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FACTORS AFFECTING THE PRODUCTIVITY OF OSPREYS NESTING IN WEST-CENTRAL IDAHO

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ABSTRACT.—An Osprey (*Pandion haliaetus*) population nesting in the vicinity of Cascade Reservoir in west-central Idaho was studied for three years. The area supported about 50 nesting pairs, which laid an average of 2.58 eggs and fledged an average of 1.37 young per active nest throughout the study. These productivity estimates suggest a healthy, increasing population. Most nests were atop snags (66%) and on private land (70%). Ospreys nesting on artificial sites and those nesting more than 1,500 m from human disturbances produced more offspring. Fish in the 11–30 cm range constituted the bulk of the diet (89%) with brown bullheads being the most important prey species (38%). Osprey captures reflected prey availability. Establishment of Cascade Reservoir increased the availability of fish, which, in turn, allowed the Osprey population to increase. Productivity of these hawks appears to be chiefly related to reservoir level and prey availability.

A large concentration of Ospreys (*Pandion haliaetus*) nest in Long Valley, Valley County, Idaho. Early census data indicate that this area contained fewer than a dozen Osprey nests in the late 1940's (Larrison et al. 1967). Although the nests were not studied intensively at that time, comparisons with recent data suggest that the population has increased since Cascade Reservoir was formed in 1948. In the past decade, the human population of Long Valley has increased 56% (State of Idaho 1980) and recreational use of Cascade Reservoir has intensified. In light of expanding human pressure on this unique Osprey habitat, the U.S. Bureau of Reclamation sponsored a three-year (1978–1980) investigation to collect base-line information on this population. The objectives were to: 1) census the population and determine its productivity, 2) identify factors influencing nest site selection and nesting success, and 3) ascertain feeding habits.

STUDY AREA

Long Valley is located in west-central Idaho approximately 100 km north of Boise, Idaho (Fig. 1). The area is a broad, flat, glacial valley with a mean elevation of 1,525 m. Vegetation in the valley ranges from agricultural grasslands to dense riparian stands of lodgepole pine (*Pinus contorta*). Long Valley is surrounded by granitic mountain ranges with peaks to 2,750 m. Ponderosa pine (*Pinus ponderosa*), grand fir (*Abies grandis*) and Douglas fir (*Pseudotsuga menziesii*) comprise the dominant overstory vegetation on the hillsides.

Precipitation varies from about 57 cm in the valley to 125 cm in the higher elevations, with most received as snow (N.O.A.A. 1978–1980). The average growing season in the valley is 65 days, and large bodies of water remain frozen until late April.

For the purpose of this investigation, we divided the Long Valley Osprey population into three subpopulations: Payette Lakes, Cascade Reservoir and Warner Pond. These subpopulations do not represent discrete biological units, but reflect the nesting habitat of the Ospreys.

Ospreys in the Payette Lakes subpopulation nest near Payette and Little Payette lakes. These deep, glacial lakes support populations of salmonids and northern squawfish (*Ptychocheilus oregonensis*). Water levels in both lakes have been raised for irrigation. Trees killed as a result of this, and those on steep hillsides around the lakes, provide Ospreys with nest sites.

In 1948, the U.S. Bureau of Reclamation completed a dam on the North Fork of the Payette River near Cascade, Idaho. The resulting reservoir is about 27 km long and ranges in width from 1.6 to 6.4 km. Its mean depth at high water is 7.6 m. This shallow, large reservoir (surface area 11,452 ha; U.S.G.S. 1980) supports an abundance of warm-water fishes, including yellow perch (*Perca flavescens*), northern squawfish, largescale sucker (*Catostomus macrocheilus*) and brown bullhead (*Ictalurus nebulosus*). Smaller populations of salmonids, including rainbow trout (*Salmo gairdneri*), mountain whitefish (*Prosopium williamsoni*), coho salmon (*Oncorhynchus kisutch*) and kokanee salmon (*O. nerka*) are also present. Ospreys nest on hillside snags near Cascade Reservoir.

