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August 2004

Prepared for
the U.S. Army Corps of Engineers
Walla Walla District
Walla Walla, Washington
under Contract DACW68-02-D-0001

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Summary

Piscivorous birds, such as gulls and terns, prey upon millions of juvenile salmonids annually as they migrate from the Columbia River Basin. Hydroelectric dams are known to attract piscivorous birds because smolts are concentrated via bypass outfalls and may become injured or disoriented subsequent to dam passage. Studies conducted in the mid- and upper-Columbia River Basin have documented avian predation rates up to 2% and 3% of the juvenile salmonids that migrated past a known "hot spot." Although American white pelicans (*Pelecanus erythrorhynchos*) are thought to prey primarily upon larger fish, persistence and use patterns below the McNary Dam complex has implicated them as contributors to the juvenile salmonid predation problem. The U.S. Army Corps of Engineers, Walla Walla District, initiated a study conducted by researchers from Battelle in 2002 and 2003 to provide baseline data to quantify the extent of predation by American white pelicans in the McNary Pool and Tailrace. This information was needed to assess fish passage conditions at McNary Dam.

Observational studies in both 2002 and 2003 indicated that pelican presence and foraging efforts below the McNary Dam tailrace generally corresponded to the temporal pattern of juvenile salmonid outmigration. Maximum and mean weekly pelican counts recorded in the immediate vicinity of McNary Dam during 2003 consistently exceeded those recorded during the 2002 outmigration season. Instantaneous counts of 80 to 120 birds were common within 1 km of the dam during June and July of 2003. Foraging rates throughout the 2002 outmigration season were highest immediately below the juvenile bypass outfall (JBO). During 2003, however, pelican use and foraging efforts decreased near the JBO and increased near the spill gates. Factors that appeared to affect changes in use and foraging patterns by pelicans near McNary Dam between 2002 and 2003 include the relative number of pelicans, bird deterrent activities, and spill rates.

Eleven adult birds were successfully captured, marked using patagial and radio frequency (RF) tags, and released near McNary Dam in 2003. Seven tagged birds were never relocated after being released, suggesting some portion of the foraging birds were from a transient population. The remaining tagged birds were repeatedly found in the McNary Dam tailrace area, within 1 km of the dam, or at the Umatilla Wildlife Refuge, approximately 7 km downstream of McNary Dam. None of the birds tagged were found near the local breeding colony, located approximately 20 km upstream of McNary Dam.

Two methods were used to estimate total salmonid consumption for pelicans based on bird abundance and predation estimates documented in the vicinity of McNary Dam during the outmigration season. One method used observed foraging rates of pelicans in the tailrace and the other method used the daily energetic requirements of an average adult pelican. Consumption estimates varied considerably between the two estimator techniques. Using pelican foraging rates observed at the McNary dam tailrace during 2003, an estimated 27, 688 individual smolt were consumed by pelicans during the smolt outmigration period. This estimate was low compared to 169,345 individual smolt that were estimated to be eaten using simple energetic model for pelicans and the mean weekly relative abundance index of pelicans observed in the McNary tailrace during 2003.. Both salmonid consumption estimator techiniques were likely biased high by assuming that 100% of the pelican's diet consisted of salmonids, and that all fish eaten were healthy and otherwise would have survived. Limited diet composition results obtained while trapping pelicans in 2003 indicated salmonids were not 100% of the pelican's diet there. Pelicans were also observed swallowing suckers and shad on several occasions and scavenging dead or injured fishes that emerged on the water's surface immediately below the dam in 2002 and 2003.

Acronyms

AFEP	Anadromous Fish Enhancement Project
ANODEV	Analysis of Deviation
JBO	juvenile bypass outfall
NMFS	National Marine Fisheries Service
PI	pelican abundance index
PNNL	Pacific Northwest National Laboratory
RF	radio frequency
SI	smolt out-migration index
USACE	U.S. Army Corps of Engineers
VHF	very high frequency

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1.0 Introduction

1.1 Background

Piscivorous birds, such as gulls and terns, prey upon millions of juvenile salmonids annually as they emigrate from the Columbia River Basin (Jones et al. 1998; Roby et al. 1998). Hydroelectric dams are known to attract piscivorous birds because smolts are concentrated via bypass outfalls. Smolts may also become disoriented and more vulnerable to predation immediately below the dam complexes. Studies conducted in the mid- and upper-Columbia River Basin have documented avian predation rates up to 2% and 3% of the juvenile salmonids that migrated past a known "hot spot" (Ruggerone 1986; Phinney et al. 1998).

Although American white pelicans (*Pelecanus erythrorhynchos*) are thought to prey primarily upon large fish, persistence and use patterns below the McNary Dam complex has implicated them as contributors to the juvenile salmonid predation problem. In 2000, up to 72 American white pelicans were observed along the Oregon shore of the Columbia River, a short distance below the McNary Dam juvenile facility during the spring migration period (National Marine Fisheries Service [NMFS] 2000). Also, pelican numbers have dramatically increased in recent years on the Yakima River, particularly near the smolt-rearing and acclimation sites.[(a)] The ISO-PIT tag recovery program, supported by the NMFS, has found salmonid pit tags in the pelican's colony, located approximately 20 km upstream of McNary Dam during 2001 (Ryan et al. 2002). ISO-PIT tag detections at bird colonies probably underestimate juvenile salmonid consumption rates because pelicans eliminate ingested pit tags via defecation at loafing sites or foraging sites, as well as potential nesting sites. In addition, it is unknown whether breeding pelicans forage near the hydroelectric facilities.

Breeding pelicans in Washington State have been absent since the early 1900s, until a single colony (approximately 30 pair) was discovered on one island in the Columbia River in 1994 (Ackerman 1994). The State of Washington Department of Fish and Wildlife lists the American white pelican as "endangered." Although large numbers (exceeding 100 pairs) of pelicans have been observed nesting at this single Badger Island colony (located approximately 20 km upstream of McNary Dam), no formal studies of nesting birds of this population have been done since the first reported occurrence. In addition, non-breeding and migrant populations of pelicans may also use the McNary Dam area during the salmonid outmigration.

Losses of juvenile salmonids to predation by American white pelicans could be significant. Adult American white pelicans require an estimated 1.8 kg of fish per day (Terres 1980), an amount equal to 36 juvenile salmonids per day per bird, assuming that 50-g juvenile salmonids were the pelican's entire daily diet. A population of ~ 60 birds near McNary Dam could therefore consume as much as 64,800 juvenile salmonids during the 30-day spring outmigration period. This can be compared to the number of juvenile salmon consumed by gulls at Bonneville Dam (11,100 to 36,000—Jones et al. 1998) and at Wanapum Dam (111,750—Ruggerone 1986).

To assess the potential extent of consumption of salmonids by pelicans near McNary Dam, the Walla Walla District of the U.S. Army Corps of Engineers (USACE) contracted with Battelle in 2002 to

(a) Personal communication from Doug Florh, Washington Department of Fish and Wildlife

quantify pelican numbers and their diel foraging efforts in the vicinity of the McNary Dam tailrace area during the juvenile salmonid outmigration season. During 2002, monitoring showed seasonal fluctuations in pelican numbers using the McNary Dam area. Pelican numbers increased around the time of the smolt outmigration peak. The area that had the highest consistent use and foraging effort by pelicans during 2002 was near the Oregon shore just below the juvenile bypass outfall (JBO), suggesting that the pelicans may be responding to smolt passage (Tiller et al. 2003). This work was continued during 2003 with the addition of capturing and tagging some pelicans in the tailrace area to assess site fidelity, use patterns, and foraging rates near McNary Dam.

1.2 Study Area

The primary study site for pelican foraging was the McNary Dam tailrace. McNary Dam is located on the Columbia River approximately 470 km from the Pacific Ocean (river mile 292). Approximately 20 km upriver from the dam is Badger Island (Figure 1), where the only active breeding colony of American white pelicans exists in Washington State.

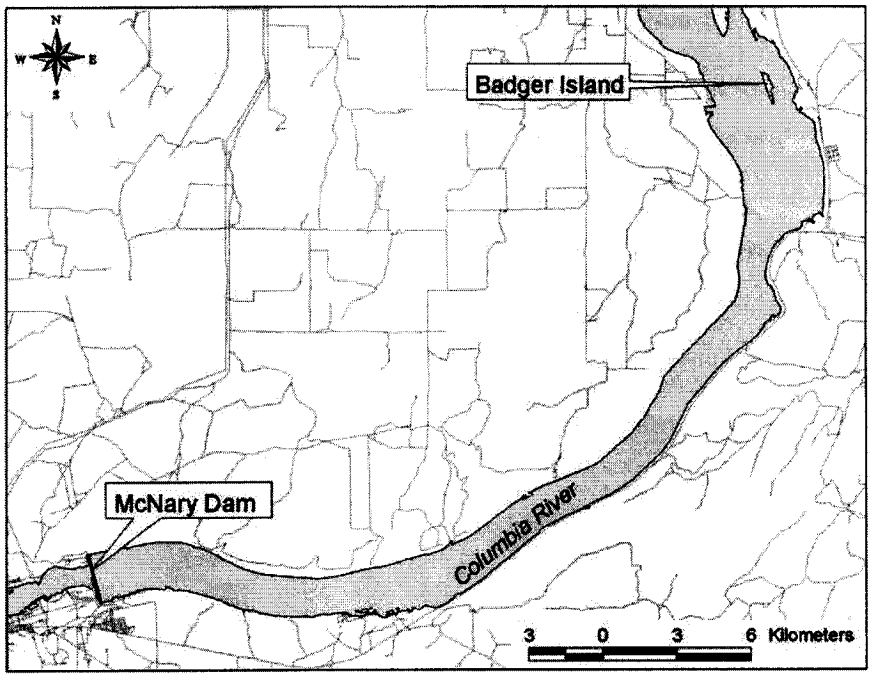

Figure 1. Map of McNary Dam and Pool Area Showing Location of Badger Island

2.0 Methods

2.1 Pelican Abundance

Observations of pelicans were made using 15 × 35 mm or 10 × 70 mm binoculars and a 12-36 × 50 mm spotting scope. Nighttime observations were made using ITT Night Quest G3 night-vision binoculars. Each day was stratified into five survey periods, as shown in Table 1.

