AN ABSTRACT OF THE THESIS OF

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Title: PRODUCTION, NEST SITE SELECTION, AND FOOD HABITS OF OSPREYS ON DESCHUTES NATIONAL FOREST, OREGON

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A study of population trends, nest site selection, and food habits of ospreys (Pandion haliaetus carolinensis) nesting on the Bend District of the Deschutes National Forest, Oregon, was conducted during 1970 and 1971. Intensive observations were made of 95 nesting attempts of ospreys. Energy demands of the population were estimated with the aid of a simulation model employing data from the study.

A total of 99 young was fledged from 95 active nests during the two breeding seasons. Average production of fledglings per active nest was approximately one. The population appeared to be stable during the study.

Ponderosa pines (Pinus ponderosa) were used exclusively by ospreys nesting over land. The average nest tree in the forest was 36.6 m tall and had a dbh of 109 cm. All nest trees had a dead, somewhat flattened, basket-shaped top typical of old-growth ponderosa pines. Nests located over water on Crane Prairie Reservoir were

generally built on snags averaging 9 m in height with a dbh of 53 cm.

Collectively, ospreys captured 43 percent tui chubs (Gila bicolor) and 57 percent salmonids. Ospreys caught approximately 0.6 more fish per hour of observation during the early morning and early evening hours than during the middle of the day.

Average daily consumption of fish estimated for different age classes of ospreys were: adults, 286 g; nestlings, 127 g; fledglings, 254 g; and juveniles, 280 g.

The impact of osprey predation on the sport fishery at Crane Prairie Reservoir was judged to be negligible.

Forest management practices should be modified to prevent logging activities within 400 m of active osprey nests from April to September. Also, potential nest sites should be preserved when possible, and timber harvesting should be prohibited within 45.7 m of lakes and streams that attract foraging ospreys.

Production, Nest Site Selection, and Food Habits of Ospreys on Deschutes National Forest, Oregon

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDIX TABLES

PRODUCTION, NEST SITE SELECTION, AND FOOD HABITS OF OSPREYS ON DESCHUTES NATIONAL FOREST, OREGON

I. INTRODUCTION

A study of ospreys (Pandion haliaetus carolinensis) nesting on the Bend District of the Deschutes National Forest, Oregon, was conducted in 1970 and 1971.

During the 1960's, when many osprey populations were declining in the eastern half of the United States (Henny and Ogden 1970), osprey numbers appeared to be increasing at Crane Prairie Reservoir on the Deschutes National Forest, Oregon. Between 1947 and 1966, W. E. Nelson (personal communication) recorded an increase from 16 to 26 nesting pairs on the reservoir. Anderson (1968) counted 27 active nests on Crane Prairie Reservoir in 1967. Personnel of the U. S. Forest Service recorded a minimum of 21 occupied nests in 1968 and 48 active nests in 1969 on the Deschutes National Forest (Roberts 1969). Thirty-seven of the 48 active nests recorded in 1969 were on or near the reservoir. Flooding of the reservoir without removing trees necessary for nesting sites for the ospreys, and the large supply of forage fish produced in this large, shallow, fertile body of water were apparently the major factors which led to the population increases noted above (Roberts 1969).

A Memorandum of Agreement, signed by the U.S. Forest Service and the Oregon Wildlife Commission on October 10, 1969 established the Crane Prairie Reservoir Osprey Management Area. The management area was "established to insure that some osprey and a small portion of true osprey habitat is preserved for future generations" (Roberts 1969:2).

No intensive study of osprey abundance in Oregon had been made prior to the establishment of the Crane Prairie Reservoir Osprey Management Area. Records of osprey abundance in the state were limited to designations of the bird as being "rare" or "common" with no attempts at actual enumeration of breeding pairs (Gabrielson and Jewett 1940). In a statewide survey in 1968, Marshall (1969) recorded 56 active nests plus an additional 7 pairs that probably nested. He judged the bird to be rare in Oregon.

The U.S. Forest Service and the Oregon Wildlife Commission contracted with the Department of Fisheries and Wildlife at Oregon State University to investigate the population of ospreys nesting at Crane Prairie Reservoir and on the forested lands in the Bend District, Deschutes National Forest. A study of the habitat requirements of ospreys using nest sites in the forest was suggested to provide guidelines for the alteration of timber harvest practices to insure the provision of osprey nesting habitat for the future.

The objectives of the study were to:

(1) Measure the productivity of breeding pairs of ospreys on the Bend District, Deschutes National Forest, and determine osprey population trends.

(2) Determine the factors governing the selection of nest sites by those ospreys nesting in the forest compared to those nesting over water.

(3) Determine the types of fish consumed, determine the hours of the day when ospreys fish, and estimate the impact of osprey predation on the sport fishery at Crane Prairie Reservoir.

II. STUDY AREA

The study area was the Bend District of the Deschutes National Forest, located in the Cascade Mountains west of Bend, Oregon. It consists of approximately 1,619 km^2 (400,000 ac.) with elevations ranging between 1,219 and 2,895 m (4,000 and 9,500 ft). The dominant trees on the Bend District are lodgepole pine (Pinus contorta) and ponderosa pine (Pinus ponderosa) at the lower elevations, and mountain hemlock (Tsuga mertensiana) and grand fir (Abies grandis) at higher elevations.

The study was concentrated on the 42.9 km^2 (10,600 ac.) Crane Prairie Reservoir Osprey Management Area located 72.5 km (45 mi.) southwest of Bend (Figure 1), but included approximately 607 km^2 (150,000 ac.) surrounding the reservoir up to 1,830 m (6,000 ft.) elevation. The surface area of Crane Prairie Reservoir approximates 15.6 km^2 (3,850 ac.) when filled to an elevation of 1,372 m (4,500 ft.). Of the 6.1 km^2 (1,500 ac.) of trees left standing in the pool area in the early 1920's, approximately 4.1 km^2 (1,000 ac.) of standing snags (dead trees) remain. The remaining 27.3 km^2 (6,750 ac.) of the management area consists of lodgepole and ponderosa pine forest surrounding the reservoir.