In the Warner Pond subpopulation, Ospreys nest near three small reservoirs along tributaries of the North Fork of the Payette River (Warner Pond, Horsethief Reservoir and Corral Creek Reservoir). Rainbow trout have been introduced into these reservoirs; however, fluctuations in water levels between and within years affect the sizes of these fish populations. Snags and large conifers provide abundant nesting sites for Ospreys in this area.

METHODS

PRODUCTIVITY

We located Osprey nests by ground and aerial searches, and by interviewing local residents. We then counted nesting pairs, their eggs and young of fledging age during two helicopter flights (Carrier and Melquist 1976) each nesting season. The first flight was made in early June to count eggs and territorial pairs. Each nest encountered was categorized as active, occupied, or inactive. Nests that were defended and contained eggs were classified as "active." "Occupied" nests had at least one Osprey present but no eggs in the nest. A nest was considered "inactive" if we saw no Osprey in the vicinity and no new nesting material on the nest. During the second flight, in late July, we counted nestlings. We used data obtained during these flights to calculate various productivity parameters including mean clutch size, young per occupied territory (active and occupied nests), young per active nest and per successful nest, and overall nesting success. By employing one-way analysis of variance tests (ANOVA) and *t*-tests (Zar 1974), we were able to isolate any variations in productivity parameters among nesting subpopulations and among nesting seasons.

NEST SITES

Each nest site was numbered and visited at least once to determine its exact location, type of nest support structure and nest height. We estimated elevations from U.S. Geological Survey topographic maps. Distances of nests from fishable water, nearest active Osprey nest and nearest human disturbance (i.e., major road, occupied home, etc.) were estimated from U.S. Forest Service 1:31,680 quadrate maps. Nests in the vicinity of Horsethief Reservoir were excluded from an analysis of factors influencing productivity because we were unable to determine their exact locations. Elevation of the nest site was not considered an important biological factor, and therefore was not subjected to statistical analysis.

Nest heights were recorded in four categories: <5 m, 5–10 m, 10–20 m, >20 m.

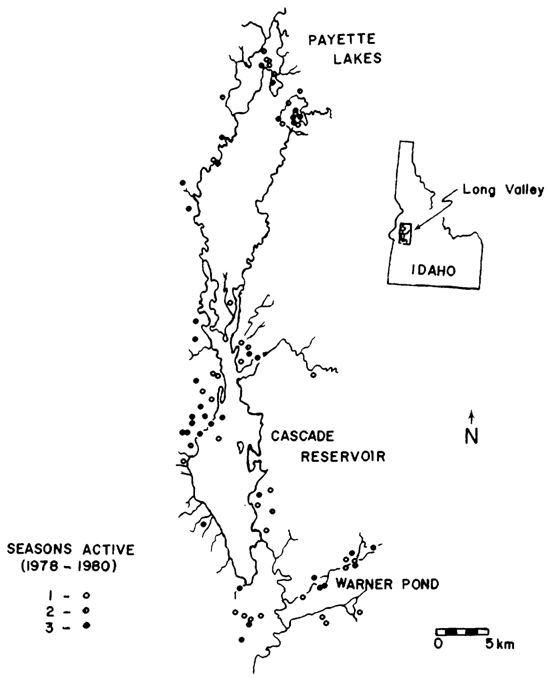

FIGURE 1. Locations and seasons of use of active Osprey nests in Long Valley, Idaho, 1979–1980.

Numbers of young Ospreys produced within height categories were then compared with an ANOVA test. A similar test was employed to compare the productivity of Ospreys within categories of nest support structure (snag, live tree, power pole or nesting platform). If the ANOVA test indicated a significant difference in these types of nest sites, *t*-tests were used to isolate the differences. Distances of nests to water, active Osprey nests and human disturbance were recorded to the nearest meter and segregated into three categories: close (<500 m), mid-distance (500–1,500 m), and far (>1,500 m). Productivity in each of the categories was then analyzed with ANOVA and *t*-tests.

