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Nutrient utilization by and diet preference of American white pelicans when offered diets of channel catfish and (or) grass carp

Treena Lee Ferguson

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NUTRIENT UTILIZATION BY AND DIET PREFERENCE OF AMERICAN WHITE
PELICANS WHEN OFFERED DIETS OF CHANNEL CATFISH
AND(OR) GRASS CARP

By

Treena Lee Ferguson

A Thesis
Submitted to the Faculty of
Mississippi State University
in Partial Fulfillment of the Requirements
for the Degree of Master of Science
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in the Department of Animal and Dairy Science

Mississippi State, Mississippi

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NUTRIENT UTILIZATION BY AND DIET PREFERENCE OF AMERICAN WHITE
PELICANS WHEN OFFERED DIETS OF CHANNEL CATFISH

AND(OR) GRASS CARP

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Twelve pelicans captured in northeast Mississippi were used for a 7 day metabolism trial followed by a 2 day preference trial and a trial to evaluate the effect of consuming plastic tags. In the metabolism trial, pelicans were allotted to one of three treatment diets (4 birds/diet): catfish only, carp only or both (50 % catfish and 50% carp). Pelicans consuming the catfish only diet metabolized less dry matter, organic matter and energy than those consuming only carp or both. Four pelicans were used to determine preference for carp or catfish. Pelicans ate more ($P = 0.001$) carp (89 % of diet) and digested nutrients from carp more efficiently than they did from catfish. Plastic tags were attached to numerous fish fed to pelicans in the preference trial, which were regurgitated or retained by pelicans, with no effect on the plastic tags by digestion.

Key words: pelicans, metabolism, preference

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CHAPTER I

LITERATURE REVIEW

Introduction

American White Pelicans (*Pelecanus erythrorhynchos*) are large aquatic birds which migrate from the northern United States and southern Canada to the southern United States, Mexico, and Central America. They spend summer months in the northern climate and winter months in southern climates. They have often been seen nesting alongside Double-crested Cormorants (*Phalacrocorax auritus*), and are less likely to be seen nesting with Herons (*Ardeidae*), Terns (*Sternidae*) and Geese (*Anatidae*; Knopf and Evans, 2004). American White Pelicans are large birds that are mostly white in color but have black tips on their wings. Pelicans have yellow bills and orange feet and undergo various molts as they mature. Their wings are large, which allow for enhanced soaring capability as they will often use lift from warm air rising to keep aloft. Juveniles will often have brown eyes but change to blue by the time they reach maturity (three years of age). Body size ranges from 127 to 170 cm long, with a bill which measures from 33 to 37 cm long for males and from 26 to 33 cm long for females. Apart from bill length, females and males have a very similar physical exterior although females will often be slightly smaller.

Breeding

American White Pelicans reach breeding age between two and three years of age (Derby and Lovvorn, 1997), and during the breeding season will display a yellowish hue on their breast feathers. During breeding, male and female pelicans grow a laterally flattened horn on the upper bill, which usually falls off after mating and laying eggs (Johnsgard, 1993). Mating rituals are often observed with “bowing” or “strutting” taking place followed by copulation (Johnsgard, 1993). Female pelicans can lay from one to five eggs. Since pelicans use their feet to incubate eggs they usually only successfully incubate two eggs. Knopf (1976, 1979) reported that of the 1323 nests observed, 0.85 young fledged per nest. Dunbar (1984) reported a mean clutch size of 1.94 eggs for a colony of pelicans that had minimal disturbance by humans. Common losses of eggs include rolling out of the nest or predation. Schaller (1964) reported fewer eggs in a clutch than Dunbar (1984), with an average of 1.64 eggs after eggs had rolled out of the nest. If more than one egg hatches, siblicide may occur when nestlings compete for survival (Johnsgard, 1993). The mean incubation time period for a pelican egg was reported by Knopf (1976) as 31.5 days. Adult pelicans may feed their young as frequently as four times a day, but as chicks mature frequency of feeding decreases (Johnsgard, 1993). Overall, a 70 % mortality rate for chicks up to three months of age is reported in the wild due to various causes including; starvation, harassment, nest abandonment and eggs rolling out of nests succumbing to hypothermia (Knopf, 1976, 1979). Fledging may occur as early as 62 days (Schaller, 1964). Fledging rates range from 0.21 to 1.23 birds per nest (Johnson and Sloan, 1978; Sloan, 1973). Large colonies and colonies with less intrusion by humans have better reproduction rates (Johnsgard,

1993). A colony contained 600 pairs of birds and fledged from 0.45 to 0.83 young per nest compared to larger colonies of 1750 or more pairs which fledged from 0.86 to 1.22 young per nest (Johnsgard, 1993). Johnson and Sloan (1978) observed a similar pattern of 0.21 to 0.45 young per nest in a colony of 300 breeding pairs while an increased fledging rate of 0.99 to 1.23 young per nest when there were 900 or more breeding pairs. Knopf (1979) reported nest abandonment by 22 % of pelicans in 1973 and 29 % in 1974 due to human disturbance and animal predation during nesting (Dunbar, 1984).