The area immediately below the dam was divided into five observation zones to provide spatial information on pelican foraging within the tailrace (Figure 2). Zone 1 is the area immediately below the powerhouse down to the JBO. Zones 2 and 3 consist of the area between the Oregon shore and the spillway channel and immediately below the JBO to about 1 km downstream of the dam. The dividing line between 2 and 3 was just below the picnic area on the Oregon shore. Zone 4 is immediately below the spillway, and zone 5 is mid-channel and the navlock entrance (Figure 2).

Table 1. Survey Periods

Name	Time Period
Sunrise	1 hr prior - 1 hr after sunrise
Morning	>1 hr after sunrise- noon
Afternoon	noon - 1 hr before sunset
Sunset	1 hr before sunset - 1 hr after sunset
Night	1 hr before sunset - 1 hr prior to sunrise

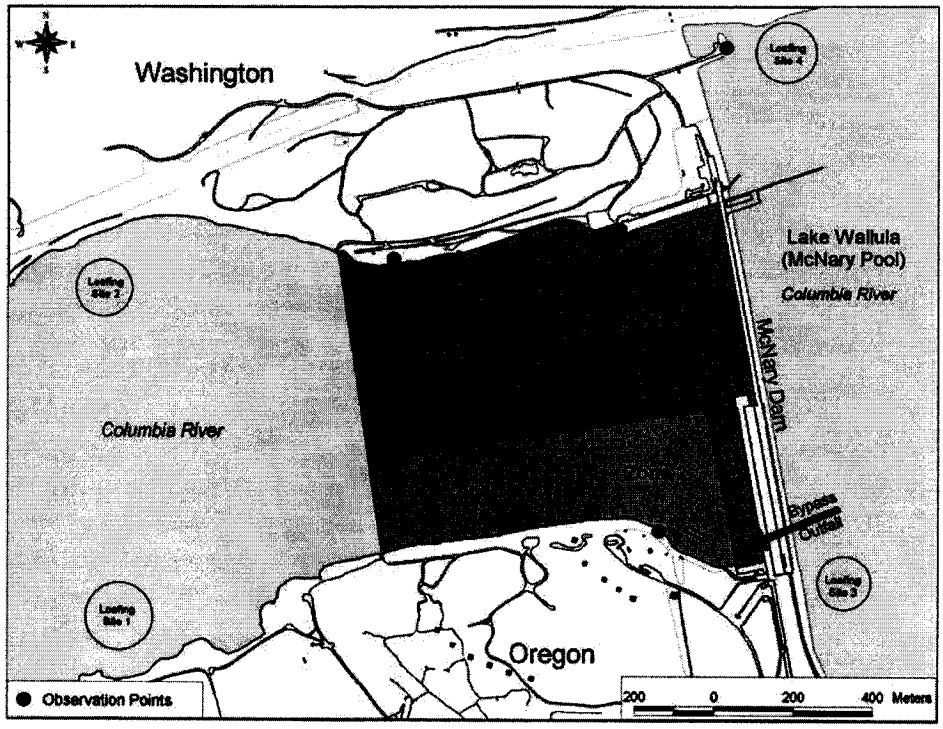

Figure 2. Map of the Tailrace Observation Zones and Loafing Sites Monitored During the 2002 and 2003 Studies

There were also four areas where pelicans were consistently observed loafing on exposed rocks. These were designated as loafing sites 1 through 4 (Figure 2). The numbers of pelicans using the loafing areas were recorded, but behavioral observations were not conducted at these sites.

Observations of pelican activity were made from the Oregon shore immediately below the dam, from the Washington shore just below the navlock wing wall, and the Washington shore boat launch in the forebay. At predetermined intervals, two observers performed an instantaneous count of all pelicans visible within each of the observation zones of the tailrace and in the loafing site areas. The observer on the Oregon shore counted pelicans in Zones 1 through 4, while the observer on the Washington shore counted pelicans in Zone 5 and at the loafing sites. Each count was conducted at least 30 minutes apart and at least 3 times within each survey period. All survey periods were not covered consecutively on the same day but were covered systematically within each week. All pelicans observed in these areas were as to whether they were actively feeding or not at the time of the instantaneous count.

To determine pelican abundance in the McNary Dam area, supplemental boat surveys were performed from Ice Harbor Dam to the Umatilla Wildlife Area Patterson Unit, located 20 km below McNary Dam. Surveys from a truck with radio telemetry equipment and a spotting scope were also conducted three times from mid- to late-August to search for tagged birds. These surveys covered the Snake River up to Lower Monumental Dam and on the Yakima from the mouth of the Yakima River to above Horn Rapids.

2.2 Foraging Rate

Detailed observations of individual focal birds were conducted to quantify foraging efforts. Focal birds were selected based upon their presence in the observation zones (1-5) when focal monitoring was scheduled (between the 30-minute instantaneous bird counts). If more than one bird was found in the study region during the foraging evaluations, a bird was arbitrarily selected by the observer. If a tagged pelican was present in the observation zone and it was not loafing, then it was selected as the focal bird. The focal bird was observed until it left the observer's field of view (e.g., flew off, drifted away, was lost in the troughs of large waves, or lost among a group of other pelicans) or another count was performed. The start and end times of the focal bird observations and the zones in which the bird was observed were recorded. The time, number of bill dips, and successful bill dips were recorded for each of the zones where the focal birds were observed. A successful feeding attempt was defined as either a rapid jerk of the head (referred to as a "pop") or when the bill was raised past horizontal to swallow the prey. Foraging rates were calculated as the number of bill dips per hour per bird. The success rate was defined as the percentage of the observed bill dips that resulted in a successful prey capture. Kleptoparasitism (taking the prey from another avian predator) was also recorded if observed.

2.3 Radiotelemetry and Tagging

To tag and band pelicans using the McNary Dam tailrace, birds were captured using soft leg-hold traps anchored to stakes in the substrate and spread out in the tailrace areas where pelicans were observed loafing. Trapping efforts were consistent with Pacific Northwest National Laboratory's (PNNL's) state and federal scientific collecting permits 02-129 and 07781, respectively, and were compliant with the Laboratory's Animal Care Requirements. The primary trap site was a sand bar located about 60 m off the Oregon shoreline halfway between the end of the McNary Dam tailrace survey zone and the highway

bridge (Loafing Site 1) (Figure 2) used in our pelican count surveys. A second trap area was used near the boat launch by the navlock entrance on the Washington side of the forebay (Loafing Site 4) (Figure 2).

Trapping efforts were kept to a minimal disturbance level to prevent changes in pelican use patterns near McNary Dam. The traps were set as quickly as possible, and the researchers then boated away from the island to wait for the pelicans to return. A plastic decoy was placed near the traps to induce the pelicans to return. The trap area was continuously observed from the time the traps were set so that captured birds would be immediately subdued, tagged, and released.

The captured pelicans were approached by the field crew with a large blanket that was quickly draped over the bird to block its vision and prevent wing flapping. The bird was then secured in a comfortable position and its foot removed from the trap. The bird, still subdued in the blanket, was then transferred to the boat. To prevent the bird from overheating, the blanket was wetted down. Captured birds were then placed inside a large duffle bag and suspended from a scale to obtain a weight. Next, the left leg was banded with a USFWS migratory-bird leg band. Each wing was then successively extended, and a yellow wing (patagial) tag attached to each through the space between the radius and ulna. A radio frequency (RF) tag was then glued to the upper bill just below the nostrils using medical-grade epoxy and the tag was held in place by hand for approximately 10 minutes for the epoxy to set. Solar powered very high frequency (VHF) radio tags were glued to the patagial tags on five pelicans. The bird was then carefully released over the side of the boat.

2.4 Analysis of Abundance Relative to Operations

Survey data were used to develop a pelican index of abundance (PI) for the purposes of quantifying pelican abundance dynamics with respect to dam operations, out-migration of salmonid smolts, and upriver migrations of American shad during the study period. Due to variation in the time increments in the data, 4 main issues were addressed in separate analyses:

1. Changes in PI by spatial zone, time of day, and week for pelican survey counts summarized on a weekly basis.
2. Correlation in the PI with respect to the smolt out-migration index (SI) and Shad counts at McNary Dam on a daily basis. (Note: shad are also considered as potential prey species as pelicans were observed feeding on shad during the 2002 and 2003 seasons).
3. The relationship between the PI and spill levels at McNary Dam by zone on an hourly basis.
4. Analysis of the combined effects of spill and hazing activities by zone on individual survey counts.

Pelican abundance obtained from the instantaneous counts was summarized by week, by observation zone, and by survey period. The weekly trends in pelican numbers were compared to mean weekly spill rates and mean weekly smolt passage. The observed foraging rates (number of foraging attempts/hour/pelican) were compiled from the whole season and summarized by survey period and observation zone.

We used Poisson regression modeling (McCullagh and Nelder 1989; SAS Institute 2001) to assess correlations with PI from a contingency table on week, day period, and zone. Data on the hourly spill rates was obtained from data provided by USACE to the Columbia River Data Access in Real Time web page. Smolt and shad index numbers were obtained from the USACE web site.

2.5 Estimates of Impacts on Juvenile Salmon by Pelicans

To estimate potential smolt consumption, two methods were employed using various scenarios based upon a hypothetical percentage of juvenile salmonids that were in the pelican's diet. The scenarios represent estimates based on both 100% and 50% of the fish consumed by pelicans were scavenged (fish eaten that were dead or dying from dam passage or other causes).

One estimator technique was based on the daily energetic requirements of an American white pelican, as indicated in Terres (1980), and the mean and maximum numbers of pelicans recorded each week during 2003 in the vicinity of McNary Dam. Several assumptions were used to facilitate this calculation. First, it was assumed that each pelican consumed its entire daily energetic requirements of fish near McNary Dam (1.8 kg/day). The number of juvenile salmon eaten per day was approximated based on an average weight of a salmonid smolt (50 g). Two diet composition scenarios were used; one that assumed 100% of the daily diet of pelicans using the tailrace consisted of smolts and another that assumed 50% of the pelicans' daily diet was smolts.