FEEDING HABITS

We investigated the feeding habits of Ospreys at Cascade Reservoir by direct observation of nesting, perching and foraging sites, noting prey species and size, capture time and location. Intensive (dawn to dusk) observations were conducted at least once a week throughout the 1978 and 1979 field seasons (April to August) to obtain detailed information on prey deliveries to an active nest. Differences in the number of prey captured on specific dates of nestling development between years were tested with a chi-square test.

To estimate the availability of various prey items to Ospreys, we worked with personnel

TABLE 1. Average number of young Ospreys produced per active nest in Long Valley, Idaho, 1978–1980.

Location	1978	1979[a]	1980	Total
Cascade Reservoir	1.17 (27/23)[c]	1.89 (49/26)	1.64 (46/28)	1.58 (122/77)
Warner Pond	1.50 (9/6)	1.00 (13/13)	1.00 (5/5)	1.13 (27/24)
Payette Lakes	1.00 (11/11)	1.13 (18/16)	1.17 (14/12)	1.10 (43/39)
Long Valley total[b]	1.18 (47/40)	1.46 (80/55)	1.44 (65/45)	1.37 (192/140)

[a] Significant difference ($P < 0.05$) in 1979, Cascade Reservoir ospreys were more productive than either Warner Pond or Payette Lakes ospreys.
[b] No significant difference.
[c] (Young Ospreys/active nests).

of the Idaho Department of Fish and Game setting horizontal gill nets and "Fyke" nets to sample fishes in the upper 2 m at various locations in Cascade Reservoir in 1979 and 1980. Net captures were compared with Osprey captures by means of chi-square and Bonferoni-z tests (Neu et al. 1974). Fish obtained from the nets were weighed and measured. A linear regression formula (length vs. $\log_{10}$ weight) was applied to these data to generate a model for predicting prey weight and biomass from length.

We periodically collected prey remains from below Osprey nests and perches, and compared them to a reference collection to determine species (Swenson 1978). Opercular (gill cover) bones were used in a model to estimate prey size (Newsome 1977, Prevost 1977). We constructed the operculum model by collecting and measuring average maximum operculum lengths from fish of known lengths obtained in the net samples. Linear regression analysis was employed to create a predictive model of total fish length from operculum length. Chi-square analysis was used to compare prey collections to visual observations of Osprey captures.

RESULTS

PRODUCTIVITY

During the three nesting seasons of this study, we found 110 Osprey nests in the Long Valley area. In 1978, 40 nests were active and 2 occupied, in 1979, 58 active and 3 occupied, and in 1980, 46 active and 6 occupied (Fig. 1). Territorial, nonbreeding pairs constituted 7.3% of the population during the study. Clutch sizes averaged 2.58 eggs per active nest and did not change significantly ($P > 0.05$) among years or subpopulations. Sixty-eight percent of the nesting attempts were successful in fledging at least one young, and 66% of the eggs laid developed into fledglings. Productivity averaged 1.37 young per active nest; however, the three subpopulations differed significantly ($P < 0.05$) in 1979. During that year, Ospreys nesting near Cascade Reservoir produced significantly more young per active nest than those nesting in the other subpopulations (Table 1). The number of young per successful nest averaged 2.00 but differed significantly among years ($P < 0.05$; Table 2). Average number of young produced per territorial pair was 1.27 and did not change significantly among years. The nesting chronology of these Ospreys resembled that of Ospreys nesting in north Idaho (Melquist 1974). In the Long Valley population, the nesting period averaged 50 to 60 days.

NEST SITES

All Osprey nests in Long Valley had a relatively unobstructed view of their surroundings and all had at least one nearby perch where the male rested. Nest site elevations ranged from 1,463 to 1,768 m and averaged 1,557 m. There appeared to be no shortage of suitable nesting sites in the study area. Most Osprey nests (82%) were built more than 20 m from the ground and most were on private land (70%). Productivity did not differ significantly ($P > 0.05$) between the nest height categories.

