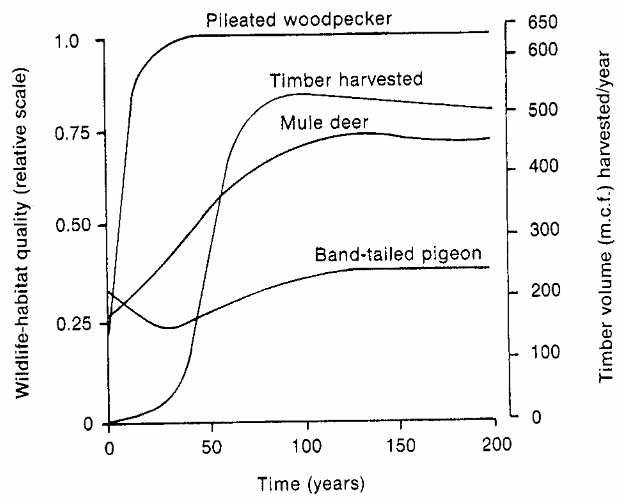

Figure 49.3. Wildlife-species and timber-harvest responses to the long rotation DYNAST simulation. Timber-management information for this alternative provided in Table 49.1 (m.c.f. = thousands of cubic feet of harvested timber).

years, respectively), whereas the long-rotation alternative (Fig. 49.3) showed a decline (to approximately 0.70) after attaining the highest point of habitat quality.

Discussion

Resource responses

The DYNAST simulation model displayed the potential effects of three different management approaches on a study area characterized by an uneven distribution of age-classes within the different land types. The model indicated that the time to reach peak timber production and total timber volume varied considerably according to the different alternatives. This variation is to be expected because the simulation model is rapidly harvesting the older successional stage timber at an accelerated rate to bring the entire study area to a steady-state or sustained-flow-of-timber condition.

The model harvests timber at all times whenever any amount of acreage reaches the specified harvest age. However, the study area was not initially in a steady-state or normal distribution of all age-classes. Consequently, the first 100–200 years of harvesting resulted in wide variations of timber production until steady-state was reached. If the user specifies a long rotation (e.g., 200 years before harvest), then it will take the model longer to reach steady-state than if a shorter rotation (e.g., 80 years before harvest) is used. Also if the user does not allow harvest to occur on certain land types, this will also affect the amount of timber that can be harvested.

Both the mixed-rotation and optimal-timber alternatives were very beneficial to band-tailed pigeons because of the resulting balance between the older mast-producing stands and younger stands supporting fruit- and berry-producing shrubs. Band-tailed pigeons feed extensively on mast during all seasons except summer (Grenfell et al. 1980). The mast is produced primarily by mature trees. In summer, forbs, fruits and berries, and grains become important diet items (Grenfell et al. 1980). Thus, the best habitat for band-tailed pigeons occurs where hardwood trees are harvested after mast production begins to decline and hardwoods are regenerated, producing younger tree stands supporting forbs and berry-producing shrubs.

Pileated woodpeckers found the most suitable habitat under the long-rotation alternative, in which trees and associated snags could grow to large sizes and provide the nesting sites that these birds need (McClelland 1979). Thus, under the long-rotation alternative, the habitat quickly reached maximum quality, which was retained throughout the 200-year simulation. Habitat quality declined as rotation lengths were shortened and large trees and snags were less readily available. Therefore, the optimal-timber alternative, which was based on relatively short rotation periods, provided the poorest-quality habitat for pileated woodpeckers.

Alternatives most beneficial to mule deer were the mixed-rotation and optimal-timber ones. Rotation age was also important to mule deer in relation to production of mast and to the amount of foraging habitat available. The shorter the rotation age, the greater the proportion of area suitable as foraging habitat (i.e., younger stands supporting shrubs, forbs, and grasses). Harvest-unit size also influenced deer habitat quality; very large and very small units lowered habitat values. Thus, those alternatives with relatively short rotation ages, yet retaining mast-producing trees, produced the best habitat for mule deer.

Value of DYNAST to decision makers

The greatest benefit of DYNAST to land and resource managers is its ability to portray management trade-offs in an understandable format, so that decision makers can select the alternative most closely meeting intended goals for the area. A second major benefit is the display of the cumulative effects of management decisions on resources. DYNAST can be altered to incorporate incremental, deleterious effects (e.g., soil loss and reduced productivity) or even thresholds for population viability. Simulations also will assist project-development teams by providing qualitative information on trade-offs for preparation of planning documents. Environmental documents that use graphics produced by DYNAST will enable the general public to visualize the consequences of actions.

Accuracy of DYNAST simulations

DYNAST outputs must be interpreted with caution. DYNAST was developed for use in the eastern United States and was later modified for western applications. The model uses information provided by the user concerning successional stages of vegetation. As a consequence, it can incorporate known successional information that is applicable to the specific area being modeled.

The DYNAST simulation is not a timber-stand model, because it does not operate on the basis of individual timber-stand development; instead it operates on the basis of land area occupied by user-specified vegetation cover (or land) types. The model also uses silvicultural controls, including rotation age, harvest-patch size, and percentage of land area converted or reverted from one cover (or land) type to another cover type. Wildlife and other resource models used within DYNAST may not relate directly to those variables, so resource responses may not be realistic. Finally, the model has not, to our knowledge, been tested for accuracy in the United States. Similarly, the wildlife models have not been verified. They are based on the literature and on professional judgment, but the accuracy of the proposed relationships has not been tested for many species.

Conclusion

Decisions to produce various timber and wildlife outputs are being made continually, and DYNAST simulations may provide decision makers with a better understanding of resource gains and losses. DYNAST provides managers of multiple-use forests with a tool to display quickly possible trade-offs under different timber-harvest options. Employment of this or other simulation procedures, in the absence of reasonable alternatives, has the potential to result in better informed and better documented decisions.

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