The second method of estimating potential smolt consumption was based on the weekly mean and maximum observed pelican foraging success rates from the focal bird observations and the weekly mean and maximum numbers of pelicans recorded using the tailrace. The observed success rates of the focal birds were averaged for each week then multiplied by the mean number of pelicans observed in the tailrace zones in each week. This produced a weekly mean consumption estimate which was then totaled using all the weeks in the study period. A maximum value was also calculated using the maximum success rate observed as well as the maximum number of pelicans observed in each week. This value was given to provide an upper limit to the consumption estimate. These methods assumed that all the pelicans using the tailrace had the same foraging success rates of the focal birds throughout each week.

3.0 Results

3.1 Visual Observations

Pelican numbers observed during each daytime survey period (sunrise, morning, afternoon, and sunset) were recorded twice a week during June and July, and at least once a week during May and August by a minimum of three instantaneous counts at least 30 minutes apart each day. A total of 1,845 surveys were conducted during 2003. Surveys conducted during the nighttime period during 2002 yielded no foraging pelicans in the tailrace regions and therefore nighttime period surveys were not systematically conducted during 2003. Appendix A has a breakdown of the numbers of surveys and the total pelican counts by survey period, zone, and week.

3.2 Pelican Abundance Index

During 2002, observations began in April and continued through the end of August. During 2003, observations began in early May and continued through late August. Overall pelican numbers were higher throughout the season during 2003 than the numbers observed during 2002 based on maximum counts (Figure 3). Maximum count equals the largest number of birds observed during any survey period during a week.

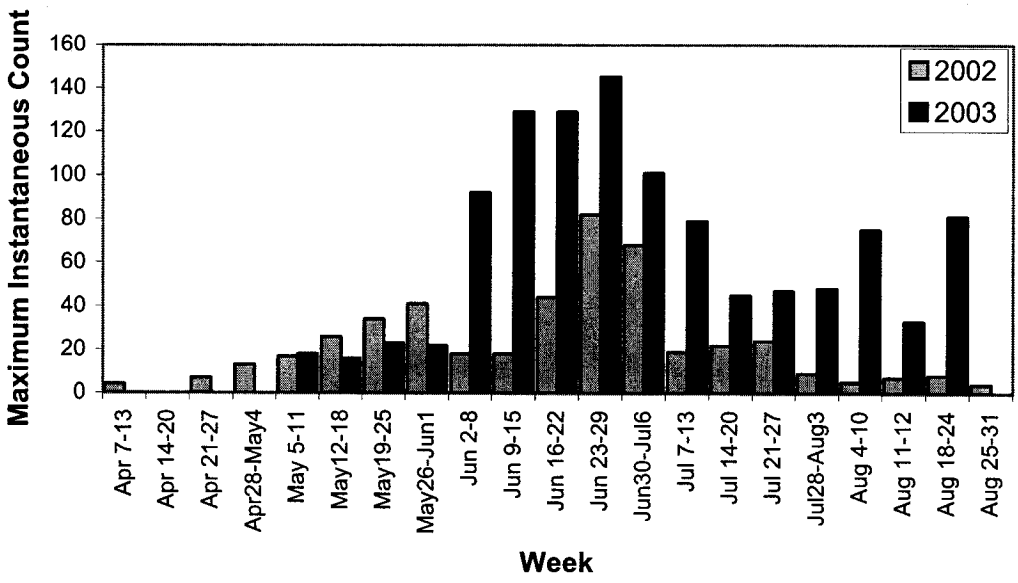

Figure 3. Maximum Instantaneous Counts of Pelicans in the McNary Dam Tailrace Observation Zones Across All Survey Periods Throughout the 2002 and 2003 Study Seasons

Pelican abundance varied significantly across weeks and observation zones, but not among survey periods (Table 2). Furthermore, there was no significant change in spatial use patterns by pelicans as the study progressed, as shown by the interaction term in the Analysis of Deviation (ANODEV) model (Table 3).

Table 2. Univariate Poisson Regression of Pelican Abundance on Week, Survey Period, and Observation Zone

Factor Variable	Df	Deviance	Resid. Df	Resid. Dev	F. Value	Pr(F)
Week	14	4658.873	303	13727.575	7.150	<0.001*
Survey Period	4	331.446	313	18055.002	1.213	0.305
Zone	6	8065.963	311	10320.485	38.789	<0.001*

Table 3. Main Effects and First-Order Interaction, Sequential ANODEV Table[a]

Model Factors	Df	Deviance	Resid. Df	Resid. Dev	F Value	Pr(F)
NULL			317	18386.448		
Week	14	4658.873	303	13727.575	18.067	<0.001
Zone	6	7629.996	297	6097.579	69.040	<0.001
Week* Zone	81	1985.540	216	4112.039	1.331	0.054

[a]Factor coefficients and estimated scale parameter are shown in Appendix A.

Diel pelican abundance index patterns during 2002 identified a major shift in activity from foraging during the day to loafing at night (Figure 4), whereas diel abundance did not seem to fluctuate much across survey periods throughout the 2003 study season (Figure 5).

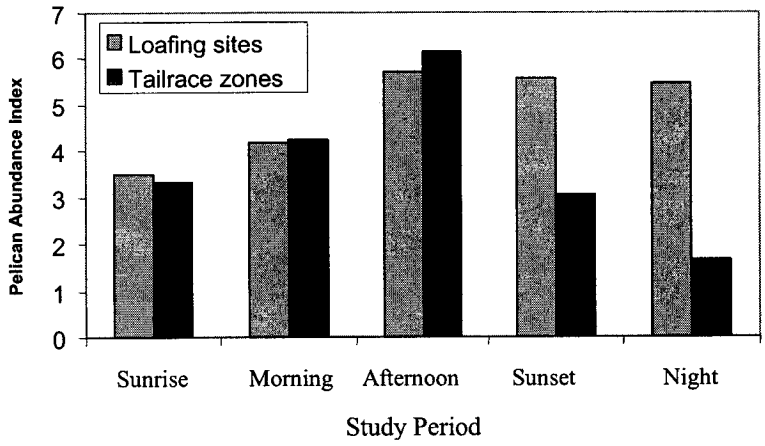

Figure 4. Relative Pelican Abundance at Loafing Sites and in the Tailrace Zones During Each Survey Period During 2002

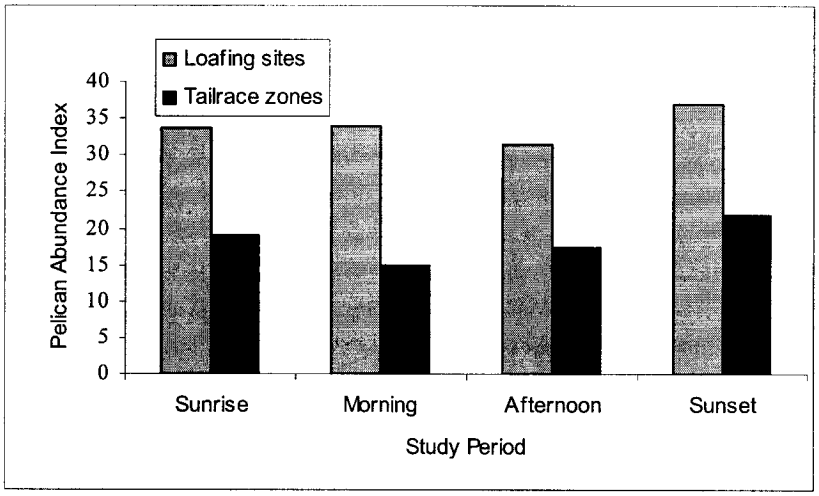

Figure 5. Relative Pelican Abundance at Loafing Sites and in the Tailrace Zones During Each Survey Period During 2003.

3.3 Relationship to Fish Passage

Figure 6 shows the relative distribution of pelicans in the tailrace observation zones compared to the mean weekly smolt passage through the 2003 study period. Figure 7 shows the same, only with the shad passage index instead. Both smolt and shad numbers follow a similar weekly trend in 2003.

Pelican use in both zones 2 and 3 (nearshore at and below JBO) increased beginning a few weeks prior to the peak in the smolt outmigration and generally followed the smolt outmigration index measured during 2003 at McNary Dam (Figure 6). Pelican use generally appeared to increase again near the end of July through mid-August during 2003. Pelican use patterns again shifted substantially during the last period monitored during 2003 (the latter half of August) and the birds appeared to spend the majority of their time in zone 5, near the loafing sites.

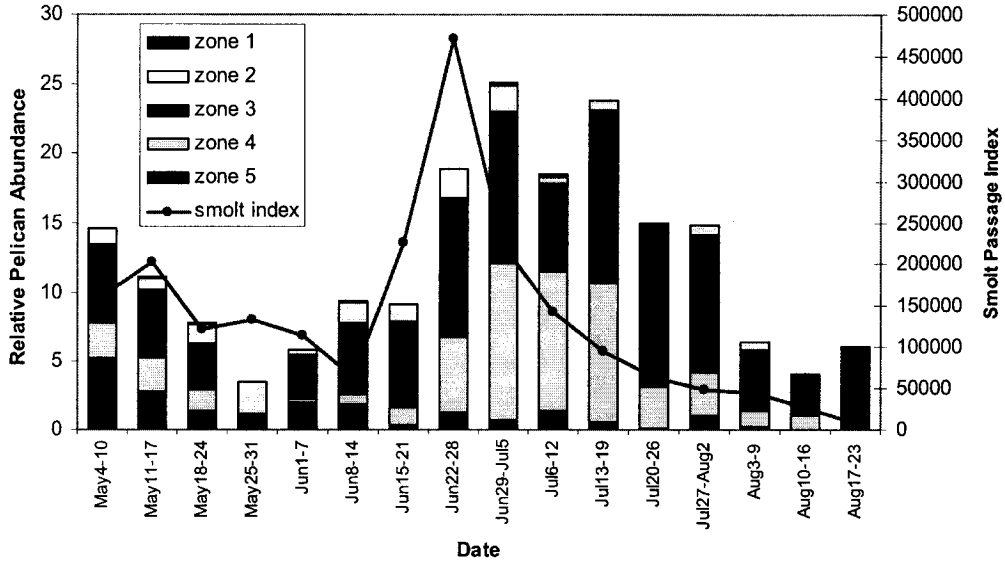

Figure 6. Relative Abundance of Pelicans in the Tailrace Observation Zones During 2003 Compared to the Smolt Passage Index

