

## FIELD EXPERIMENTS IN PREY SELECTION BY RESIDENT BALD EAGLES IN THE BREEDING AND NON-BREEDING SEASON

J. MARK JENKINS

*Technical and Ecological Services  
Pacific Gas and Electric Co.  
3400 Crow Canyon Road  
San Ramon, California 94583 USA*

RONALD E. JACKMAN

*BioSystems Analysis, Inc.  
P.O. Box 776  
Fall River Mills, California 96028 USA*

**Abstract.**—A field experiment, offering a choice of two prey fish of unequal sizes to foraging Bald Eagles (*Haliaeetus leucocephalus*), was devised. The objective of the field experiment was to determine if eagles preferred one prey item over another, and if this preference varied between breeding and non-breeding seasons. A total of 67 trials were conducted on four nesting pairs of eagles, 32 trials in the breeding season and 35 in the non-breeding season. Eagles selected the large fish 71.8% of the time during the breeding season, as opposed to 34.2% in the non-breeding season. Eagles took the small fish in about equal numbers in each season (25.0% breeding, 28.6% non-breeding). Eagles failed to respond to either fish size 37.1% of the time during the non-breeding season, however, as opposed to one instance of no response (3.1%) in the breeding season. Mean response time was generally shorter in the breeding season than in the non-breeding season, and eagles responded more quickly when they took the large fish irrespective of season. It is concluded that eagles discriminate between large and small prey items, and may alter their prey selection based upon increased energetic requirements of the breeding season. These results were consistent with predictions of optimal foraging models and suggest reasons, in addition to changing prey availability, why food habits of Bald Eagles vary between the breeding and non-breeding season.

### EXPERIMENTO PARA DETERMINAR LA SELECCIÓN DE PRESAS DURANTE LA ÉPOCA REPRODUCTIVA Y NO REPRODUCTIVA POR PARTE DE INDIVIDUOS RESIDENTES DE *HALIAEETUS LEUCOCEPHALUS*

**Sinopsis.**—Se diseñó un experimento de campo en el cual se le ofrecían como presa, a individuos de águila calva (*Haliaeetus leucocephalus*), peces de diferente tamaño. El objetivo del experimento fue determinar si las águilas tenían preferencia por una presa particular y si estas preferencias variaban entre la época reproductiva y la no-reproductiva. Se llevaron a cabo 67 pruebas en cuatro parejas de águilas; 32 durante la época reproductiva y 35 durante la no-reproductiva. Las águilas seleccionaron a la presa de mayor tamaño en el 71.8% de las ocasiones durante la época reproductiva y en tan sólo el 34.2% de las ocasiones durante la época no-reproductiva. Las rapaces tomaron el pez más pequeño en números similares en cada temporada (25% en la época reproductiva y 28.6% en la no-reproductiva). Durante la época no-reproductiva, las águilas no respondieron al tamaño del pez en el 37.1% de los casos, en contraste a un caso de no respuesta (3.1%) durante la época reproductiva. El tiempo de respuesta al pez resultó más corto durante la época reproductiva. De igual manera se respondió más rápidamente, en cualquiera de las épocas, cuando se seleccionó la presa de mayor tamaño. Se concluye que las águilas discriminan sobre el tamaño de la presa, y pueden alterar la selección de presas en respuesta a la demanda energética como consecuencia de la época reproductiva. Estos resultados son consistentes con la predicción de los modelos de forajeo óptimo, y ofrece otras razones, además de cambios en la disponibilidad

de presas (alimento), a la variación en los hábitos alimentarios de las águilas durante las épocas reproductivas y no-reproductivas.

Implicit in the assumptions of optimal foraging is that animals are capable of exercising choice in their foraging decisions (Charnov 1976). Among other things, optimization decisions may require an animal to balance the energetic costs of obtaining a food item with the relative value of the item (Stephens and Krebs 1986). Foraging decisions may vary with changing environmental conditions, such as seasonal food supplies or reproductive status.