Although most nests were on snags, such nests had the lowest productivity (Table 3). Productivity differed significantly ($P < 0.05$)

TABLE 2. Average number of young Ospreys produced per successful nest in Long Valley, Idaho, 1978–1980.

Location	1978	1979	1980	Total
Cascade Reservoir	1.69 (27/16)[b]	2.33 (49/21)	2.19 (46/21)	2.10 (122/58)
Warner Pond	1.80 (9/5)	1.63 (13/8)	1.67 (5/3)	1.69 (27/16)
Payette Lakes	1.57 (11/7)	2.57 (18/7)	1.75 (14/8)	1.96 (43/22)
Long Valley total[a]	1.68 (47/28)	2.22 (80/36)	2.03 (65/32)	2.00 (192/96)

[a] Productivity in 1978 was significantly lower ($P < 0.05$) than in 1979 or 1980.
[b] (Young Ospreys/successful nests).

TABLE 3. Osprey productivity as related to nest support structure in Long Valley, Idaho, 1978–1980. Percent in parentheses.

	Type of support structure				
	Snag	Live tree	Power pole	Nesting platform	Total
Active nests	84 (66.1)	25 (19.7)	11 (8.7)	7 (5.5)	127 (100.0)
Young produced	101 (56.4)	39 (21.8)	22 (12.3)	17 (9.5)	179 (100.0)
Average young per active nest[a]	1.20	1.56	2.00	2.43	1.41

[a] Natural sites (snag and live tree) significantly less productive than artificial sites (power pole and nesting platform; $P < 0.05$).

between snags and artificial sites (power poles and artificial nesting platforms) and between natural sites (snags and live trees) and artificial sites.

We noted no significant differences ($P < 0.05$) in productivity relative to the distance of a nest to fishable water or other active Osprey nest. The categorical distance from human disturbances was found to affect productivity significantly ($P < 0.05$). Further analysis indicated that nests farther than 1,500 m were significantly more productive than those nests closer to regular human activities (Table 4).

FEEDING HABITS

All Osprey prey items seen and collected from below perches and nests were fish, and Ospreys were observed fishing in all areas of Cascade Reservoir. We saw Ospreys from the Warner Pond subpopulation regularly fishing at Cascade Reservoir, and prey collections at nests up to 10 km from the reservoir revealed bullhead remains. In the valley, this species is restricted to Cascade Reservoir.

The diet of Long Valley Ospreys consisted primarily of brown bullheads (Table 5), with prey items usually in the 11–30 cm size class (Table 6). Diet changed significantly ($P < 0.05$) in composition by month (Fig. 2), especially with respect to salmonids and squawfish. A change approaching significance ($0.10 > P > 0.05$) was noted between 1978 and 1979 in the dietary composition of the Ospreys at our intensive observation nest (Table 7). Although it is impractical to extrapolate this change to the entire population, we noted a significant increase ($P < 0.05$) in the number of squawfish taken when the reservoir level was low (1979) versus when the level was high (1978). Comparing Osprey captures with net captures from Cascade Reservoir, the hawks caught significantly more ($P < 0.05$) bullheads and salmonids, and fewer squawfish, perch and suckers than were caught in the nets (Table 5).

Intensive observations of nesting Ospreys in 1978–1979 indicated that males captured 95% of the prey brought to the nest. These deliveries occurred throughout the day; however, most were during the morning and late afternoon–early evening (Fig. 3). The timing of prey deliveries was constant in both years and throughout the nesting seasons, regardless of the number of young in a nest.

After eggs hatched, adults brought an average of 4.6 fish per day to a nest with two young, and 5.6 fish per day to a nest with three young. Compared with Garber's (1972) data for prey deliveries at Eagle Lake, California, Ospreys of the Long Valley population followed a similar delivery pattern, but consistently delivered more prey per day.