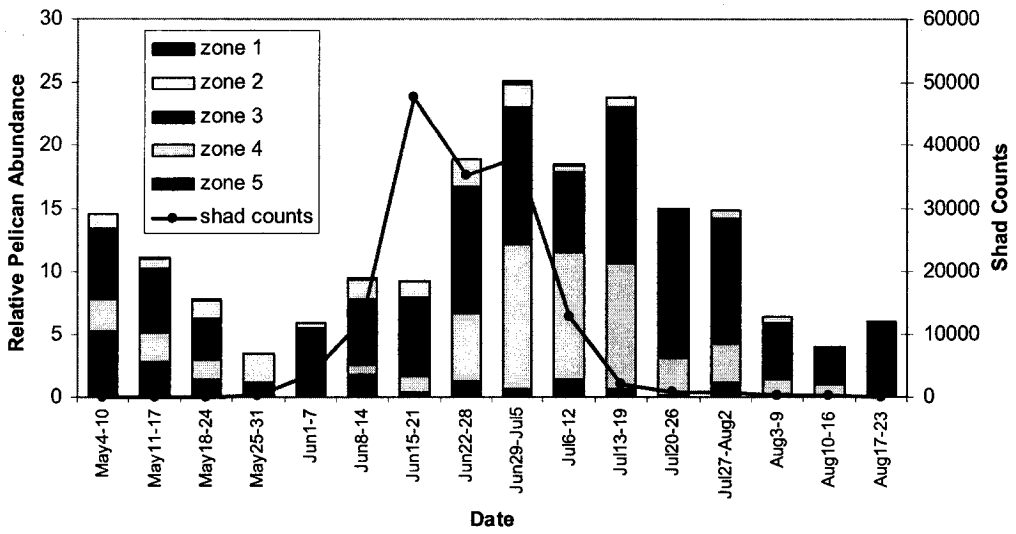

Figure 7. Relative Abundance of Pelicans in the Tailrace Observation Zones During 2003 Compared to the Shad Passage Index

Observation zone 2 was located at and immediately below the JBO; therefore, the use of this zone by foraging pelicans may have been influenced by the amount of fish emerging from JBO. The use of this zone by pelicans does in fact increase in the weeks prior to and during the peak smolt outmigration. The peak in shad also occurs around the same time but one week prior to the peak smolt passage.

The period when pelican foraging success was highest corresponded to the peak smolt passage period. When foraging success was high, the relative number of birds foraging in the tailrace was lower compared to the number of birds loafing. In other words, the results indicated higher general use by pelicans in the McNary Dam area, but reduced time foraging during the peak smolt and shad passages. A similar trend was observed during 2002 as well, where the peak in pelican numbers near the dam occurred one week after peak smolt outmigration (Tiller et al. 2003).

The distribution of pelicans near the McNary Dam tailrace zones during 2002 did not fluctuate much over the course of the season with the exception of an increase in the number of pelicans using region 2 (JBO region) when the majority of smolt outmigration occurred (Figure 8).

Relationships between pelican use patterns near McNary Dam and the passage of potential prey species over McNary Dam during 2003 (i.e., smolt and shad), were computed using correlations by zone between daily summaries on the PI, smolt abundance index, and counts of upstream migrating shad at McNary Dam. These results are shown in Table 4. The correlations shown in Table 4 reflect a 5% trim to exclude potential outliers. Pair-wise plots of these data are shown in Appendix B.

Pair-wise correlations between the smolt and PI were highest for loafing site 2 (0.742) followed by zone 1+2 (0.591) and zone 4 (0.588). Correlations between the shad counts and pelican index were also highest in loafing site 2 (0.708), followed by zone 1+2 (0.703). The shad counts were also compared to the smolt index and produced a relatively high correlation at approximately 0.8 across the project and study period.

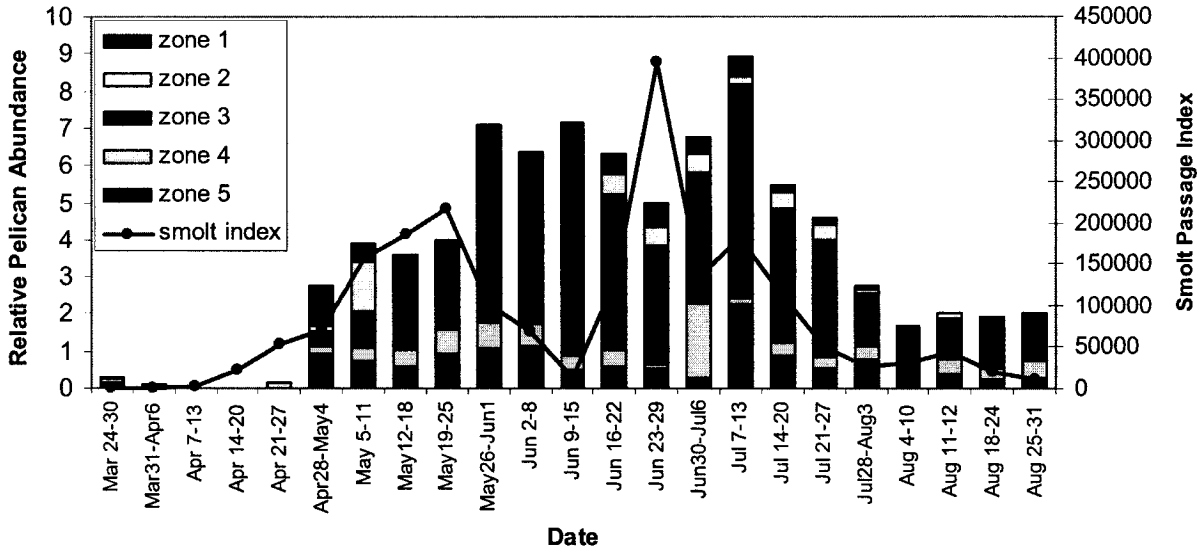

Figure 8. Relative Abundance of Pelicans in the Tailrace Observation Zones During 2002 Compared to Smolt Passage Index

Table 4. Correlations Between Pelican Index to Smolt and Shad Passage Index in 2003

Zone	Smolt Index	Shad Passage Index
Zone 1+2	0.591	0.703
Zone 3	0.306	0.302
Zone 4	0.588	0.469
Zone 5	-0.032	0.096
Loafing Site 1	0.447	0.384
Loafing Site 2	0.742	0.708
Loafing Site 3+4[(a)]	0.529	0.248

(a) Zones 1 and 2 and loafing sites 3 and 4 were combined in the analysis due to their proximity to each other (Figure 2) and the fact that zone 1 and loafing site 3 had almost no pelicans recorded throughout the 2003 study season.

3.4 Relationships to Operations

3.4.1 Pelican Index and Spill

It was evident that pelican activities were impacted by McNary Dam operations during 2003, particularly in terms of total spill and the number of pelicans using observation zones 2 and 3, located near the JBO (Figure 9). During the study periods, spill levels were mandated under the Anadromous Fish Enhancement Project (AFEP) to enhance survival and increase the transport time of downstream migrating smolts. During periods of spill, much of zone 4 immediately below the spill gates was inaccessible to pelicans and pelican use increased in zones 3 and 5. In zone 4, the PI stayed around zero during periods of spill, and immediately rebounded above zero when spills abated.

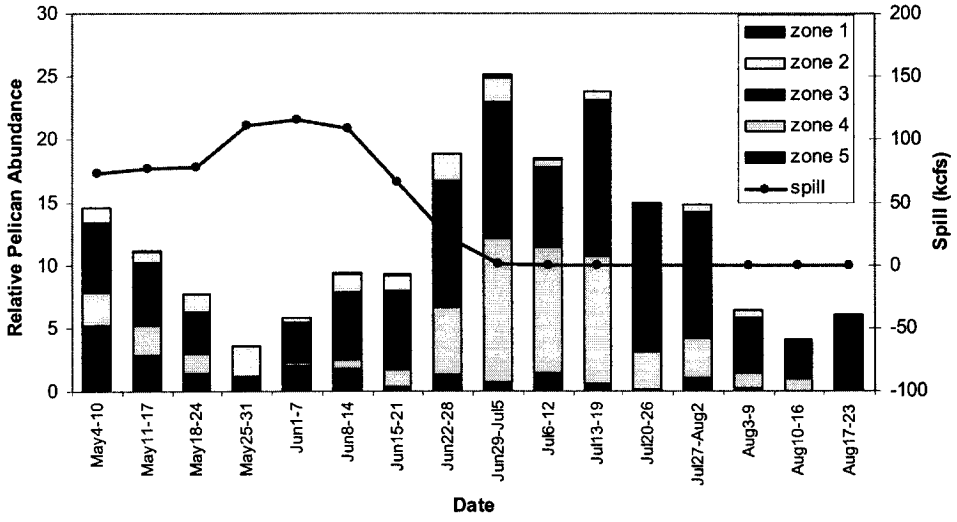

Figure 9. Relative Pelican Abundance in the Tailrace Observation Zones Compared to Mean Weekly Spill During 2003

The main area of use during 2002 was zone 3 (Figure 10), which included the nearshore regions immediately below the JBO. During 2003, pelican use in zone 3 was also consistently high, but the use of zone 1 (turbines) and 2 (JBO) was much less.