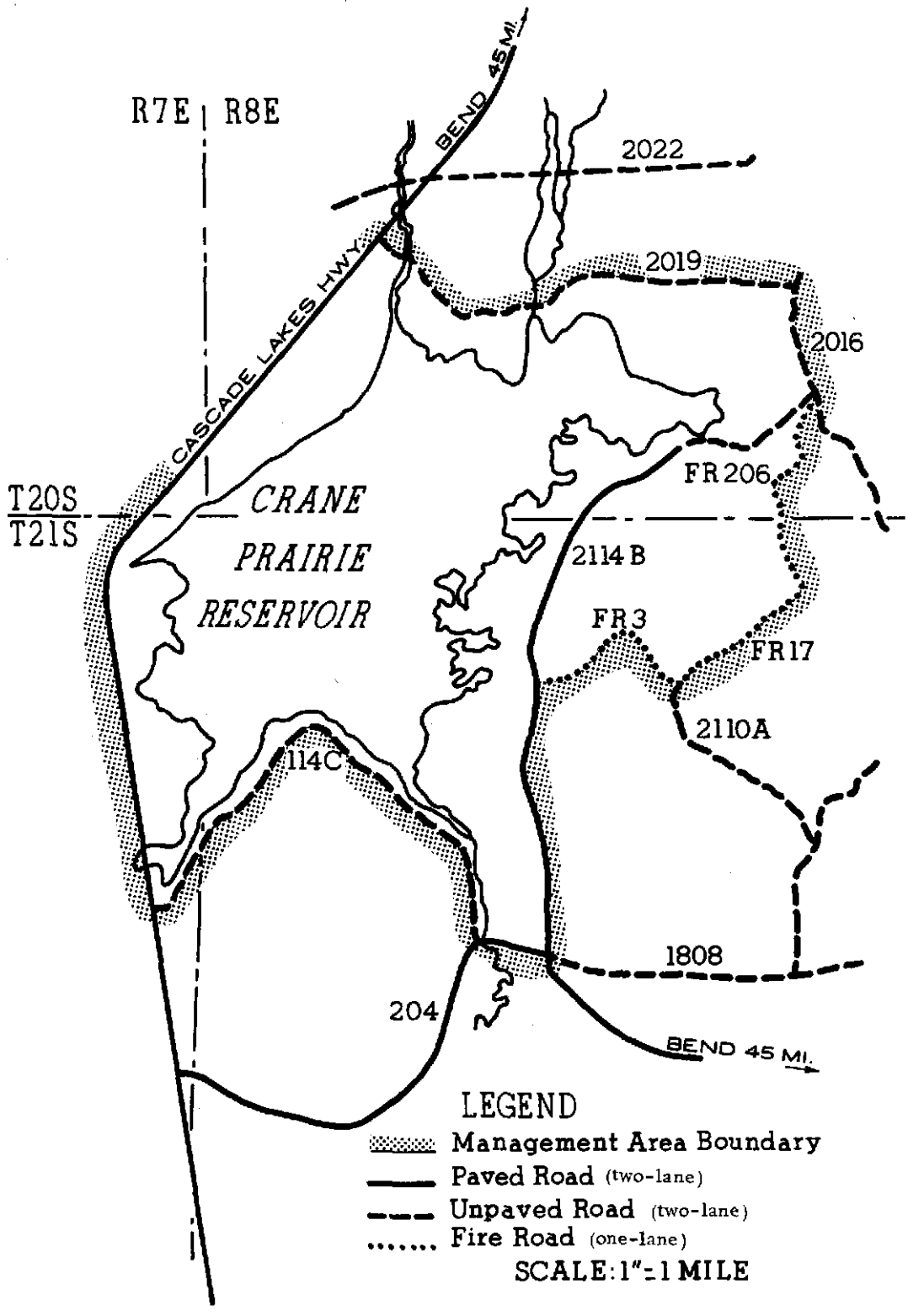


Figure 1. Crane Prairie Reservoir Osprey Management Area (Roberts 1969).

III. METHODS

Production

Each nest tree located on the Bend District, beginning in 1969, was numbered at its base with paint, and its precise location plotted on a map or aerial photograph by Hadley Roberts of the U.S. Forest Service. My observations of nests began in late April of 1970 and 1971.

All known osprey nests were visited at least once every 10 days until it was determined which nests were active. Observation of incubation behavior was sufficient to classify a nest as active. Incubation behavior was determined by the position the adult bird assumed on the nest. The incubating position is typified by tucked wings and a breast down position. A helicopter was employed once each year during the incubation period to verify the status of the nests. Fledging success was determined by repeated observations of active nests, and dates of fledging were estimated.

Nest Site Selection

Osprey nests on the Bend District were assigned to one of two categories: (1) "Lake nests" (those nests on trees or snags in Crane Prairie Reservoir, or located within 91.4 m (100 yd.) of the mean shoreline), and (2) "Forest nests" (those nests on trees or

snags located in excess of 91.4 m (100 yd.) from the mean shoreline).

The distances between each active nest and (1) the nearest active nest, (2) the nearest successful nest (a nest where young fledged), (3) the nearest body of water (forest nests only), (4) the nearest two-lane road (forest nests only), and (5) the nearest boat channel (lake nests only) were determined from aerial photographs and maps. These distances were used as independent variables in an evaluation of factors involved in nest site selection. The statistical procedures used in the analysis of these data were a clustering analysis using a matrix of correlation coefficients as a basis for clustering, stepwise multiple linear regression, and the pairwise Student's t-test.

In addition, each nest site in the forest was evaluated to determine the existence of vegetative and/or physical patterns that would allow forest managers to predict sites suitable for nesting ospreys as the availability of snags in the reservoir declines. Observations of osprey behavior were made to determine the vegetative and/or physical features of the habitat that appeared important in nest site selection, and the role that each of these features plays in the nesting behavior of the birds. Measurements of total height and diameter at breast height (dbh) were determined for all nest trees in the forest, and the overstory trees within 91.4 m (100 yd.) of the nest tree.

Heights of trees were determined with a clinometer. Positions of trees surrounding the nest tree in relation to the nest tree were recorded. Finally, the live nest trees (all of which were ponderosa pines) and surrounding ponderosa pine trees were classified according to the 10 age characters and 7 crown vigor characters described by Keen (1943).

Foods and Feeding Habitats

To facilitate the identification of fish in talons of ospreys the fish of Crane Prairie Reservoir were divided into two groups: (1) the "salmon-trout-char" group which included rainbow trout (Salmo gairdneri), brook trout (Salvelinus fontinalis), kokanee (Oncorhynchus nerka kennerlyi), and coho salmon (Oncorhynchus kisutch); and (2) the "whitefish-chub" group which included tui chub (Gila bicolor) and mountain whitefish (Prosopium williamsonii). The hour of the day when ospreys were observed capturing fish from Crane Prairie Reservoir was recorded.

In order to estimate the impact of the osprey population on the sport fishery at Crane Prairie Reservoir, it was necessary to estimate the energy demands of the osprey population. This was accomplished by using a simulation model described by Wiens and Innis (1974). This model estimates population density flux, biomass changes, and bioenergetic demands of bird populations with reference

to the breeding season. Data gathered during this study on clutch size, reproductive phenology, nestling mortality, fledging success, age class distribution, and ambient temperature were combined with a logistic function which allows calculation of weight changes in young birds, the bioenergetic formulations of Kendeigh (1970), and considerations of the costs in energy of digestion, activity, molt, egg production, and growth as inputs to the computer model. Synthesis of the information in the model provides an estimation of the daily energy requirements of each age class of the osprey population based on the area occupied by the population. This was translated into average energy requirements of individuals in each age class and then summed.

Creel censuses performed by personnel of the Oregon Wildlife Commission were used to estimate the sport fishery catch from the reservoir (J. Griggs personal communication).

IV. RESULTS AND DISCUSSION

Production

Returning ospreys were first sighted at Crane Prairie Reservoir on 7 April 1970 (C. Hofstedt personal communication), and 12 April 1971 (P. Schatz personal communication). Intensive observations were begun on 27 April 1970, and 5 May 1971.

Active Nests

There were 43 active osprey nests (25 lake nests and 18 forest nests) on the Bend District in 1970, and 52 (28 lake nests and 24 forest nests) in 1971 (Table 1). Except for the discovery of two forest nests whose locations were not known in 1970, the increase in active nests in 1971 can be attributed to nests that were inactive in 1970 becoming active in 1971 and apparently resulted from an increase in the number of breeding pairs in the population.

In addition to the ospreys associated with active nests, six pairs in 1970, and five in 1971 were associated with particular nests and added nesting material to them. However, incubation behavior was not exhibited, and it was assumed that these 11 pairs did not produce eggs. They were considered to constitute a non-breeding segment of the population (presumably sub-adults). Henny and Van Velzen (1972) concluded from an analysis of banding data that

Table 1. History of osprey nests on the Bend District, Deschutes National Forest, Oregon in 1970 and 1971.

Category	Lake nests		Forest nests		Subtotals		Totals
	1970	1971	1970	1971	1970	1971	
Active nests	25	28	18	24	43	52	95
Nests abandoned before hatching	13	9	6	9	19	18	37
Nests in which young hatched	12	19	12	15	24	34	58
Percentage of active nests in which young hatched	48	68	67	62	56	65	61
Nests in which all young died prior to fledging	2	2	2	1	4	3	7
Young that died prior to fledging	4	3	3	1	7	4	11
Successful nests (young fledged)	10	17	10	14	20	31	51
Percentage of successful nests	40	61	56	58	46	60	54
Young fledged	21	35	18	25	39	60	99
Young fledged per successful nest	2.1	2.1	1.9	1.6	2.0	1.9	1.9
Young fledged per active nest	0.8	1.3	1.0	1.0	0.9	1.2	1.0

5 to 10 percent of the pairs in an osprey population will be non-breeding 2-year-olds which they referred to as "house keepers." The percentages of "house keeping" 2-year-olds on the Bend District were 12.2 in 1970, and 8.8 in 1971.