Analysis of prey biomass brought to nestlings is a more meaningful statistic than the number of fish delivered daily. Using a model developed by Wiens and Innis (1974), Lind (1976) calculated that adult Ospreys require 286 kcal per day, and juveniles of fledging age need 254 kcal per day. Winberg (1960) estimated fish to contain 1 kcal per gram body weight. Using these values, a nest with two young and one adult (male Ospreys rarely ate

TABLE 4. Osprey productivity as related to the distance of the nest site to human disturbance, Long Valley, Idaho, 1978–1980. Percent in parentheses.

	Distance to human disturbance[a]			
	Close (<500 m)	Mid-distance (500–1,500 m)	Far (>1,500 m)	Total[b]
Active nests	70 (55.1)	32 (25.2)	25 (19.7)	127 (100.0)
Young produced	95 (53.1)	36 (20.1)	48 (26.8)	179 (100.0)
Average young per active nest[c]	1.36	1.13	1.92	1.41

[a] Regular human disturbance (well traveled road, occupied dwelling, etc.).
[b] Average distance from human disturbance = 770 m (2526′).
[c] Far nests significantly more productive than mid-distance or close nests ($P < 0.05$).

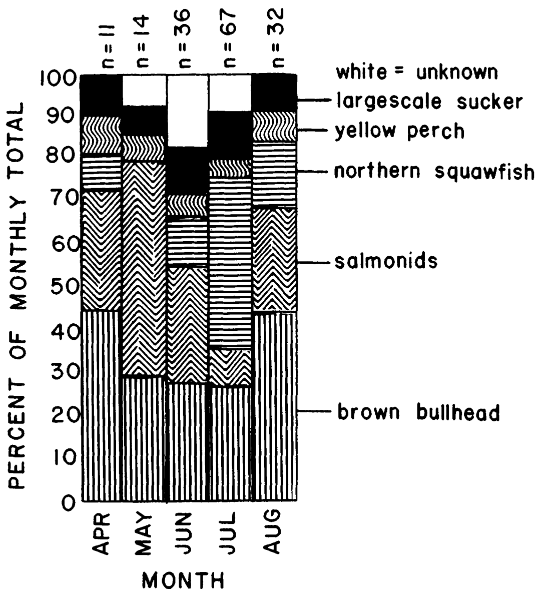

FIGURE 2. Prey consumption, by month, of Ospreys nesting in Long Valley, Idaho, 1978–1979.

at the nest) would require 794 g of fish per day at fledging time, and a nest with three young and one adult would require 1,048 g. Although prey deliveries were more erratic in 1978 (two young) than in 1979 (three young), the calculated minimum requirement was achieved prior to fledging in both years (Fig. 4). In both years, males spent an average of 40% of the daylight hours perched near the nest, a pattern similar to that noted by Stinson (1978). In 1978 males were, however, away from the nest for significantly ($P < 0.05$) longer periods of time than in 1979.

We used fish captured by nets to regress operculum lengths on total lengths and, thus, determine the size of fish captured based on prey remains at perching and nesting sites. Correlation coefficients (r) in linear regression models of total fish lengths to operculum lengths ranged from 0.95 to 0.99 for the five prey groups tested ($n = 52–136$). Operculum shapes were sufficiently different to allow species identification except in the case of salmonids. Thus, mountain whitefish, rainbow trout, coho salmon and kokanee salmon were only identified to the family level. The species composition of opercula found at perching and nesting sites was not significantly different ($P > 0.05$) from what we observed captured by Ospreys. However, in prey collections from perching sites, yellow perch were significantly more abundant than in collections from below nests ($P < 0.05$). This suggests that collections must be made from both perching and nesting sites in order to obtain an accurate estimate of the diet of these birds.

TABLE 6. Size of fish taken as prey by Ospreys in Long Valley, Idaho, 1978–1980. Percent in parentheses.