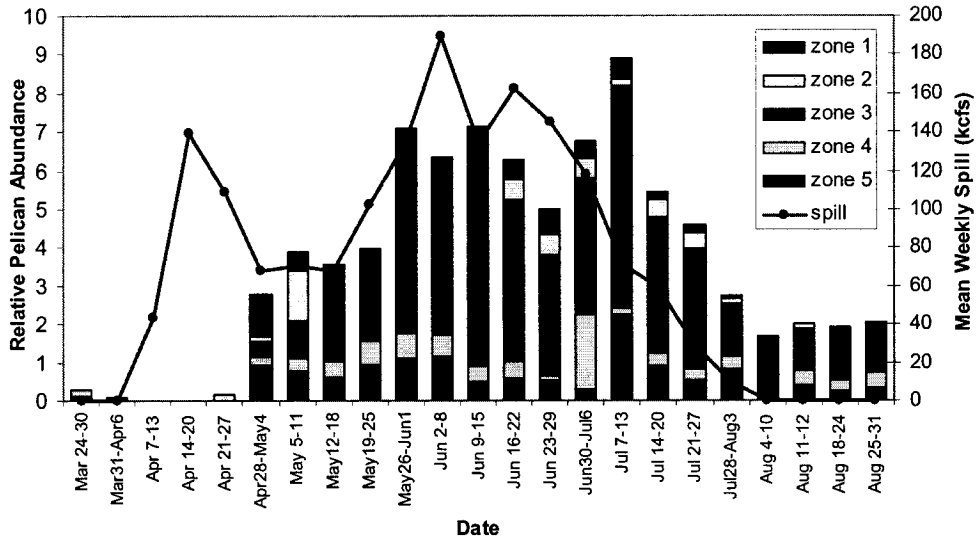

Figure 10. Relative Pelican Abundance in the Tailrace Observation Zones Compared to the Mean Weekly Spill During 2002

3.4.2 Bird Deterrent Efforts

During 2002, pelicans were frequently observed foraging at the base of the JBO and tended not to flush when automated bird deterrent devices, including water and propane cannons, were fired. On other occasions, pelicans simply drifted away from the outfall after a hazing event. When the pelicans were flushed by the deterrent devices, the first pelican returned to the region within an average of 1.5 minutes, and was quickly followed by other birds within an average of 1.6 minutes after the deterrent was fired.

During 2003, human-operated hazing efforts were employed routinely between 07:00 and 15:00 hrs near the JBO and near the spill region (zone 4) from May through early July. The presence of a human near the deterrent devices appeared to make the pelicans wary of using the turbine and JBO regions (zones 1 and 2). The relative abundance of pelicans near the turbines and the JBO did not rebound after bird deterrent efforts ceased (evening times, and mid-July through August).

3.5 Foraging

Focal birds were observed during 2003 for a total of 50 hours and 8 minutes between May 10 and July 29, which was approximately 4% of the total time pelicans could have foraged near McNary Dam during the study year. No focal birds were observed in observation zone 1 (directly below the turbine outlets) and no foraging data were collected there during 2003. The majority of focal-bird observations collected during 2003 were from zones 3, 4, and 5.

Overall, pelican foraging efforts recorded during 2003 were much lower when compared to the rates observed during 2002 (Figures 11 and 12). Pelican foraging and success rates during 2002 were highest in zones 1 (turbines) and 2 (JBO) (Figure 11). Zone 2 had the highest mean success rate at 7.2%, and zone 1 had the highest mean bill dip rates at 28.2 bill dips per hour.

Pelican foraging attempts (bill dips) and success rates were highest in observation zone 2 during 2003 (Figure 12), but overall levels were lower compared to foraging rates recorded in 2002 (Figure 11).

In 2003, 56% of all observed bill dips were associated with kleptoparasitism, and 49% of these were recorded as successful prey captures. This success rate was higher than the overall success rate (34%) that resulted when kleptoparasitism was not present.

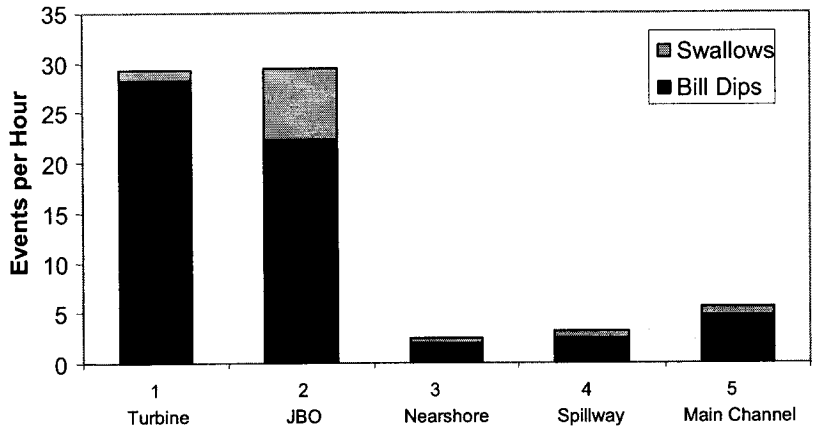

Figure 11. Mean Bill Dip and Success Rates per Hour Observed in Each of the McNary Dam Tailrace Regions Throughout the 2002 Study Period

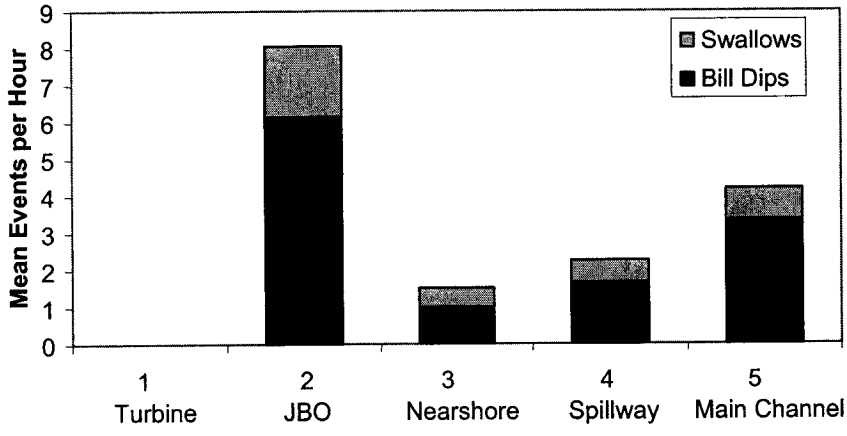

Figure 12. Mean Pelican Bill Dip and Success Rates per Hour Observed in Each of the McNary Dam Tailrace Regions Throughout the 2003 Study Period

3.6 Consumption Estimates

Table 5 provides consumption estimates of salmonids using instantaneous counts of pelicans recorded in the McNary Dam tailrace during 2003 based on energetic requirements. American white pelicans eat an estimated average of 1.8 kg of fish during a 24-hr period (Terres 1980), which would roughly equal 36 juvenile salmonids per day (assuming an average size fish of 50 g). Consumption estimates were given under two scenarios, where 50% or 100% of the pelican's diet consisted of smolt. Estimates were also provided using a scenario where 50% of the fish captured by the pelicans were scavenged (i.e., the fish were dead, injured, or temporarily disoriented from dam passage or other causes).

Table 5. Estimates of the Number of Smolt Consumed Based on the Energetic Requirements (36 smolt per bird per day) Using the Weekly Mean and Maximum Numbers of Pelicans Recorded During 2003. (Two hypothetical diet composition and scavenging rate scenarios were included for comparison purposes.)

	100% Healthy		50% Scavenged	
Pelican Index	100% Diet	50% Diet	100% Diet	50% Diet
Mean	169,345	84,672	84,672	42,336
Maximum	245,952	122,976	122,976	61,488

Table 6 provides pelican consumption estimates using the same diet composition and scavenging rate scenarios, but this estimator calculates consumption based on foraging efforts and success rates monitored and documented during this study. Success rates were calculated by the mean and maximum swallows or bill pops that were observed per foraging bird hour. Data from all regions of the tailrace (1, 2, 3, 4, 5) were combined. This estimator assumes that the success rates of focal birds represent the success rates of all the pelicans using the tailrace area and that one fish was swallowed during each successful foraging event.

Table 6. Estimates of the Number of Smolt Consumed Based on the Observed Weekly Foraging Rates of Focal Birds and the Weekly Mean and Maximum Number of Pelicans Observed. (Two hypothetical diet composition and scavenging rate scenarios were included for comparison purposes.)

		100% Healthy		50% Scavenged	
Pelican Index	Foraging Success	100% Diet	50% Diet	100% Diet	50% Diet
Mean	Mean Successes/hr	27,688	13,844	13,844	6,922
Mean	Max BDs/hr	392,730	196,365	196,365	98,183
Maximum	Max BDs/hr	618,369	309,185	309,185	154,592

BDs = "bill dips."

Observations recorded during 2002 and 2003 indicated that at least some portion of the pelicans' diet consisted of fish species other than salmonid smolt. Pelicans were observed swallowing large fish such as shad and suckers on several occasions when the tail of the fish was visible from the pelican's beak as it attempted to swallow it. Four fish samples were collected from two pelicans that regurgitated stomach contents when they were captured, tagged, and released during 2003. The fish samples are identified in Table 7.

Table 7. Species and Size Composition of Regurgitated Prey Recovered from Pelicans at Point of Capture

Species	Length[(a)]	Weight[(a)]
Steelhead (wild) – (*Onchorhyncos mykiss*)	~20 cm	Not sampled
Common Carp – (*Cyprinis carpio*)	27 cm	329 g
Sucker – (*Catostomis* spp.)	18 cm	76 g
Sucker – (*Catostomis* spp.)	11 cm	12 g

(a) Length and weights were taken from remaining portions. The fish's entire head was missing from all samples.

The fact that all regurgitated fish had missing heads suggested that they may have been injured or killed during turbine passage and the pelicans were scavenging these fish as they emerged near the water surface below the dam (Normandeau Ass. and J. Skalski 2003). Thus, estimates of the overall impact from pelicans on smolt survival may be much lower, i.e., if the pelicans' diet was not composed entirely of healthy smolt that would otherwise continue their downstream migration if not for the predation by pelicans (Tables 5, 6).

3.7 Capture and Tagging

Three adult pelicans were captured at the main loafing area (loafing site 1, Figure 2) below McNary Dam during July 2002. Yellow wing (patagial) tags with black lettering numbered A00, A01, and A02 respectively for each bird, were attached to each wing of each of the birds. On July 22 and 24, pelican A00 was re-sighted in the tailrace area. None of the three tagged pelicans were seen during the subsequent boat surveys conducted from the mouth of the Snake River to the McNary Dam forebay.