Successful Nests

The increase in the number of active nests on the Bend District during the 2 years coincided with increases in the number of nests in which young hatched, the number of successful nests, total young fledged, and young fledged per active nest (Table 1).

The increase in percentage of successful nests from 46 in 1970 to 60 in 1971 (Table 1) was partly related to a reduction of human harrassment of active nests in 1971. In 1970, one suspected and two known instances were reported of fishermen (apparently inadvertently) preventing adult ospreys from tending either eggs or very young chicks for periods ranging from 1 to 2 hours. None of these pairs successfully fledged young. Also, two young and one adult were shot by unknown persons in 1970. No harrassment of nesting ospreys was reported on the study area in 1971.

The 1.0 young fledged per active nest determined in this study (Table 1) is within the range of 0.95 to 1.3 young that Henny and Wight (1969) calculated must be produced each year by each breeding age female in the population in order to maintain a stable population.

Other studies conducted in the western United States indicate that ospreys in Idaho, Montana, and California are producing 1.0 to 1.1 young fledged per active nest (Table 2) with no observed population declines (Schroder and Johnson in press, D. L. MacCarter 1972, Garber 1972). Most workers studying ospreys in the eastern and mid-western states, where declines have been noted, have reported reproductive rates of less than 1.0 young fledged per active nest (Table 2). Even though the work of Henny and Wight (1969) was based on mortality schedules computed from banding data obtained from an osprey population on the east coast of the United States, it appears that their conclusions are also applicable to osprey populations in the western United States.

Nestling Mortality

Of seven nestlings that died on the study area in 1970 (Table 1), four died because of harrassment by fishermen, two were illegally shot, and one died because a deformed wing prevented successful flight. The deaths of four nestlings in 1971 (Table 1) were due to falls from their nests.

Fledging Dates

Approximate dates of fledging were determined for 38 fledglings in 1970, and 60 in 1971 (Table 3). Young ospreys fledged from

Table 2. Comparative fledgling success of osprey populations in the United States.

Location	Years	Number of active nests	Number of young fledged per active nest	Source
Massachusetts	1971	21	0.8	Fernandex (unpublished)
Maine	1964	8	0.4	Kury (1966)
Connecticut	1960-63	157	0.3	Ames & Mersereau (1964)
Connecticut	1964-65	30	0.3	Peterson (1969)
Maryland	1963-69	527	1.0	Reese (1970)
Virginia	1970-71	503	0.8	Kennedy (1971)
Florida	1968-69	83	1.2	Henny & Ogden (1970)
Minnesota	1966-68	161	1.0	Dunstan (1968)
Wisconsin	1952-65[a]	195	0.8	Berger & Mueller (1969)
Michigan	1965-67	162	0.4	Postupalsky (1969)
Montana	1967-70	80	1.0	D.L. MacCarter (1972)
Idaho	1970-71	87	1.0	Schroder & Johnson (in press)
California	1970-71	87	1.1	Garber (1972)
Oregon	1970-71	95	1.0	This study

[a]Data not collected in 1957.

Table 3. Approximate fledging dates of 38 ospreys hatched in 1970, and 60 hatched in 1971 on the Bend District, Deschutes National Forest, Oregon.

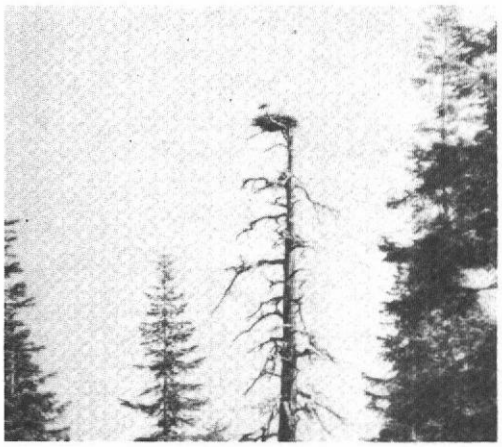
Dates	1970		1971	
	Numbers fledged	Percent of total	Numbers fledged	Percent of total
August				
3-7	3	7.8	3	5.0
8-12	1	2.6	6	10.0
13-17	7	18.4	5	8.3
18-22	11	28.9	17	28.3
23-27	5	13.1	17	28.3
28-1	4	10.5	6	10.0
September				
2-6	7	18.4	2	3.3
7-10	-	-	4	6.6

3 August through 6 September in 1970, and from 3 August through 10 September in 1971. The peak of fledging occurred between 13 and 22 August in 1970, and between 18 and 27 August in 1971.

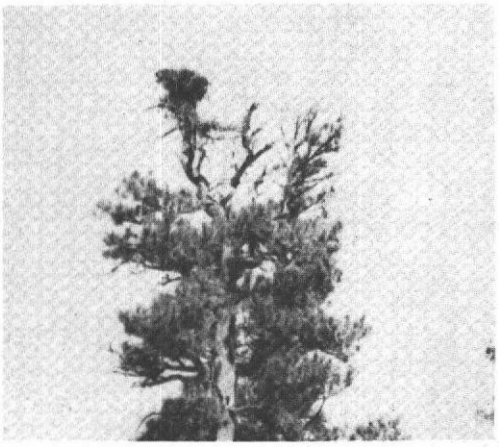
Nest Site Selection

Forest Nests

All of the 27 nest trees in the forest on the Bend District were ponderosa pine 200 years old or older (Figure 2, A and B). This was true even at higher elevations where ponderosa pines were relatively scarce, and grand fir and mountain hemlock were the dominant tree species. Of the 27 nests in the forest, 56 percent (15) were built in snags (Figure 2A). All of the trees used for nesting in the forest had the somewhat flattened, basket shaped top characteristic of old-growth ponderosa pine (Keen 1943). The average nest in the forest was built in a ponderosa pine 36.6 m (120 ft.) tall, with a dbh of 109 cm (43 in.), and a dead and somewhat flattened top. Generally, the live nest trees in the forest can be classed in the 3C or 4C categories of Keen's (1943) classification system. That is, they were large dominant trees with reduced crown vigor (Figure 2, B and C). However, the "dead top" phenomenon which was characteristic of the live nest trees was not included in Keen's system. In addition, 88 percent (24) of the forest nests were constructed so that at least



A



B

C

D

Figure 2. Nesting and perching structures used by ospreys on the Bend District, Deschutes National Forest, Oregon. A. Forest nest (snag); B. Forest nest (live tree); C. Perch tree or potential nest tree; and D. Lake nest.

one branch approximately 5 to 13 cm (2 to 5 in.) in diameter protruded 0.6 to 2.1 m (2 to 7 ft.) to the side or above the nest. This branch was used as a perch by both the adults and the fledglings (Figure 2, A and B).

The average number of trees over 27.4 m (90 ft.) tall within 91.4 m (100 yd.) of the nest was 10, and ranged from 2 to 23. These trees were predominately ponderosa pines. No discernible pattern in the positions of these trees around the nest tree was apparent from one nest site to another, indicating that this is not an important factor in nest site selection by ospreys.

Aside from the nest tree itself, at least one other large tree, located within 137 m (150 yd.), was also regularly used by the nesting pair and the fledglings. This tree characteristically was an old-growth ponderosa pine snag or live tree with a dead top (Figure 2C). The adult ospreys used this tree as a "lookout" perch and feeding post. Typically, when the male brought a fish to the nest during the incubation period, the female would take the fish to the perch tree and consume it there. Meanwhile, the male would assume the incubation duties while the female was off the nest. Adults were not observed eating at the nest unless there were young present. The male could usually be found in the perch tree if he was in the area when I visited the nest.

The perch tree was also used by the fledglings for approximately 2 weeks following their first flight. They regularly flew from the nest tree to the perch tree and back. Both adult and young ospreys appeared to prefer perching on dead, bare branches compared to live, foliated branches.