Size class	Number taken by Ospreys
0–10 cm	5 (3.3)
11–20	64 (42.1)
21–30	71 (46.7)
31–40	10 (6.6)
41+	2 (1.3)
Total	152 (100.0)

DISCUSSION

A long-term productivity average of 0.95–1.30 young per active nest (Henny and Wight 1969, Henny 1977) and a population composed of 5–10% nonbreeding pairs (Henny and Van Velzen 1972) have been suggested for the maintenance of a stable Osprey population. During our study, the Long Valley population met or exceeded these productivity and recruitment requirements necessary for stability. These productivity estimates compare favorably with those of other stable Osprey populations (Henny 1977, MacCarter and MacCarter 1979, Newton 1979) and they sug-

TABLE 5. Summary of Osprey prey captures versus net captures in Cascade Reservoir, Idaho, 1978–1980. Sample size in parentheses.

Prey species	Observed Osprey captures	Gill and Fyke net captures
Brown bullhead	37.7% (78)	7.6% (75)
Salmonids[a]	20.8 (43)	5.9 (58)
Northern squawfish	19.3 (40)	36.4 (359)
Yellow perch	11.6 (24)	28.4 (280)
Largescale sucker	10.6 (22)	21.7 (214)
Total	100.0 (207)	100.0 (986)

[a] Includes rainbow trout, coho salmon, kokanee salmon and mountain whitefish.

TABLE 7. Prey items brought to an Osprey nest on Gold Fork Arm of Cascade Reservoir, Idaho, 1978–1979. Sample size in parentheses.

Prey species	1978	1979
Brown bullhead	36.4% (20)	22.2% (16)
Salmonids[a]	23.6 (13)	18.1 (13)
Northern squawfish	10.9 (6)	33.3 (24)
Largescale sucker	10.9 (6)	11.1 (8)
Yellow perch	5.5 (3)	5.6 (4)
Unknown	12.7 (7)	9.7 (7)
Total	100.0 (55)	100.0 (72)

[a] Includes rainbow trout, coho salmon, kokanee salmon and mountain whitefish.

gest that the population is continuing to increase.

The growth of this population is largely due to local nesting success, since most Ospreys return to breed in the vicinity of their natal areas (Henny and Van Velzen 1972, Henny 1977). As Österlöff (1977) noted, however, some Ospreys establish their first breeding territories more than 1,000 km from their natal areas. Therefore, some members of the breeding population may be recruits from other populations in the western United States. Regardless of origin, it is evident that the population increase has been favored by the habitat improvement provided by local reservoirs, especially Cascade Reservoir. Ospreys can readily pioneer new habitat (Henny and Noltemeier 1975) and reservoir development has been responsible for much of the expansion of the breeding range of Ospreys throughout the western United States (Roberts and Lind 1977, Henny et al. 1978a, b). Before Cascade Reservoir was formed, Long Valley's cool climate and deep lakes probably provided marginal habitat for Ospreys. Reservoir development and subsequent management practices have produced an excellent shallow-water fishery and, thus, abundant food for these birds. The

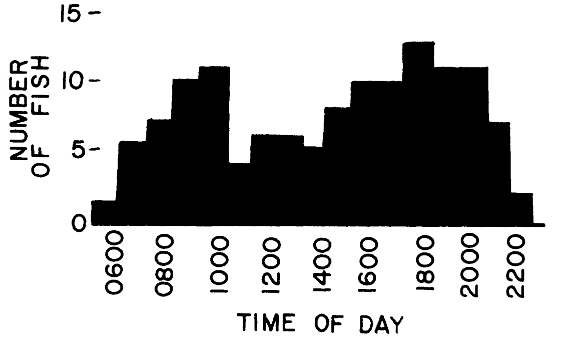

FIGURE 3. Timing of prey deliveries to an Osprey nest in Long Valley, Idaho, 1978–1979.

importance of Cascade Reservoir to Ospreys is evident from the fact that 65% of the Ospreys nesting in Long Valley regularly fish in the reservoir, some flying up to 10 km to do so.