Eleven adult pelicans were captured and tagged at loafing site 1 and loafing site 4 during 2003. Yellow patagial tags were attached to each wing of each bird numbering A03 to A13. An RF tag was attached to the upper bill of each bird, and five of the birds had solar-powered VHF radio transmitters attached to the patagial tags. Date of capture, capture location, and the number of days from tagging to last subsequent resighting are given in Table 8.

Table 8. Dates and Trap Locations of Pelicans Captured in 2003

Date	Trap Location	Patagial Tag	Leg Band	Days in Area[(a)]
May 18	Loafing Site 1	A03	0669-20651	21
June 5	Loafing Site 4	A04	0669-20604	0
June 13	Loafing Site 1	A05	0669-20605	0
June 13	Loafing Site 1	A06	0669-20606	0
June 16	Loafing Site 1	A07	0669-20607	23
June 23	Loafing Site 1	A08	0669-20608	42
July 1	Loafing Site 1	A09	0669-20609	0
July 1	Loafing Site 1	A10	0669-20610	11
July 7	Loafing Site 1	A11	0669-20611	0
July 16	Loafing Site 4	A12	0669-20612	0
July 23	Loafing Site 4	A13	0669-20613	0

(a) Number of days that the pelican was observed near McNary Dam or within the survey area downstream to the Umatilla Wildlife Area Patterson Unit (Figure 12).

3.8 Fidelity of Pelicans Near McNary Dam

Only four tagged birds were re-sighted after the initial day they were captured. Figure 13 shows the locations of the tagged birds when they were re-sighted.

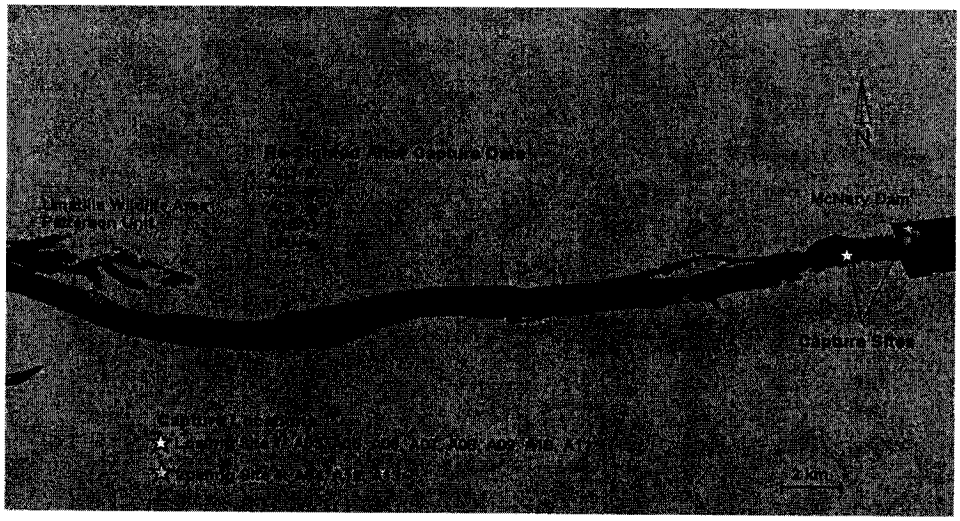

Figure 13. Locations of Re-Sightings and Capture Locations of Tagged Pelicans

More widespread surveys were also conducted in late-July and August to search for tagged birds from Lower Monumental Dam on the Snake River, up the Yakima River mouth, and throughout the McNary Dam Pool (Figure 14). These surveys yielded no sightings of tagged pelicans.

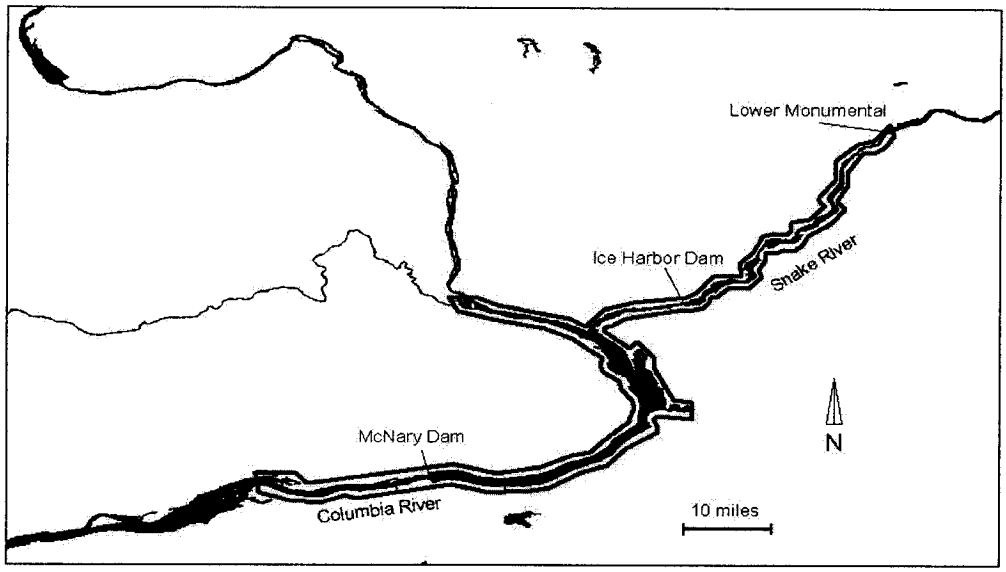

Figure 14. Range of Surveys Conducted to Locate Tagged Pelicans in the McNary Dam Region During August 2003

The duration of time birds were observed near McNary Dam after being tagged ranged between zero and 42 days (see Table 8). The number of birds captured and tagged during any given period was too low during 2003 to statistically interpret the results. One limitation was that the techniques used to capture birds (soft-catch leg-hold traps) were chosen to minimize any potential influence on bird use patterns that may have been caused by the trapping events. However, changes in pelican fidelity patterns near McNary Dam from the results shown in Table 8 might be apparent even at these low sample sizes. Pelicans tagged between June 16 and July 1 appeared to have higher fidelity near McNary Dam as compared to those captured before and after these dates. Results presented in Table 8 represent an average of 5.25 ± 5.25 1 SE days per bird for four capture events that occurred between May 18 and June 13, as compared to an average of 19.0 ± 8.9 SE days per bird for four capture events between June 16 and July 1, and compared to zero days per bird for three capture events between July 7 and July 23 (Figure 15).

3.9 Radio Frequency Tags

Radio frequency tags, developed at PNNL, were employed to help assess foraging rates in addition to observational data sets. The tags were built and tested to record the presence of tagged birds within approximately 200 meters of the RF interrogator station (date, time, and tag id), and the number of times the bill was inundated (bill dip), and the number of times the tag was tipped up (successful swallow).

In mid-February 2003, a small-scale captive pelican study was completed. Results from three captive American white pelicans indicated the RF tags did not adversely affect the birds when mounted to the upper bill. No tissue damage was observed from the cyano-acrylate adhesive, and the tag did not interfere with breeding sail (bill nob) development. Foraging efficiencies of the three captive birds (successful foraging rates) did not appear to be affected by the presence of the tag. Records generated using the RF interrogation system recorded bill dips and bill tips during the study. The tags stayed on the captive birds for approximately 1 to 2 weeks.

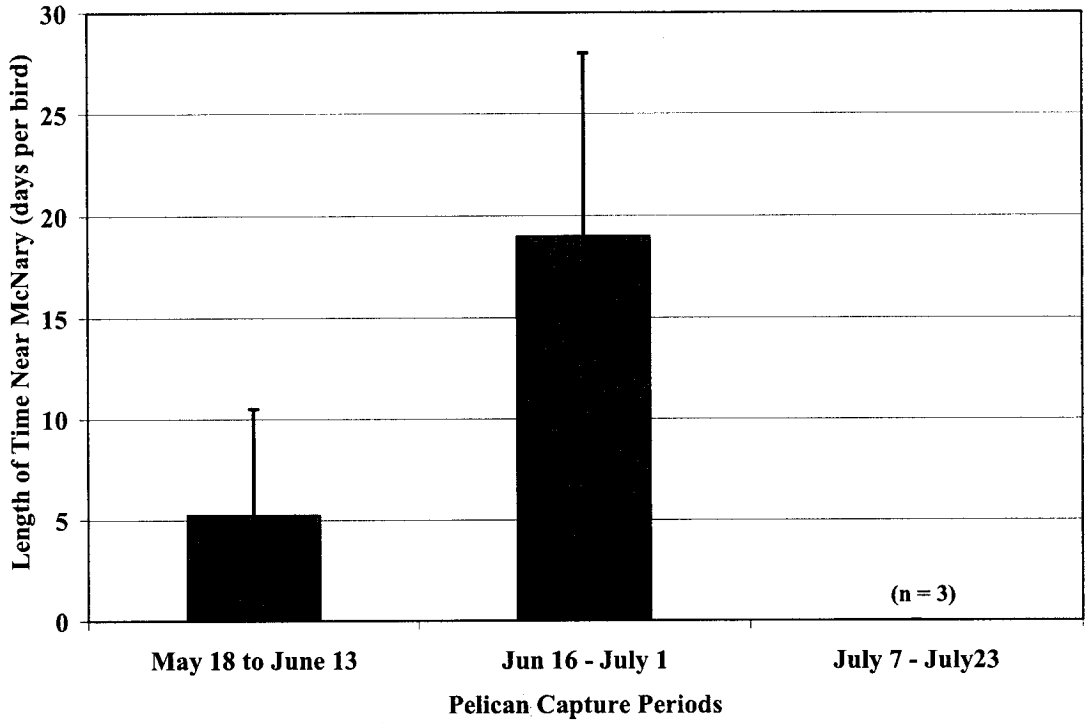

Figure 15. Mean Duration of Time Tagged Pelicans Were Re-Sighted Near McNary Dam (error bars represent ±1 standard error)

Bill dip rates from all three captive pelicans consistently underestimated the actual number of times that the bird made a foraging attempt. This was likely caused by a residual drop of water that remained on the water-sensor immediately after a bill dipping (foraging attempt) event. Bill dip results (successful foraging event) consistently over-estimated the actual number of times the bird made a successful foraging event (swallowing a fish) and was found to be related to the bird's attempts to re-arrange the position of the fish in order to swallow it head-first. Without further testing, the data from the RF tags would provide a relatively consistent measure of foraging rates over time provided that wild birds tagged with the RF tags were allowed to use the sites where RF station interrogators were located. Based upon these findings, approval by the U.S. Geological Survey and the Washington Department of Fish and Wildlife was given to attach RF tags to adult birds captured near the McNary Dam tailrace during 2003.