There was no significant difference ($P>0.05$) between 26 successful and 15 unsuccessful forest nesting attempts in relation to the distance between each active nest and the nearest active nest, the nearest successful nest, the nearest two-lane road, and the nearest body of water. Stepwise multiple regression analysis indicated that the distance from a given active nest to the nearest successful nest was of greatest importance although only about 7 percent of the variability was accounted for by this parameter ($r^2 = 0.0697$). The distance from a given active forest nest to the nearest body of water was the least important of the four parameters tested.

The average successful forest nest was farther from the nearest active nest, the nearest successful nest, and the nearest two-lane road than the average unsuccessful forest nest (Table 4). This was expected due to the effects of territorial defense by the birds, and human disturbance. The average successful forest nest was also farther from the nearest body of water. This was not expected because selection of short distances to foraging areas would seem to be a requirement for reproductive fitness for a predator. Further

Table 4. Distances in meters (yards in parentheses) from 26[a] successful and 15 unsuccessful forest nests to the nearest active nest, the nearest successful nest, the nearest two-lane road, and the nearest body of water on the Bend District, Deschutes National Forest, Oregon in 1970 and 1971.

Category	Successful nests			Unsuccessful nests		
	Mean	Standard deviation	Range	Mean	Standard deviation	Range
Nearest active nest	1636.8 ± (1790)	1102.8 (1206)	321.9-5986.6 (352-6547)	1176.8 ± (1287)	782.7 (856)	177.4-2703 (194-2956)
Nearest successful nest	2310.7 ± (2527)	1737.4 (1900)	321.9-6308.5 (352-6899)	1509.7 ± (1651)	662.9 (725)	321.9-2702 (352-2956)
Nearest two-lane road	1110.1 ± (1214)	790.9 (865)	45.7-2767.9 (50-3027)	925.4 ± (1012)	654.7 (716)	80.5-2188.2 (88-2393)
Nearest body of water	1925.7 ± (2106)	1662.4 (1818)	128.9-4828 (141-5280)	1663.3 ± (1819)	1421 (1554)	128.9-4764 (141-5210)

[a]This number differs from the total successful forest nests reported in Table 1. At two nests, young that were near the fledging stage were killed as a result of falls from their nests, and not from causes that could be attributed to territorial behavior. Therefore, these nests were classified as successful in this analysis.

analysis of these data revealed that ospreys nesting over 91.4 m (100 yd.), but within 914.4 m (1,000 yd.) of water produced more young per nest than those birds nesting in excess of 914.4 m (1,000 yd.) of water. While only 36 percent (15) of the forest nestings were attempted within 914.4 m (1,000 yd.) of water, 49 percent (23) of the young produced at forest nests were the result of these 15 nesting attempts. The chi-square for this comparison was significant at the $P<0.10-0.05$ level. The above percentages were virtually the same when 1970 and 1971 data were analyzed separately. Therefore, those forest nest sites located within 914.4 m (1,000 yd.) of a body of water appear to be more important to the reproductive success of the population than those located in excess of 914.4 m (1,000 yd.) from water. However, of the four nestings in excess of 4572 m (5,000 yd.) from water, three were successful and produced six young.

Two pairs of ospreys nested successfully 321.9 m (352 yd.) apart; however, the average distance between successful forest nests was 2310.7 m (2,527 yd.) (Table 4).

Lake Nests

Lake nests at Crane Prairie Reservoir were in lodgepole pine or ponderosa pine snags standing in the water (Figure 2D). These snags averaged approximately 9 m (30 ft.) in height, and had an average dbh of 58 cm (23 in.).

There was no significant difference ($P > 0.05$) between 29 successful and 24 unsuccessful lake nesting attempts in relation to the distance between each active nest and the nearest active nest, the nearest successful nest, and the nearest boat channel. The average successful lake nest was farther away from the nearest active nest, the nearest successful nest, and the nearest boat channel than the average unsuccessful lake nest (Table 5).

Foods and Feeding Habits

Prey

Of 90 prey items identified during the two seasons, 48 percent (43) were in the salmon-trout-char group, and 52 percent (47) were in the whitefish-chub group. In most cases, it was possible to differentiate between tui chub and mountain whitefish. Tui chub made up about 43 percent (38 of 90 fish) of the diet of ospreys feeding at Crane Prairie Reservoir.

Over 80 percent of the fish taken in gill nets at Crane Prairie Reservoir by the Oregon Wildlife Commission in the last 10 years have been tui chub, and the net catch of tui chub has remained relatively constant throughout this period (Campbell and Locke 1961-1970). The question arises as to why the ospreys do not utilize tui chubs in proportion to their apparent numbers. I believe this may be

Table 5. Distances in meters (yards in parentheses) from 29[a] successful and 24 unsuccessful lake nests to the nearest active nest, the nearest successful nest, and the nearest boat channel on Crane Prairie Reservoir, Oregon in 1970 and 1971.

Category	Successful nests			Unsuccessful nests		
	Mean	Standard deviation	Range	Mean	Standard deviation	Range
Nearest active nest	388.6 (425)	± 263.4 (288)	96.9-1222.5 (106-1337)	331.9 (363)	± 309.1 (338)	80.5-1303 (88-1425)
Nearest successful nest	518.5 (567)	± 310 (339)	112.5-1448.4 (123-1584)	471.8 (516)	± 366.7 (401)	96.9-1303 (106-1425)
Nearest boat channel	245.1 (268)	± 197.5 (216)	0-643.7 (0-704)	156.4 (171)	± 205.7 (225)	0-603.5 (0-660)

[a]This number differs from the total successful lake nests reported in Table 1. At two nests, young that were near the fledging stage were killed as the result of falls from their nests, and not from causes that could be attributed to territorial behavior. Therefore, these two nests were classified as successful in this analysis.

partially accounted for by the size and/or availability of the tui chub. M. L. Montgomery (personal communication) reports that although tui chubs have been known to attain a size of 28 cm (11 in.) at Crane Prairie Reservoir, those in excess of 15 cm (6 in.) in length are in the minority. On the other hand, rainbow and brook trout taken in gill nets at Crane Prairie Reservoir in the past 5 years have averaged 27 and 23 cm (10.6 and 9.2 in.) respectively (Campbell and Locke 1966-1970). My observations and those of Garber (1972) and D. S. MacCarter (1972) indicate that ospreys generally select fish that range from 15 to 30 cm (6 to 12 in.) in length. It appears that most tui chubs in Crane Prairie Reservoir are too small to be selected by ospreys, whereas trout are more likely to be selected on the basis of size alone.

Kimsey (1954), working at Eagle Lake, California, and Bird (personal communication) at East Lake, Oregon, report that tui chubs generally feed near the bottom. Salmonid species often feed near the surface. This bottom feeding trait of the tui chubs would make them less available to foraging ospreys.

Predation Efficiency

Lambert (1943) defined a strike as a fishing attempt in which an osprey actually comes in contact with the water. Predation efficiency may be defined as the number of successful strikes divided by

the total number of strikes and expressed as a percentage. I observed a predation efficiency of 58 percent (Table 6) at Crane Prairie Reservoir. This predation efficiency is comparable to the observations of D. S. MacCarter (1972) at Flathead Lake, Montana (63 percent), and Garber (1972) at Eagle Lake, California (56 percent). However, Lambert (1943) reported a predation efficiency of 89 percent for ospreys fishing off the coast of Nova Scotia (Table 6). The reason for this difference in predation efficiency between lake and ocean habitats is unknown.

Observations of Ospreys Fishing

One hundred ninety-two fish were observed in the talons of ospreys during 237 hours of observation on Crane Prairie Reservoir. To estimate fishing activity by time, eight 2-hour intervals from 0500 to 2100 hours were used. This 16-hour segment of the day generally includes the period from the beginning of civil twilight in the morning to the end of civil twilight in the evening from 1 May through 15 September (Kimball 1916).

Ospreys caught more fish per hour during the 0500 to 0700 and 1900 to 2100 intervals than in any of the other 2-hour intervals (Figure 3). In addition, ospreys at Crane Prairie Reservoir apparently increase their fishing activity during the middle of the day after 1 July (when most of the young have hatched) to meet the needs of

Table 6. Predation efficiency of one coastal and three inland populations of ospreys.