As a result of their highly visible foraging, especially in winter, Bald Eagles (*Haliaeetus leucocephalus*) have been the subject of a number of recent field studies of foraging behavior and ecology (Brown 1993, Hanson 1986, Knight and Knight 1983, Knight and Skagen 1988). The caloric requirements of territorial breeding eagles are expected to increase in the breeding season, as a result of the demands of feeding nestlings and the increased activity of birds associated with nesting. Territorially breeding Bald Eagles ideally fit a model of central place foraging proposed by Orians and Pearson (1979). In this model, animals return prey to a central place (the nest), and are confined to a single prey item per foraging trip, a so-called single-prey loader (Lessels and Stephens 1983). Assuming travel and prey manipulation times are equal, the model predicts that the optimal forager should always take the most energetically favorable prey item. Relying on two attributes of our study population (the propensity of eagles to take carrion fish and their habituation to boat traffic), we devised a field experiment to test whether Bald Eagles selected large over small prey items, and if selection might differ between the breeding and the non-breeding season.

#### STUDY AREA AND METHODS

Field experiments were conducted on Lake Britton (121°W, 41°N) in Shasta Co., California. This reservoir currently supports six occupied Bald Eagle nesting territories. The foraging ecology (Hunt et al. 1992) and other aspects of this eagle population have been studied since 1983 (Jenkins 1992). Lake Britton was created in 1925 when the Pit 3 Dam was constructed on the Pit River. It is approximately 13 km long and less than 1 km wide in most places, with a surface area of approximately 520 ha. The Pit River originates in Modoc County, drains much of northeastern California, and is a major tributary of the Sacramento River system.

Habitat types around Lake Britton are characteristic of Cascade and Sierra Nevada mountain regions. Seven habitat types occur around the lake, with the dominant habitat being Ponderosa pine (*Pinus ponderosa*) forest in open stands as tall as 70 m. Oregon oak woodland is found primarily at the easternmost portions of Lake Britton and is interspersed with Ponderosa pine and valley- and foothill-introduced grasslands. Small areas of Sierra mixed-coniferous forest, north coast riparian woodland, montane chaparral, and meadow and seep habitat also occur at Lake Britton (Holland 1986).

We conducted our experimental trials on Lake Britton between 1989 and 1991. Eagles in foraging positions (perched near shore) were offered two fish of the same species (Family Cyprinidae), but of unequal sizes in both the breeding and non-breeding seasons. Trials were considered during the breeding season from 1 March through 30 June when eagle nests had eggs or young (Jenkins 1992). Non-breeding trials were outside these months, and we avoided trials during the transition between breeding and non-breeding seasons. The larger fish were typically 340–380 mm (standard length), whereas the smaller fish were about 230–275 mm in length. Smaller large fish were paired with smaller small fish in an attempt to maintain a constant relative size difference between the two items. To ensure flotation, the body cavities of experimental fish were injected with air using a 60 cc syringe. Fish were dropped in the water simultaneously from a slowly moving boat within about 100 m of a foraging eagle. We then motored away from the eagle and observed from a distance of about 200 m. The eagle was allowed 30 min to select a prey item, and if no selection occurred in this time, the prey items were recovered. When foraging did occur, the item taken was recorded and the second item was recovered. We also recorded the amount of time taken by the eagle to select a prey item.

We have avoided considering multiple observations of an individual bird as independent events. Such pooling of repeated observations of the same individual creates correlated data sets, which violate the assumption of independence inherent in most inferential statistics, such as regression analysis, ANOVA, and non-parametric tests (Beal and Khamis 1990, Machlis et al. 1985). Instead, we emphasize descriptive statistics (Guthery 1987) and use the total number of nesting territories (four) as the sample size. This is justifiable because the high degree of territoriality exhibited by resident birds makes it probable that an adult within a specific territory is either the male or female of that pair.

#### RESULTS

We conducted a total of 67 trials on four nesting pairs of eagles, 32 in the breeding season and 35 in the non-breeding season. Overall, the large prey was selected more frequently in the breeding season (71.8%) than in the non-breeding season (34.2%). Eagles selected the small fish in near equal proportions during each season (25.0% breeding, 28.6% non-breeding). Perhaps more importantly, eagles exhibited a lack of response much more frequently in the non-breeding (37.1%) season than in the breeding season (3.1%). As these data include repeated observations of a minimum of eight individuals, they are not considered independent events. If they were, however, a chi-squared contingency test indicates a highly significant difference between the breeding and non-breeding seasons ( $\chi^2 = 14.23$ ,  $df = 2$ ,  $P < 0.01$ ).