All 11 birds captured and tagged during 2003 had RF tags attached to their upper bills. Data from these tags was unfortunately very limited due to the lack of time the tagged birds (and untagged birds) spent near zones 1 and 2 during 2003 (see Figures 9, 10, 11, and 12). The lack of results recorded using RF tags was also affected by the lack of time tagged pelicans remained in the McNary Dam tailrace area after being captured.

Use and foraging patterns reported for pelicans near McNary Dam during 2002 identified a "hot-spot" immediately at and below the JBO (zones 1 and 2) during the peak smolt outmigration (Tiller et al. 2003). Two RF interrogator stations were placed on the JBO barge dock to capture this behavior during 2003. However, during 2003, pelicans were never observed in region 1 and use of region 2 was dramatically less during 2003 compared to 2002. One tagged pelican that remained in the tailrace for a substantial

amount of time (bird #A08) retained its RF tag for 8 days, allowing information from the tagged bird to be successfully recorded. On August 6, 7, and 8, one of the RF interrogators was removed from the JBO barge dock and was placed on a boat where observers could approach tagged pelicans to transmit the RF tag information from the bird to the RF interrogator.

3.10 Supplemental Pelican Use and Foraging Observations Near Badger Island Colony During 2002

In April and May of 2002, pelican flight departure directions and foraging patterns observations were collected near the pelican colony on Badger Island during daylight hours (survey periods 1 through 3). During the snap-shot counts (conducted at 30 minute intervals as described for the McNary Dam tailrace data), pelicans were often found foraging in the shallow-water regions of the Columbia River within approximately 1 km upstream of Badger Island. On average, approximately 9.3% of the pelicans observed near the colony area were foraging during the surveys. Foraging was also noted in areas located approximately 1 km upstream of Badger Island and close to shore along the E side of Badger Island near the colony. Most foraging noted near the Badger Island colony appeared to involve a different strategy than that typically observed near the McNary Dam tailrace. During 2002, pelicans foraging near Badger Island typically involved single individuals that appeared to be capturing foodstuffs found in or near benthic substrate that largely consisted of sand or silt. Group foraging strategies described by McMahon and Evans (1992b) were also observed, as well as few kleptoparasitism events.

Arrivals and departures to and from the colony occurred mostly in the early morning and late afternoon. Out of the 49 departures observed during the colony observations, 14.3% headed downstream, usually towards the Walla Walla River delta. The remaining pelican flight departures from the Badger Island colony recorded during 2002 (85.7%) were heading upstream of Badger Island (see Figure 1). Also, out of the 46 observed arrivals to the colony area, only 8.7% came from downstream regions. On several occasions pelicans were observed flying up the Walla Walla River. The arriving or departing birds were observed in "flocks" ranging from 1 to 8 (mean 2.7; n =35), which accounted for only 3.7% of the average number of pelicans observed around the colony in total.

4.0 Discussion

This study was designed to examine the relative abundance and foraging behavior of the American white pelicans using the areas immediately below McNary Dam (see observation zones in Figure 2). It was evident early in the study that pelicans foraging near the dam also loafed in nearby areas and most of the birds observed using the tailrace for foraging would fly or float back and forth between the loafing sites and the areas below the dam.

Typically, most birds became active at first light and foraged in zone 3 below the JBO and zone 4 later in the season when there was no spill. During 2002, activity below the dam typically subsided in late morning, and the birds moved to the loafing sites. Tailrace use and foraging activity typically increased in the afternoon until dusk when bird use at the foraging sites decreased. Bird use of the loafing sites increased overnight until the following morning. During 2003, pelican use of the zones and loafing sites did not fluctuate much across survey periods, but birds did fly or paddle to and from loafing sites and the tailrace throughout the day. Once darkness occurred, the pelicans usually retreated to a nearby loafing site. There was no indication that pelicans foraging near McNary Dam were active breeders from the Badger Island pelican colony.

No foraging activity was observed at night in the McNary Dam tailrace. Other studies on pelican foraging have demonstrated significant foraging at night (Anderson 1991; McMahon and Evans 1992a), but this likely relates to the lack of available prey during daylight. Because the pelicans lack visual references at night, nocturnal foraging is accomplished by trolling their bills through the water until they come into contact with a potential prey item (McMahon and Evans 1992a). Pelicans foraging in the vicinity of McNary Dam tailrace probably cannot hunt efficiently by trolling because the likelihood of encountering fishes with their bill there is simply too low. The abundance of foodstuff in the tailrace and successful foraging during the day may also play a role in the lack of nighttime foraging by pelicans in the McNary Dam tailrace vicinity.

Studies have also documented foraging strategies where groups of pelicans would work cooperatively to herd fish into shallow areas for easier capture (O'Malley and Evans 1984; Anderson 1991; McMahon and Evans 1992b). This group foraging behavior was not observed in the pelicans near the McNary Dam tailrace, although this strategy was observed for some pelican groups foraging in other portions of the McNary Dam pool and further downstream of McNary Dam. The pelicans in the McNary Dam tailrace tended to forage as individuals, and they relied heavily upon seeing another predator that was attempting to consume a fish (kleptoparasitism). The pelicans in the tailrace often cued off the successes of each other as well as other piscivorous bird species (gulls and terns). Pelicans were observed a number of times trying to steal prey from gulls and terns, or trying several successive foraging attempts (bill dips) in the region where a gull or tern was seen making prey capture attempts.

The physical constraints of the tailrace environment may play a role in the lack of group foraging seen by pelicans there. The strong current and relatively deep water likely prevent the birds from successfully herding fish into an area where they would be easier to catch. It is likely that it is more efficient for them to forage opportunistically (and independent of one another). Therefore, foraging near and below the JBO affords the pelicans a better chance of catching any fish that are near the surface, perhaps those fish that become injured or disoriented after passing over the dam through the JBO, spillway, turbines, or other routes. Due to the fact that American white pelicans hunt visually, and dip

their bills into the water from a floating position rather than diving beneath the surface, only prey within approximately 1m of the water's surface are available to consumption by pelicans. Thus, dead, injured, or disoriented fish may comprise a substantial portion of the pelicans' diet in the McNary Dam tailrace.

The trends in pelican numbers found near the McNary Dam generally followed the smolt and shad passage indexes reported during 2002 and 2003. The relative numbers of pelicans using the McNary Dam tailrace area was considerably higher during 2003 compared to 2002, but their overall foraging effort near the dam actually decreased in 2003. Bird deterrent efforts probably contributed to reduced pelican foraging that was recorded near the turbines and the JBO (zones 1 and 2) during 2003. It was noted that human-operating hazing efforts conducted during 2003 appeared to make pelicans wary of approaching within approximately 200 meters of the hazing device and operator, which was also where the RF interrogation systems were placed at the beginning of 2003, based on the pelican use and foraging observations recorded during 2002. Automated bird deterrent activities (water cannon and sounding devices) near observation zones 1 and 2 (turbines and JBO) during 2002 did not appear to affect the foraging patterns of pelicans there. In contrast, human operation of the sounding devices was probably the leading cause of lower pelican foraging events being recorded near the turbines and the JBO during 2003.

A study of pelicans in Wyoming suggested that diet composition was primarily determined by prey vulnerability (Findholt and Anderson 1995). In the samples of regurgitated prey recovered from two birds captured in this study during 2003, all four fish identified in the pelican stomach contents were missing their heads, suggesting they may have been victims of dam-induced mortality. Turbine passage is known to produce sheer forces that decapitate fish passing through this route (Normandeau Assoc. and J. Skalski 2003). This supports the premise that pelicans scavenge a portion of their diet below the McNary Dam tailrace.

Patterns of pelican use within the tailrace and loafing sites were clearly influenced by the spill regime. It was evident that pelican activities were impacted particularly in terms of total spill and the number of pelicans using observation zones 2 and 3, located near the JBO (Figure 9). Use of zone 4 increased immediately when spill ceased, and when spill was occurring, the pelicans would typically shift their use and foraging effort to zones 2 and 3. However, pelicans were found in relatively high numbers in zones 2 and 3 during periods when spill was minimal, but this was after the smolt index had declined to near zero.

One possibility for the apparent increase in pelican use at McNary Dam during late-July and August (despite the low smolt-passage index values) was because of hatching at the colony and subsequently increased energetic demands for the adult pelicans. However, the movement patterns of tagged pelicans and pelican flight departures obtained during 2002 and 2003 suggested the population found near McNary Dam did not readily intermix with birds from Badger Island. Pelican arrival and departure observations from both the colony and the McNary Dam tailrace suggested that the birds tended to loaf and forage within their respective areas and did not appear to travel between the colony and the dam. The pelicans observed heading to and from the colony in the downstream direction usually were seen landing near the Walla Walla River delta or flying inland and up the Walla Walla River.

Consumption estimates for 2003 varied considerably dependent upon the different assumptions and scenarios. Consumption estimates using maximum bird counts and foraging rate samples recorded during 2003, combined with a hypothetical 100% diet of live smolt, represented the extreme upper-limit estimate of impacts on smolt by pelicans near McNary Dam. This scenario is not likely because of the improba-

bility that the maximum number of pelicans reported during any week were using the tailrace and consuming only healthy smolt to attain 100% of their daily intake requirement of 1.8 kg fish per day. The number of samples collected and used to estimate the average relative abundance of pelicans near McNary Dam during 2003 was probably sufficient to represent bird use patterns there. Foraging rates and success rate samples recorded during this study were more variable and realistic fish consumption estimates by pelicans should consider the possibility that both the mean and maximum weekly foraging success rates may represent realistic bounds of smolt consumption by pelicans there.