During the course of our study, weather changes may have accounted for some of the variation in the length of the nestling period and productivity. Ospreys nesting in similar habitat in Sweden also had lower productivity following cold, wet springs (Odsjö and Sondell 1976). The most important factor influencing productivity in Long Valley, however, was prey

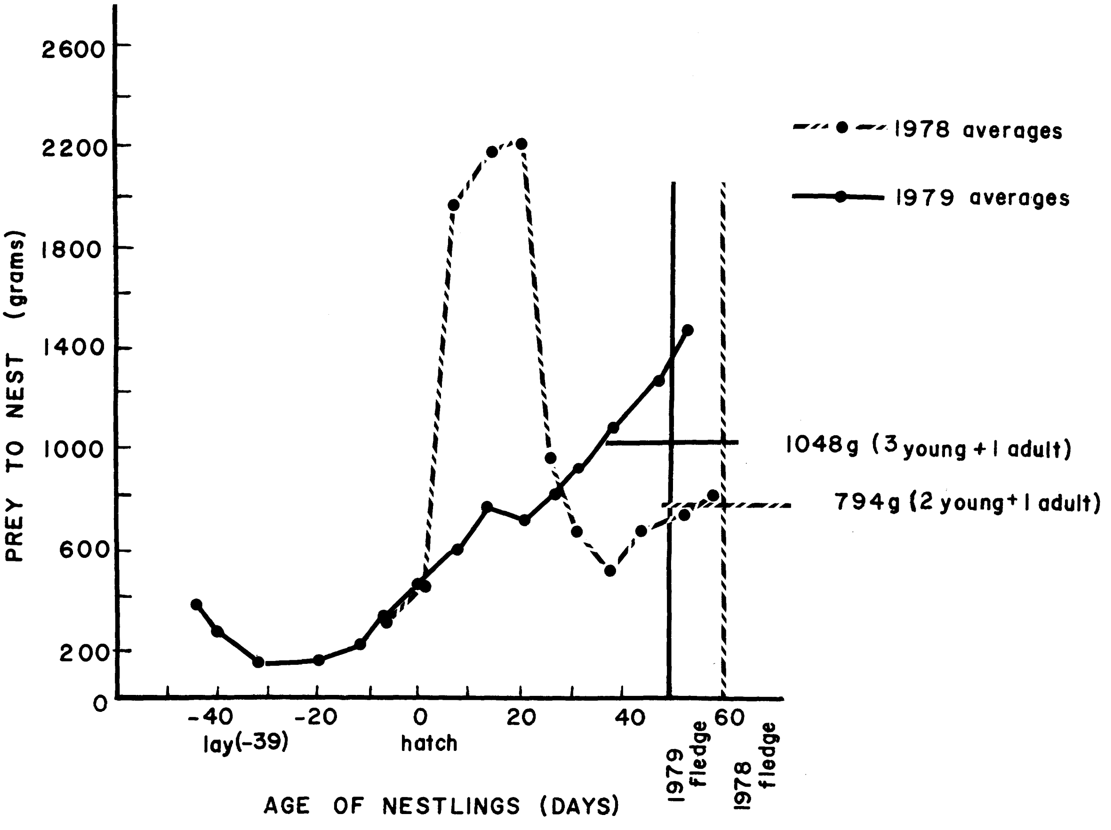

FIGURE 4. Prey biomass delivered to an Osprey nest in Long Valley, Idaho, 1978–1979. Averages are three-day moving averages.

availability. Significant productivity changes noted in the Cascade Reservoir subpopulation during this study were related to changes in water levels. Productivity was highest in 1979, the year of the lowest water levels. Observations of a nesting Osprey pair indicated that the male spent significantly more time away from the nest site, and that he delivered fewer fish during the high-water years. Although intensive data are available only from this nest, observations of other nesting pairs around the reservoir substantiate the hypothesis that prey was more readily available to Ospreys at Cascade Reservoir during the year of low water. Similar numerical responses in the form of increased productivity to an increase in prey availability have been noted in other western U.S. Osprey populations (Koplin et al. 1977, MacCarter and MacCarter 1979). Although productivity is reduced, sufficient prey are secured during the years of high reservoir levels to meet productivity requirements for a stable population. However, increased prey availability during the low-water period improves productivity and enhances the opportunities for continued expansion of the population.