As the results of experimental trials in each of the four nesting territories are independent, we categorized results in each territory (Fig. 1). In every territory, results were similar to the combined data, i.e., large

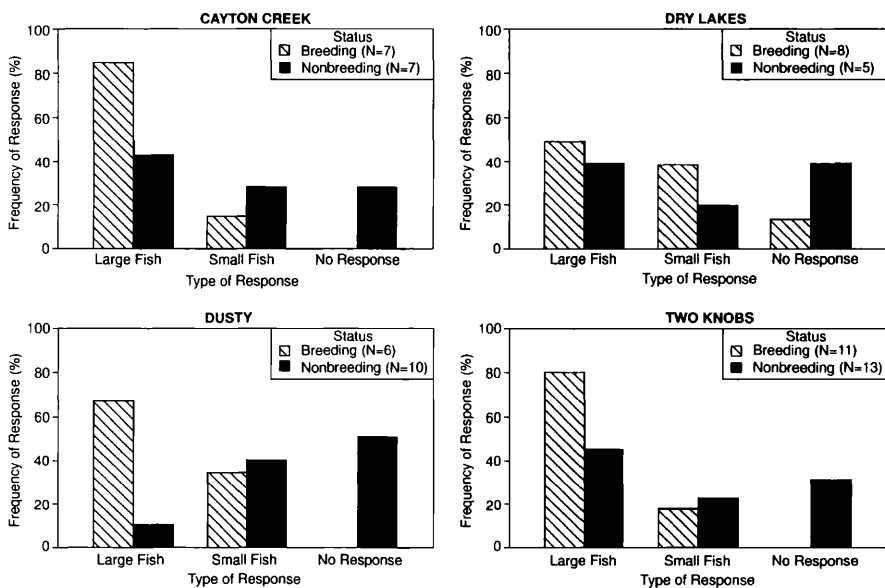


FIGURE 1. Results of 67 trials of a prey selection experiment at four nesting territories on Lake Britton, 1989–1991.

fish were taken more frequently in the breeding season, and more non-responses occurred in the non-breeding season. Response time was shorter when eagles selected the larger fish, particularly in the non-breeding season (Table 1). Mean response time was generally shorter in the breed-

TABLE 1. Mean response time in minutes for Bald Eagles responding to prey-selection experiments in the breeding and non-breeding seasons.

Territory	Large fish	Small fish
Breeding season		
Cayton Creek	8.4 (6) <sup>a</sup>	—
Dry Lakes	2.9 (3)	5.0 (3)
Dusty	2.0 (3)	6.5 (2)
Two Knobs	2.5 (9)	5.5 (2)
Mean	3.9 (4) <sup>b</sup>	5.7 (3)
Non-breeding season		
Cayton Creek	3.0 (3)	15.5 (2)
Dry Lakes	0.6 (2)	—
Dusty	—	17.0 (3)
Two Knobs	10.1 (6)	4.7 (3)
Mean	4.6 (3)	12.4 (3)

<sup>a</sup> Number of responses per territory.

<sup>b</sup> Sample size of responding territories is used to avoid pooling of repeated observations.

ing season, independent of the size of fish selected. This is particularly evident if the large number of non-responses, not included in Table 1, is considered in the non-breeding results.

#### DISCUSSION

Results of our breeding season trials were generally consistent with the predictions of central place foraging models by single-prey loaders, as eagles predominately selected the larger prey item during the breeding season. The larger prey item had slightly higher costs in transport and time of consumption, which could account for some use of the smaller item. In the non-breeding season, eagles are no longer central place foragers, i.e., they no longer return prey to the nest, and therefore, no longer fit the assumptions of the central place model. In winter we frequently observed eagles feeding on experimental prey near the capture site.