Lacking actual diet composition and fish scavenging rate data on pelicans, hypothetical scenarios provided in this report (see Tables 5 and 6) were used to illustrated the potential effect these variables may have on the overall impact (additional smolt mortalities) on smolt by pelicans documented near McNary Dam during 2003. It is unclear why the relative abundance of pelicans increased near McNary Dam during 2003 compared to 2002. Population growth of the pelican colony is likely contributer to non-breeding pelicans throughout the Columbia Basin, however, no efforts have been made to systematically measure the growth and recruitment of this population to support this premise. Continued growth of Columbia Basin pelican population as a whole should be expected.

Scavenging rates may dramatically affect the overall impact of pelicans on the out migrating salmonid smolt stocks if some proportion of the pelicans' diet consisted of dead or mortally wounded fish that would not have survived anyway. The fact that the regurgitated prey recovered during our study was missing their heads suggested they were victims of dam-induced mortality, more specifically turbine-passage mortality, where the sheer forces have been known to decapitate fish (Normandeau Assoc. and J. Skalski 2003). To date, no study has examined the condition of smolt that are available to piscivorous birds (near the water's surface) immediately below a major hydroelectric facility. However, a substantial number of fish are known to be injured or killed during dam passage, and survivorship varies by passage route and by dam (Cada 2001).

Site fidelity of pelicans near McNary Dam is still unclear but some insight was gained during this study. The diel use patterns of pelicans near McNary Dam recorded during this study indicated that a number of the pelicans using the tailrace during daylight hours typically remained in the area after dark. During 2003, three of four birds captured over a two-week period between June 16 and July 1 stayed in the vicinity of McNary Dam for a relatively long period of time (see Table 8 and Figure 15). The number of sample results used to examine fidelity during 2003 was not sufficient to permit rigorous analysis of the results; however, it appeared birds captured during peak periods of fish migration had relatively higher fidelity to the area. None of the birds tagged near McNary dam were subsequently found at the Badger Island pelican colony. Bird flight patterns monitored near McNary and near the colony also indicated little- to no intermixing of pelicans between these two regions. Stress induced during the capture events may have caused some of the tagged pelicans to leave the area, and could have affected their use patterns (i.e., reduced site fidelity).

5.0 Conclusion

This study demonstrated that the use of the McNary Dam tailrace by the American white pelicans coincided with the juvenile salmonid outmigration seasons in 2002 and 2003. A noticeable increase in pelican use and foraging near the JBO area was evident during the JBO period during 2002. Pelican numbers increased substantially during 2003 compared to 2002. However, overall pelican foraging rates observed during 2003 were lower than during 2002, and the use of the areas near the turbine units and the JBO was less than the previous year. This was likely related to both reduced spill and enhanced bird deterrent activities during 2003. The spill regime recorded during 2002 appeared to have little effect on the distribution of pelicans in the tailrace. However, during 2003, the pelican use of the spillway regions showed a marked increase during times of no spill and generally appeared to correspond with a reduction of pelican use near the JBO.

Our observations showed that the pelicans using the McNary Dam tailrace area did not forage substantially at night or in large co-operative flocks. The pelican population in the McNary tailrace area did not appear to intermix with the breeding colony of pelicans located on Badger Island, approximately 20 km upstream of the dam. No tagged birds were ever found near the colony or at other areas upstream of McNary Dam. In addition, pelicans from the colony were observed foraging in shallow backwater areas of the Columbia River within a short distance of the colony.

The length of time tagged birds remained in the McNary Dam Tailrace suggested an increase in fidelity during the period of juvenile salmon outmigration during late June and early July. However, sample sizes were too low to quantify population-level trends of the fidelity of pelicans in the McNary Dam tailrace.

Visual observations of pelicans swallowing large non-salmonid fish as well as the regurgitated prey samples provide evidence that smolt did not comprise the entire diet of pelicans at McNary Dam. Visual observations and regurgitated samples also suggested that the fish eaten by pelicans there may not all be otherwise viable and healthy fish. Thus consumption estimates of smolt by the pelicans would be biased high relative to the actual impact on the outmigrating salmonids if it was assumed that prey were all healthy and otherwise would have survived. Diet composition of the pelicans at the tailrace and the condition of the smolt available for consumption by pelicans after passing through McNary Dam passage routes could be used to refine estimates of the overall impact on smolt mortality from pelicans foraging near McNary Dam.

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Appendix A

Main-Effects Factor Coefficients and Scale Parameter Estimates

Appendix A

Main-Effects Factor Coefficients and Scale Parameter Estimates

Parameter	Factor Level	DF	Odds Ratio	Estimate	StdErr	LowerCL	UpperCL	ChiSq	ProbChiSq
Intercept		1		2.966	0.570	1.850	4.083	27.110	<0.0001
Week	1	1	4.335	1.467	0.687	0.120	2.814	4.560	0.0328
Week	2	1	1.606	0.474	0.636	-0.773	1.720	0.550	0.4563
Week	3	1	0.537	-0.623	0.894	-2.374	1.129	0.490	0.4859
Week	4	1	3.113	1.136	0.589	-0.018	2.290	3.720	0.0537
Week	5	1	4.848	1.579	0.581	0.440	2.717	7.390	0.0066
Week	6	1	4.684	1.544	0.581	0.405	2.683	7.060	0.0079
Week	7	1	7.445	2.008	0.576	0.879	3.136	12.160	0.0005
Week	8	1	6.801	1.917	0.577	0.787	3.047	11.050	0.0009
Week	9	1	8.445	2.134	0.575	1.007	3.260	13.780	0.0002
Week	10	1	6.797	1.917	0.577	0.786	3.047	11.040	0.0009
Week	11	1	3.668	1.300	0.585	0.152	2.447	4.930	0.0264
Week	12	1	3.266	1.184	0.608	-0.009	2.376	3.790	0.0517
Week	13	1	1.336	0.290	0.617	-0.920	1.499	0.220	0.6388
Week	14	1	0.125	-2.079	1.699	-5.410	1.251	1.500	0.221
Week	16		1.000						
Zone	1+2	1	0.068	-2.689	0.282	-3.242	-2.137	91.010	<0.0001
Zone	3	1	0.435	-0.831	0.131	-1.088	-0.575	40.330	<0.0001
Zone	4	1	0.255	-1.365	0.159	-1.677	-1.054	73.760	<0.0001
Zone	5	1	0.073	-2.620	0.273	-3.155	-2.085	92.110	<0.0001
Zone	Loafing Site 1	1	0.870	-0.139	0.107	-0.349	0.070	1.710	0.1912
Zone	Loafing Site 2	1	0.595	-0.519	0.119	-0.753	-0.286	19.040	<0.0001
Zone	Loafing Sites 3+4		1.000						
Scale				4.531					

From the scale parameter estimate of 4.531, it is clear that over-dispersion is a factor in the fitted model. Thus, the F-test was used in Table 5 to assess the significance of factor correlations.

Appendix B

Pelican Survey Counts by Factor Variables and Factor Levels

Appendix B

Pelican Survey Counts by Factor Variables and Factor Levels

Factor	Factor Level	Total Count	Foraging Count	Percent Foraging	Number of Surveys
Survey period	1	3,317	1,198	36.1	456
Survey period	2	3,419	1,052	30.8	512
Survey period	3	3,369	1,193	35.4	506
Survey period	4	2,881	1,063	36.9	371
Survey period	5	0	0		10
Zone	1	14	14	100.0	246
Zone	2	264	264	100.0	244
Zone	3	1,782	1,562	87.7	247
Zone	4	1,045	695	66.5	238
Zone	5	298	298	100.0	240
Zone	Loafing Site 1	3,404	602	17.7	217
Zone	Loafing Site 2	2,328	787	33.8	214
Zone	Loafing Site 3	24	0	0.0	8
Zone	Loafing Site 4	3,827	284	7.4	201
Week	1	140	140	100.0	54
Week	2	246	196	79.7	153
Week	3	43	21	48.8	35
Week	4	797	306	38.4	183
Week	5	1,241	700	56.4	208
Week	6	1,199	683	57.0	151
Week	7	1,906	496	26.0	168
Week	8	1,741	522	30.0	153
Week	9	2,162	309	14.3	179
Week	10	1,740	496	28.5	180
Week	11	939	310	33.0	128
Week	12	418	180	43.1	87
Week	13	342	128	37.4	152
Week	14	8	7	87.5	8
Week	16	64	12	18.8	16

Appendix C

Correlations (with 5% trim) Between Pelican Index, Smolt Index, and Shad Passage Index at McNary Dam in 2003

Appendix C

Correlations (with 5% trim) Between Pelican Index, Smolt Index, and Shad Passage Index at McNary Dam in 2003

Correlations	Pelican Index	Smolt Index	Shad Passage Index
Zone 1+2			
Pelican Index	1.000	0.591	0.703
Smolt Index	0.591	1.000	0.798
Shad Passage Index	0.703	0.798	1.000
Zone 3			
Pelican Index	1.000	0.306	0.302
Smolt Index	0.306	1.000	0.798
Shad Passage Index	0.302	0.798	1.000
Zone 4			
Pelican Index	1.000	0.588	0.469
Smolt Index	0.588	1.000	0.798
Shad Passage Index	0.469	0.798	1.000
Zone 5			
Pelican Index	1.000	-0.032	0.096
Smolt Index	-0.032	1.000	0.798
Shad Passage Index	0.096	0.798	1.000
Loafing Site 1			
Pelican Index	1.000	0.447	0.384
Smolt Index	0.447	1.000	0.794
Shad Passage Index	0.384	0.794	1.000
Loafing Site 2			
Pelican Index	1.000	0.742	0.708
Smolt Index	0.742	1.000	0.794
Shad Passage Index	0.708	0.794	1.000
Loafing Sites 3+4			
Pelican Index	1.000	0.529	0.248
Smolt Index	0.529	1.000	0.794
Shad Passage Index	0.248	0.794	1.000