Location	Total strikes	Successful strikes	Predation efficiency (percent)	Source
Government Point, Nova Scotia	469	419	89	Lambert (1943)
Flathead Lake, Montana	274	173	63	D.S. MacCarter (1972)
Eagle Lake, California	36	20	56	Garber (1972)
Crane Prairie Reservoir, Oregon	60	35	68	This study

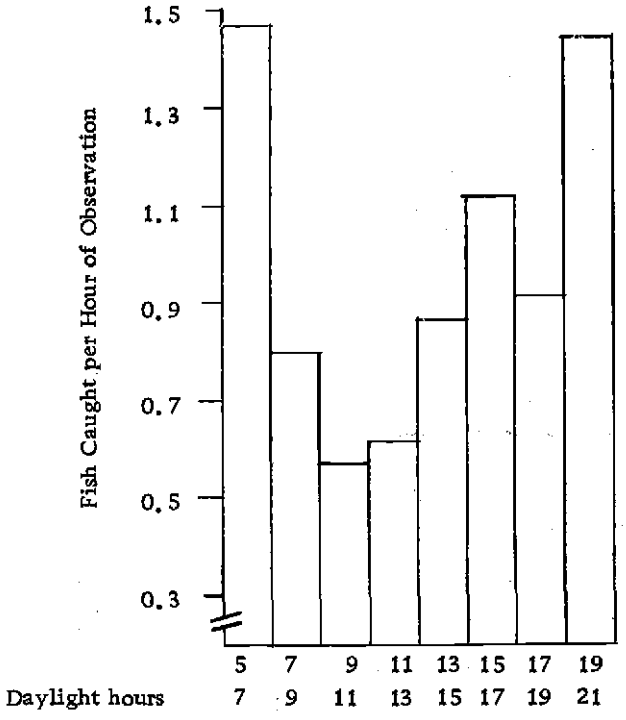


Figure 3. Fishing of ospreys at Crane Prairie Reservoir for 1970 and 1971 expressed in fish caught per hour of observation during the breeding season.

their young (Figure 4). From 1 May to 1 July, I observed an average of 0.51 fish per hour in the talons of ospreys between 0700 and 1900 hours. However, between 2 July and 15 September I observed an average of 0.98 fish per hour during those same hours.

Energy Requirements

Little is known about the energy requirements of ospreys. Estimates of the weight of fish consumed by adults and young have been limited to counting the number of fish brought to the nest and making rough estimates of the fishes' size (D.S. MacCarter 1972, Garber 1972). Kennedy (1971) obtained limited data on food consumption of young hatched in an incubator.

The simulation model described by Wiens and Innis (1974) was used to estimate the energy requirements of the osprey population nesting on the Crane Prairie Reservoir Osprey Management Area in 1971. For the purposes of this analysis, I assumed that birds nesting on the Crane Prairie Reservoir Osprey Management Area obtained all of their food from Crane Prairie Reservoir.

The approximate age distribution of the osprey population at 5-day intervals throughout the 1971 breeding season was calculated based on observed population densities of adults, nestlings, and fledglings on the Management Area (Table 7). Adult mortality was assumed to be zero. The drop in total population from 116 to 113

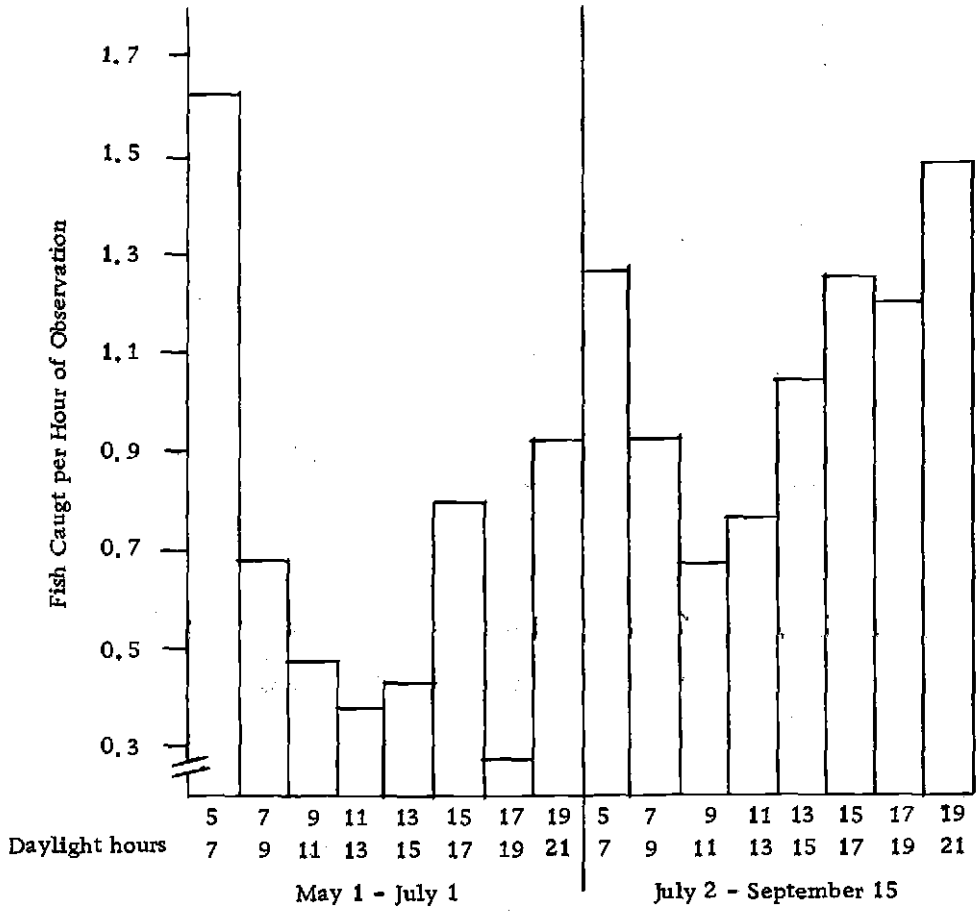


Figure 4. Fishing of ospreys at Crane Prairie Reservoir for 1970 and 1971 expressed in fish caught per hour of observation during two segments of the breeding season.

Table 7. Approximate age class distribution of the osprey population on the Crane Prairie Reservoir Osprey Management Area during the 1971 breeding season as computed from the simulation model developed by Wiens and Innis (1974).

Date		Number of adults and juveniles	Number of nestlings	Number of fledglings	Totals
April	16	17	-	-	17
	21	44	-	-	44
	26	72	-	-	72
May	1	72	-	-	72
	6	72	-	-	72
	11	72	-	-	72
	16	72	-	-	72
	21	72	-	-	72
	26	72	-	-	72
	31	72	-	-	72
June	5	72	-	-	72
	10	72	1	-	73
	15	72	6	-	78
	20	72	19	-	91
	25	72	34	-	106
	30	72	42	-	114
July	5	72	44	-	116
	10	72	44	-	116
	15	72	44	-	116
	20	72	44	-	116
	25	72	44	-	116
	30	72	44	-	116
August	4	72	43	1	116
	9	72	38	6	116
	14	72	25	17	114
	19	72	10	31	113
	24	72	2	39	113
	29	76	-	37	113
September	3	85	-	26	111
	8	98	-	12	110
	13	106	-	3	109
	18	88	-	-	88
	23	11	-	-	11

between 9 and 19 August was the result of the deaths of three nestlings during that period. The reduction in population beginning in September is a simulation of migration by the population to the wintering grounds.

Estimates of the energy requirements of ospreys nesting on the Crane Prairie Reservoir Osprey Management Area during the 1971 breeding season were computed (Table 8). I also calculated the overall energy requirements of the osprey population throughout the 1971 breeding season (Figure 5) using the same model (Wiens and Innis 1974).