Our data have several other implications for foraging behavior and prey selection in Bald Eagles. Apparently, and perhaps not surprisingly, eagles are capable of discriminating between large and small items. Fischer (1985) found that Bald Eagles attempt to pirate large fish more frequently than small fish. More importantly, eagles may alter their selection of prey items because of the energetic requirements of breeding, such as laying eggs, or feeding and tending young. Stalmaster and Gessaman (1984) documented the energy requirements of wintering Bald Eagles and cited various behaviors that may maximize energy intake and reduce energy loss. Also, eagles appear to forage more intensively during the breeding season, as evidenced by the reduced incidence of non-responses and decreased mean response time in the breeding season. Our data suggest reasons for differences in food habits between breeding and non-breeding populations of Bald Eagles, independent of seasonal changes in prey availability.

#### ACKNOWLEDGMENTS

This study was supported by Pacific Gas and Electric Co. in conjunction with a larger study of Bald Eagle ecology in the Pit River drainage. PG&E owns and operates the Pit 3, 4, and 5 Hydroelectric Project under license from the Federal Energy Regulatory Commission. We are grateful to D. W. Anderson, M. N. Kochert, C. Van Riper, and an anonymous reviewer for comments on previous drafts of this manuscript.

#### LITERATURE CITED

- BEAL, K. G., AND H. J. KHAMIS. 1990. Statistical analysis of a problem data set: correlated observations. *Condor* 92:248-251.
- BROWN, B. T. 1993. Winter foraging ecology of Bald Eagles in Arizona. *Condor* 95:132-138.
- CHARNOV, E. L. 1976. Optimal foraging: attack strategy of a mantid. *Am. Nat.* 110:141-151.
- FISCHER, D. L. 1985. Piracy behavior of wintering Bald Eagles. *Condor* 87:246-251.
- GUTHERY, F. S. 1987. Guidelines for preparing and reviewing manuscripts based on field experiments with unreplicated treatments. *Wildl. Soc. Bull.* 15:306.
- HANSON, A. 1986. Fighting behavior in bald eagles: a test of game theory. *Ecology* 67:787-797.
- HOLLAND, R. F. 1986. Preliminary descriptions of the terrestrial natural communities of California. California Department of Fish and Game, Non-game Heritage Program. Sacramento, California. 155 pp.

- HUNT, W. G., J. M. JENKINS, R. E. JACKMAN, C. T. THELANDER, AND A. T. GERSTELL. 1992. Foraging ecology of Bald Eagles on a regulated river. *J. Raptor Res.* 26:243–256.
- JENKINS, J. M. 1992. Ecology and behavior of a resident population of bald eagles. Ph.D. diss. Univ. of California, Davis, California. 183 pp.
- KNIGHT, R. L., AND S. K. SKAGEN. 1988. Agonistic asymmetries and the foraging ecology of bald eagles. *Ecology* 69:1188–1194.
- KNIGHT, S. K., AND R. L. KNIGHT. 1983. Aspects of food finding by wintering Bald Eagles. *Auk* 100:477–484.
- LESSELS, C. M., AND D. W. STEPHENS. 1983. Central place foraging: single-prey loaders again. *Anim. Behav.* 31:238–243.
- MACHLIS, L., P. W. D. DODD, AND J. C. FENTRESS. 1985. The pooling fallacy: problems arising when individuals contribute more than one observation to the data set. *Z. Tierpsychol.* 68:201–214.
- ORIAN, G. H., AND N. E. PEARSON. 1979. On the theory of central place foraging. Pp. 154–177, in D. J. Horn, R. D. Mitchell, and G. R. Stairs, eds. *Analysis of ecological systems*. Ohio State Univ. Press, Columbus, Ohio.
- STALMASTER, M. V., AND J. A. GESSAMAN. 1984. Ecological energetics and foraging behavior of overwintering bald eagles. *Ecol. Monogr.* 54:407–428.
- STEPHENS, D. W., AND J. R. KREBS. 1986. *Foraging theory*. Princeton Univ. Press, Princeton, New Jersey. 247 pp.

Received 9 Jul. 1993; accepted 15 Oct. 1993.