The diet of Ospreys changed among and within years, apparently in response to changes in prey availability. Bullheads were more readily available to Ospreys than net samples indicated, because they rest near the surface of the reservoir on warm days and they avoid predators less. Swenson (1979) noted that benthic-feeding fishes are often more vulnerable to Osprey attack than predaceous species which have a better predator avoidance response. This hypothesis may explain why Ospreys took fewer squawfish and perch than were apparently available; however, one would expect suckers to be taken more because of their sluggish behavior. Most suckers caught in nets were too large to be easily captured by Ospreys and, hence, were not available as prey. Salmonids spawn throughout most of the Osprey nesting season in Long Valley, rendering them vulnerable to predation. Yet the bulk of the salmonid catch occurred in May, when 35,000 to 50,000 "catchable-sized" rainbow trout were released into Cascade Reservoir (D. Anderson, Idaho Fish and Game, pers. comm.). These hatchery-raised trout were unfamiliar with their surroundings and vulnerable to predation. Fish injured in the stocking process may have formed a part of the catch also.

Ospreys caught more squawfish in a low-water year than in a high-water year because of squawfish spawning behavior. Squawfish spawn in the arms of Cascade Reservoir in late June and early July (Casey 1962). Shallow spawning areas increase squawfish vulnerability to Osprey capture. Since squawfish were the most important prey item in July, changes in their availability were largely responsible for the differences in the fishing success of male Ospreys between high and low-water years. Our data show that Ospreys did not actively select for or against fish species in Cascade Reservoir. Instead, capture rates reflect the vulnerability of each species to capture. Prevost (1977) saw an analogous response of increased capture success of more readily available prey by Ospreys nesting in Nova Scotia.

Ospreys are known to be adaptable and highly mobile raptors. These traits allow them to nest successfully in a variety of conditions (Henny et al. 1974, Henny and Noltemeier 1975, Lind 1976, Spitzer 1977) and readily adjust to some human disturbances. The only nest site parameters which affected productivity in Long Valley were the type of structure on which nests were built and the distance of the nests from human disturbances. Osprey pairs nesting on artificial sites were the most productive because these sites provided a stable support, minimizing the chance of blowdowns during severe wind storms. Most of these sites were also isolated from human disturbances, either by their height or location. Other studies have reported greater productivity on artificial structures; however, nesting success on artificial structures has not been higher in every instance (Peterson 1969, Melquist 1974, Rhodes 1977, Postupalsky 1978, Van Daele 1980).

During our study, Ospreys nesting more than 1,500 m from human disturbances were the most productive, yet the birds frequently nested close to humans. Habituation to human activities appeared to vary depending on the frequency of disturbance. Ospreys nesting near humans eventually tolerated their activities while those nesting farther from humans were less tolerant. Productivity information and subjective observations substantiate this conclusion. Ospreys nesting close to humans generally stayed on their nests longer and were more territorial during our approaches than those nesting at a greater distance, particularly during the incubation period. Spitzer (1977) indicated that Osprey eggs must be kept at 29–36°C to remain viable, and our observations revealed that Ospreys at successful nests incubated 99.5–100% of the daylight hours. Disturbances during the critical periods of incubation and early nesting stages can be fatal to embryos and nestlings if adults are kept from their nests. Therefore, until an Osprey pair becomes habituated to human activities, such activities will jeopardize their nesting success.

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