If the estimates of energy requirements are realistic, they should compare favorably with other studies of energy requirements of raptorial birds. Kennedy (1971) reported food consumption of nestling ospreys hatched in an incubator. His data show consumption of 103 g (3.6 oz.) on day 11 of life, 137 g (4.8 oz.) on day 12, 148 g (5.2 oz.) on day 15, and 178 g (6.3 oz.) on day 16. If we assume that 1 g (wet-weight) of fish flesh contains 1 kcal (Winberg 1960), a theoretical amount of fish consumed by nestlings at Crane Prairie Reservoir can be calculated from the simulation model (Wiens and Innis 1974). The model predicted that osprey nestlings at 11, 12, 15, and 16 days of age will consume 113 g (4.0 oz.), 136 g (4.8 oz.), 147 g (5.2 oz.), and 170 g (6.0 oz.), respectively. Thus, in comparison to Kennedy's (1971) study, it appears that the model is quite realistic.

Table 8. Estimated energy requirements of ospreys nesting on the Crane Prairie Reservoir Osprey Management Area during the 1971 breeding season as computed from the simulation model developed by Wiens and Innis (1974).

Age class	Average number of birds (range)	Number of days	Average kilocalories / bird/day (range)	Total kilocalories / bird	Total kilocalories / required
Adults	67.1 (7-72)	160	286 (246-317)	45,771	3,071,234
Nestlings	30.3 (1-44)	75	127 (12-241)	9,516	288,335
Fledglings	21.5 (1-39)	40	254 (218-269)	10,153	218,290
Juveniles	18.5 (4-34)	30	280 (265-293)	8,404	155,474
					3,733,333

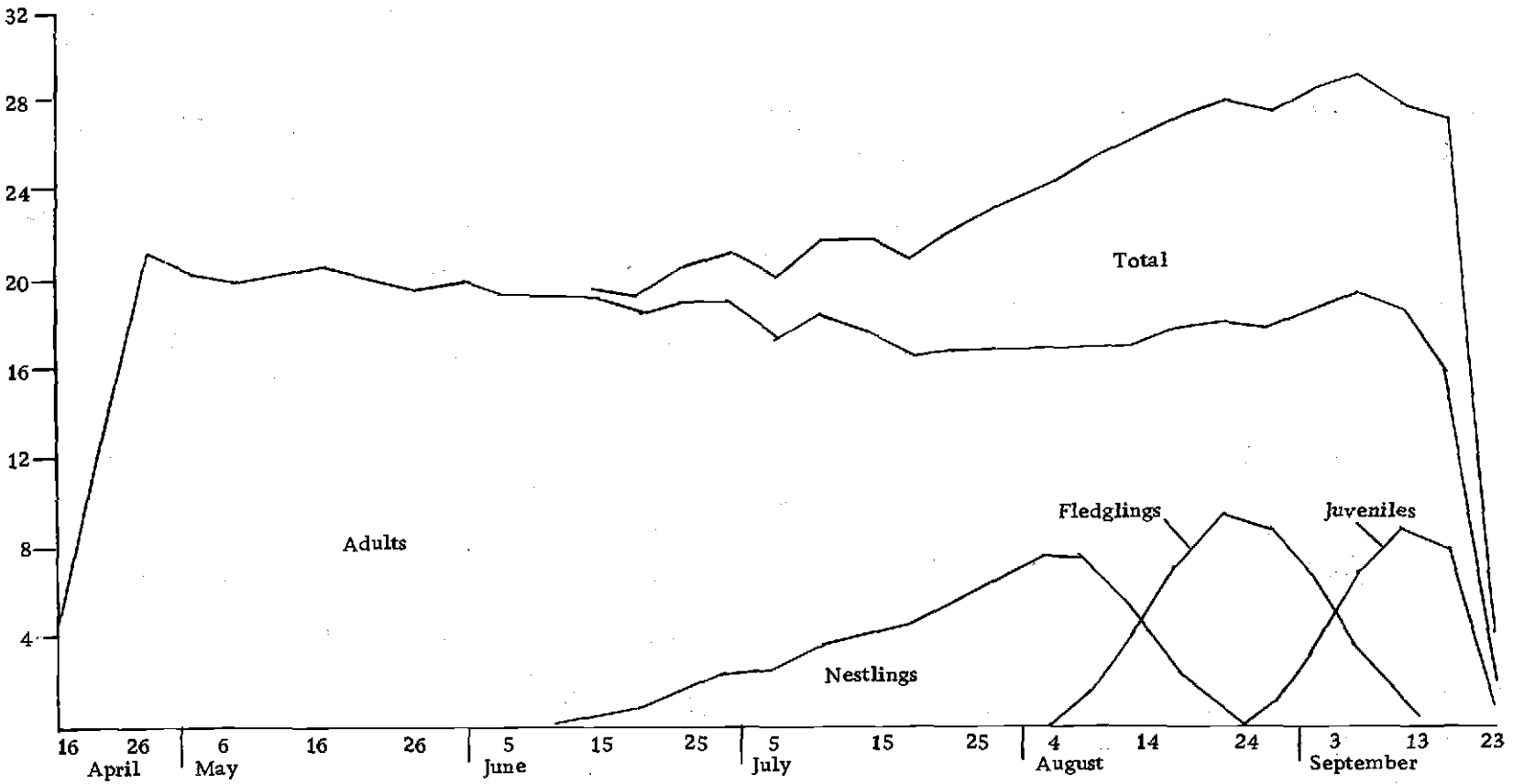


Figure 5. Estimated energy requirements of ospreys nesting on the Crane Prairie Reservoir Osprey Management Area during the 1971 breeding season as computed from the simulation model developed by Wiens and Innis (1974).

Craighead and Craighead (1956) performed feeding experiments with 10 species of semi-wild raptorial birds. These birds, from the smallest to the largest, were: sparrow hawk (Falco sparverius), screech owl (Otus asio), sharp-shinned hawk (Accipiter striatus), Cooper's hawk (Accipiter cooperii), marsh hawk (Circus cyaneus), red-shouldered hawk (Buteo lineatus), peregrine falcon (Falco peregrinus), prairie falcon (Falco mexicanus), red-tailed hawk (Buteo jamaicensis), and great horned owl (Bubo virginianus). Analysis of the Craighead's (1956) data reveals an apparent inverse relationship between the weight of the bird and the percentage of its body weight in prey consumed per day (Figure 6). For example, birds ranging in weight from 100 to 200 g (3.5 to 7.0 oz.) consumed an average of 18.2 percent of their body weight in prey per day while birds in the 800 to 1200 g (28.2 to 42.3 oz.) range averaged 7.7 percent of their body weight in prey per day.

If we assume that the average adult osprey weighs 1600 g (56 oz.), it would theoretically consume less than 7.7 percent of its body weight in prey per day. The model indicated the average daily consumption of fish by adult ospreys at Crane Prairie Reservoir to be 286 g (10 oz.) (Table 8). This is 17.8 percent of the average adult osprey's body weight. This seems to be an extremely high percentage. However, the great horned owl and red-tailed hawk subsist primarily on mammals, most of which are mice (Craighead and Craighead

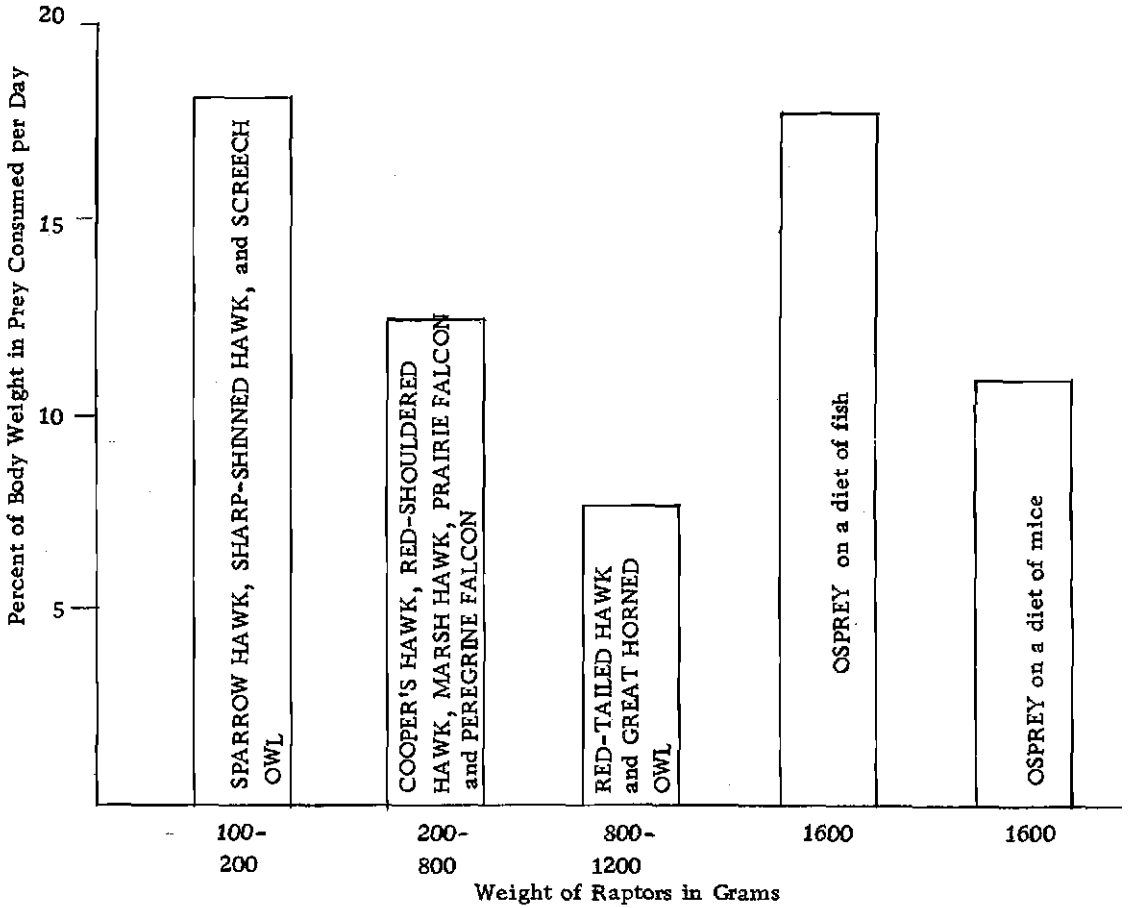


Figure 6. Comparison of average percent body weight consumed per day by small, medium, and large raptors (Craighead and Craighead 1956) with the theoretical percent of body weight consumed by ospreys on a diet of fish calculated from the simulation model developed by Wiens and Innis (1974), and a theoretical percent of body weight consumed by ospreys assuming a diet of mice.

1956). The caloric content of mouse flesh ranges between 1.4 and 1.8 kcal per g (wet-weight) (Haywood 1965, P.R. Cheeke personal communication). Therefore, if the osprey's diet consisted of mice, the bird would only need between 159 and 204 g (5.6 and 7.2 oz.) to obtain 286 kcal. The percent body weight consumed would vary between 10 and 12.7. Although the estimates computed from the model still seem to be high when compared to Craighead and Craighead's (1956) data, they appear to be more realistic. Physiological differences between great horned owls and ospreys, and the fact that the birds used in the Craigheads' study were partially restrained could account for the rest of the apparent discrepancy.

Impact on the Sport Fishery

Several assumptions were made in the assessment of the impact of the osprey population on the sport fishery at Crane Prairie Reservoir. These assumptions are as follows:

1. The catch by fishermen from Crane Prairie Reservoir in 1971 totaled 100,000 salmonids (J. Griggs personal communication).
2. The average salmonid caught by fishermen from the reservoir in 1971 was 28 cm (11 in.) long (Campbell and Locke 1970), and weighed 260 g (9 oz.). The average weight was determined by applying weight/length relationships calculated for rainbow and

brook trout from several lakes and streams in North America by Carlander (1969).

3. The average salmonid caught by ospreys from the reservoir in 1971 was 23 cm (9 in.) long (my estimate) and weighed 145 g (5 oz.) as estimated from Carlander's (1969) data.
4. The average tui chub caught by ospreys from the reservoir in 1971 was 18 cm (7 in.) long (my estimate) and weighed 116 g (4 oz.) as estimated from Kimsey's (1954) weight/length relationships of tui chubs at Eagle Lake, California.
5. The fish caught by ospreys from the reservoir in 1971 were 43 percent tui chubs and 57 percent salmonids (my estimate).
6. One gram (wet-weight) of fish has an energy value of 1 kcal (Winberg 1960).

Each assumption is an approximation due to the changing environmental factors that determine the weight/length relationship in fish and the possible inaccuracy of the estimates of the size of the fish taken by ospreys.

Mathematical analysis of the data provided by the simulation model (Wiens and Innis 1974), and use of the preceding assumptions reveal the following information about the impact of ospreys on the sport fishery at Crane Prairie Reservoir in 1971.

The total weight of the 100,000 salmonids caught by fishermen was 26,000 kg (57,320 lbs.). Because of the difference in average

weight of tui chubs and salmonids caught by ospreys (116 g and 145 g, respectively), 38 percent of the total weight caught was made up of tui chubs and 62 percent was salmonids. This is in contrast to the percentages of total numbers of fish caught (43 and 57 percent, respectively).

Ospreys caught a total of 15,963 salmonids weighing 2,314.6 kg (5,103 lbs.). This amounts to 14 percent of the number and 8 percent of the weight of salmonids caught by both fishermen and ospreys. Ospreys also caught 12,230 tui chubs totaling 1,418.6 kg (3,127 lbs.). In my judgment these data are not sufficient cause for concern since the reservoir already has an excellent sport fishery.

Individual Food Consumption

The average number of kcal required per day for the different age classes of ospreys is shown in Table 8. It was assumed above that 1 g wet-weight of fish contains 1 kcal. The calculation of average weights and numbers of different types of fish consumed by different age classes of ospreys becomes a simple matter as shown in the following example of food consumption by an adult osprey:

Daily energy requirement = 286 kcal which = 286 g

38 percent of the weight of fish consumed was tui chubs.

286 g x 0.38 = 109 g of tui chub

62 percent of the weight of fish consumed was salmonids.

286 g x 0.62 = 177 g of salmonid

The average tui chub caught by ospreys weighed 116 g.

109 g ÷ 116 g = 0.9 tui chubs

The average salmonid caught by ospreys weighed 145 g.

177 g ÷ 145 g = 1.2 salmonids

The results of similar calculations for nestlings, fledglings, and juveniles are shown in Table 9.

The theoretical numbers of fish consumed daily by ospreys at Crane Prairie Reservoir (Table 10) seem to be high when compared to observations made by D.S. MacCarter (1972) at Flathead Lake, Montana, and Garber (1972) at Eagle Lake, California. D.S. MacCarter (1972) reported that fish delivered to nests containing broods of one, two and three nestlings averaged 2.8, 2.0 and 3.9 per day respectively in 1969 and 3.8, 3.1, and 5.6 in 1970. Garber (1972) reported averages of 3.0, 3.5 and 4.1 fish delivered to broods of one, two and three respectively. However, both of these authors counted only those fish delivered to the nest. My observations indicate that the male osprey does virtually all of the foraging during the incubation and brooding periods. Furthermore, I observed many lone ospreys (presumably males) eating fish at a considerable distance

Table 9. Estimation of average daily consumption of fish by different age classes of ospreys at Crane Prairie Reservoir in 1971.

Age class	Grams of tui chub consumed daily	Grams of salmonid consumed daily	Total grams of fish consumed daily	Number of tui chubs consumed daily	Number of salmonids consumed daily	Number of fish consumed daily
Adult	109	177	286	0.9	1.2	2.1
Nestling	48	79	127	0.4	0.5	0.9
Fledgling	97	157	254	0.8	1.0	1.8
Juvenile	107	173	280	0.9	1.2	2.1

from any nest during those periods. If the male eats all of his food away from the nest, an average of 2.1 fish per day could be added to each of the numbers reported by D.S. MacCarter (1972) and Garber (1972). Adding 2.1 fish per day to the observed numbers in those studies provides totals comparable to the estimated calculations of fish consumed at Crane Prairie Reservoir (Table 10).

Also, D.S. MacCarter (1972) and Garber (1972) estimated the size of fish brought to the nest using a "size index" system where:

1 refers to fish less than 15 cm long,

2 refers to fish between 15 and 30 cm long,

3 refers to fish between 30 and 45 cm long, and

4 refers to fish in excess of 45 cm long.

The average fish brought to the nest in these two studies had a size index rating of 1.9. If we assume that a size index of 0.1 equals 1.5 cm (0.6 in.), the average fish would be about 29 cm (11.5 in.) long. My estimate of the average size of fish taken by ospreys at Crane Prairie Reservoir was 21 cm (8.1 in.). The differences in the estimates of the size of the average fish caught by ospreys was therefore another possible explanation for the differences in the estimated and observed numbers of fish consumed per day.

Based on comparisons with the studies of Craighead and Craighead (1956), Kennedy (1971), D.S. MacCarter (1972), and Garber (1972), the simulation model appears to be a relatively

Table 10. Estimation of consumption of fishes in relation to size of brood and age class of ospreys on the Crane Prairie Reservoir Osprey Management Area.

Type of fish	Number and Age Classes of Ospreys						
	2 adults	2 adults 1 nestling	2 adults 2 nestlings	2 adults 3 nestlings	2 adults 1 fledgling	2 adults 2 fledglings	2 adults 3 fledglings
Tui chubs	1.8	2.2	2.6	3.0	2.6	3.4	4.2
Salmonids	2.4	2.9	3.4	3.9	3.4	4.4	5.4
Totals	4.2	5.1	6.0	6.9	6.0	7.8	9.6

accurate means of estimating the energy requirements of osprey populations.

V. CONCLUSIONS AND RECOMMENDATIONS

The ospreys nesting on the Bend District of the Deschutes National Forest appear to be maintaining a stable population. With proper management (including some modification of timber harvest practices, maintenance of nesting structures in the pool area of Crane Prairie Reservoir, maintenance of fish populations at present or higher levels, and a public education program) this population should continue to maintain its numbers.

The reproduction of the population should continue to be monitored. I would recommend weekly visits to each nest in May to determine which pairs of ospreys are reproductively active, and three to five visits to each active nest in July and August to determine the number of young fledged.

The following recommendations should become part of the management plan in order to insure the provision of suitable nesting habitat for ospreys on the Bend District in the future:

(1) There should be no logging operations within 400 m (440 yd.) of an active osprey nest during the breeding season (April through August).

(2) When logging is conducted, the area contained within a 182 to 274 m (200 to 300 yd.) diameter circle around each existing forest nest should be preserved. The size of the area to be preserved

should be based on the location of the perch tree which should be inside the circle.

(3) When logging is conducted within 5 to 6 km (about 3 to 4 mi.) of a lake or stream that attracts foraging ospreys, at least one potential nest site should be preserved on each quarter section of the cut. This potential nest site should be a circle as described in number (2) above, and include at least one usable nest tree, one or more snags or snag-top perch trees, and five or more other large trees (from 50 to 100 years old) that will be available for use as nest or perch trees in the distant future.

(4) An area where no timber harvest is allowed should be established around all lakes and streams that attract foraging ospreys. This area should extend at least 45.7 m (50 yd.) from the shoreline.

(5) Artificial nesting platforms should be built within the pool area of Crane Prairie Reservoir to replace those established nesting structures which fall. These platforms should be placed as close as possible to the site of the original nest, and a structure for perching should be made available.

(6) If new water impoundments are established, an effort should be made to leave some trees standing in the pool area. These trees should protrude at least 3 m (10 ft.) above the high water line.

(7) A public education program to reduce the disturbance of nesting pairs of ospreys by humans should be instituted. This is most

important where ospreys are nesting over water. The desired result could probably be accomplished by erecting signs at strategic locations around the reservoir explaining the deleterious effects of certain human actions on the osprey population.

In my judgment, there is no cause to be concerned about the predation of ospreys on the sport fish in Crane Prairie Reservoir at present.

The osprey population on the Bend District is an unique ecological and aesthetic resource in Oregon. The U.S. Forest Service and the Oregon Wildlife Commission are to be commended for their efforts to maintain its well-being.

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APPENDIX

Pesticide and Mercury Analysis

The objectives of this study did not specify the collection and analysis of tissue for environmental contaminants. However, when the opportunity presented itself, samples were taken and subjected to analysis. The results of these analyses, which were performed by personnel of the Department of Agricultural Chemistry at Oregon State University, are presented in Tables A and B.

No conclusions were made as to the meaning of these data. Rather, they are presented here to provide base information for future studies.

Samples of osprey tissue were frozen within 24 hours of the death of the birds, and the egg and fish samples were frozen within 8 hours of collection.

Residues of pesticides and polychlorinated biphenyls (PCB's) were determined by gas chromatography, and those of mercury by atomic absorption spectrophotometry.

The three adults, and two of the fledgling ospreys were shot illegally by unknown persons. The third fledgling died as the result of a fall from its nest. The fish were taken from Crane Prairie Reservoir by hook and line.

Table A. Residues of pp' DDE, pp' DDT, pp' TDE, Dieldrin, PCB #1254, and total mercury in the tissues of one osprey egg, three adult ospreys, and three juvenile ospreys from the Bend District, Deschutes National Forest, Oregon. All residues are expressed in ppm wet weight.

Sample	Tissue	Mercury	pp'DDE	pp'DDT	pp'TDE	Dieldrin	PCB #1254
Osprey	egg	N.D.[a]	7.75	0.005	2.36	0.005	<0.01
Juvenile	muscle	0.058	0.10	0.005	0.005	0.005	<0.01
Juvenile	muscle	0.055	0.11	0.005	0.005	0.005	<0.01
Juvenile	muscle	0.034	0.07	0.005	0.005	0.005	<0.01
Adult ♀	muscle	0.53	0.96	0.005	0.005	0.005	<0.01
Adult ♂	muscle	1.55	0.87	<0.01	0.14	<0.001	<0.001
Adult ♂	muscle	0.82	9.70	<0.01	0.94	0.25	3.02

[a]No determination.

Table B. Residues of pp' DDE, pp' DDT, pp' TDE, Dieldrin, PCB #1254, and total mercury in the tissues of five species of fish taken from Crane Prairie Reservoir, Oregon in 1971. All residues are expressed in ppm wet weight.

Sample	Tissue	Mercury	pp' DDE	pp' DDT	pp' TDE	Dieldrin	PCB #1254
Rainbow trout	muscle	0.083	<0.002	<0.001	<0.001	<0.001	<0.001
	liver	none	N.D.[a]	N.D.	N.D.	N.D.	N.D.
	muscle	0.020	0.016	<0.001	<0.001	<0.001	<0.001
	liver	0.008	N.D.	N.D.	N.D.	N.D.	N.D.
Brook trout	muscle	0.011	N.D.	N.D.	N.D.	N.D.	N.D.
	liver	0.016	N.D.	N.D.	N.D.	N.D.	N.D.
	muscle	0.026	N.D.	N.D.	N.D.	N.D.	N.D.
	liver	0.020	N.D.	N.D.	N.D.	N.D.	N.D.
Coho salmon	muscle	0.027	N.D.	N.D.	N.D.	N.D.	N.D.
	liver	0.031	N.D.	N.D.	N.D.	N.D.	N.D.
	muscle	0.014	N.D.	N.D.	N.D.	N.D.	N.D.
	liver	0.018	N.D.	N.D.	N.D.	N.D.	N.D.
Tui chub	muscle	0.041	0.013	0.006	<0.001	<0.001	<0.001
	liver	0.029	N.D.	N.D.	N.D.	N.D.	N.D.
	muscle	0.033	<0.004	<0.001	<0.001	<0.001	<0.001
	liver	0.034	N.D.	N.D.	N.D.	N.D.	N.D.
Mountain whitefish	muscle	0.011	N.D.	N.D.	N.D.	N.D.	N.D.
	liver	0.013	N.D.	N.D.	N.D.	N.D.	N.D.

[a]No determination.