Brown Pelicans (*Pelecanus occidentalis*) begin breeding about three years of age, but have been reported to begin breeding from one to four years of age (Williams and Joanen, 1974). Dalmatian Pelicans (*Pelecanus conspicillatus*) and Great White Pelicans (*Pelecanus onocrotalus*) reach sexual maturity around three to four years of age (Brown et al. 1982; Johnsgard, 1993). Brown Pelicans, Pink-backed Pelicans (*Pelecanus rufescens*), and Spot-billed Pelicans (*Pelecanus philippensis*) have been reported to nest in trees (Baker, 1929; 1935; Keith, 1978; Johnsgard, 1993) reaching heights of 10 to 50 meters (Brown et al., 1982). Brown Pelicans and Spot-billed Pelicans are known for their enhanced reproductive performance and fertility (Johnsgard, 1993; Lamba, 1963), as both species often hatch three eggs instead of most other pelican species which often hatch two eggs. Brown Pelicans typically fledge from 71 to 88 days of age (Schrieber, 1979) and have averaged 0.93 young fledged per nest. Dalmatian Pelicans incubate eggs between 32 and 35 days (Vestjens, 1979) and generally fledge around three months of age. Crivelli et al. (1991) reported Dalmatian Pelicans averaged a clutch size of 1.8 young per nest, and saw hatching success varying from 35 to 70 %. Great White Pelicans may breed year round and have been reported to have a mean clutch size of 1.89 to 1.92 and

fledging at 65 to 70 days, with an average fledging rate of 0.85 young per nest (Brown and Urban, 1969). Pink-backed Pelicans have been reported to produce 1.98 young per nest while 82 % of nests had two eggs, 9.8 % had one egg and 7.7 % had three eggs (Din and Eltringham, 1974). Eggs are incubated for approximately 30 days. Hatchability has been reported to be 1.9 young per nest with 64.9 % of nests having two eggs. Pink-backed Pelicans also fledge around 84 days of age (Din and Eltringham, 1974). Spot-billed Pelicans have been reported to have increased reproductive success, with 50 nests hatching 102 of 150 eggs (average of 2.04 young per nest; Johnsgard, 1993).

Energetics

Pelicans

American White Pelicans nest, live and breed in temperatures ranging from below freezing during the spring to above 40 °C (Knopf and Evans, 2004). Daily maintenance needs for pelican's average around 10 % of body weight (800 to 1500 g) of fresh fish daily (Guillet and Furness, 1984; Johnsgard, 1993). Total feed needed to raise a hatchling pelican to fledging has been estimated to be 68.1 kg (as-fed basis; Hall, 1925) with breeding adults having increased energetic demands requiring 1800 g of fish daily (as-fed basis); as much as 40 % of their body weight. Nestlings may increase energy required by the parent pelican due to the increased foraging needed to supply feed for the young (Dunn, 1973; Royama, 1966). Guillet and Furness (1984) reported Great White Pelicans composing the south-western Cape Province population consumed 184 tonnes of

fish per year. They also partitioned annual energy requirements for these birds to be 69 % for maintenance, 17 % for reproduction, and 14 % flight.

Similar to other piscivorous birds, pelicans may regurgitate a bolus of partially digested fish (Dunn, 1975) and for various reasons such as stress or having consumed non-digestible material. Digestibility efficiencies were calculated to range from 70 to 90 % (as fed) for pelicans consuming various fish species (Derby and Lovvorn, 1997). Kendeigh et al. (1977) developed daily existence energy formulas using adult cormorant and pelicans and used to determine daily existence energy in adult cormorants and pelicans pending on body mass (M ;g) g existence energy (EE ; $\text{kJ}\cdot\text{day}^{-1}$) = $17.34M^{0.5444}$ when ambient temperature was $0\text{ }^{\circ}\text{C}$ and $EE = 4.472M^{0.6637}$ when ambient temperature was $30\text{ }^{\circ}\text{C}$. Body masses of 6500 g for pelicans and 2000 g for cormorants were used. Derby and Lovvorn (1997) bioenergetics models estimates energy requirements of 0.232 kJ/g of fish for an 8900 g Great White Pelican and 0.262 kJ/g of fish for a 6500 g American White Pelican. These values may under estimate actual requirements extrapolated from Great White Pelicans in energetic cages. Shmueli et al. (2000) reported the energy requirement of a Great White Pelican when consuming fish to be greater than previously predicted, requiring 1100 g/day of fish to meet the energy requirement for captive pelicans. Intake of wild Pink-backed Pelicans averages 800 g/day of tilapia, 14 % of adult body weight (Din, 1979; Din and Eltringham, 1974b). This value, however, may not equate to actual intake of wild pelicans, as it is known that intake of captive and wild cormorants may differ due to several factors such as frequency of feeding, social facilitation, and stress (Junor 1965, 1972). Male Great White Pelicans consumed more fish per day than females in Shmueli's et al. (2000) study when dry

matter metabolism was reported to be $85.9\% \pm 2.3\%$. Pelicans have been characterized as having an elevated metabolic rate (Bennett and Harvey, 1987), which decreases when housed in captivity (Piersma et al., 1995). However, a long period (one to two years) of captivity does not affect basal metabolic rate of pelicans (Weathers et al., 1983; Kersten and Piersma, 1987). For Great White Pelicans, Shmueli et al. (2000) found no differences of food consumption among seasons. Although little data exists to support differences of consumption during different seasons, there is evidence that piscivorous bird's energy requirements increase during breeding and when rearing young (Gremillet et al., 1995). Additionally there may be increased energetic demand during migration (Shmueli et al., 2000). Great White Pelicans can travel up to 1620 km using their stored body reserves of energy before needing to replenish body reserves (Shmueli et al., 2000).

Cormorants

Young Double-crested Cormorants (*Phalacrocorax auritus*) may take feed from parents five to six times a day for ten minute periods to obtain enough for optimum growth, illustrating that a large amount of energy may be required by developing young cormorants (Dunn, 1975). Increased energy need of adult pelicans by nestlings was established by Gremillet et al. (1995) who estimated 2230 g Great Cormorants (*Phalacrocorax carbo*) required 0.347 kJ/g body weight of energy for adults laying and incubating eggs, 0.419 kJ/g body weight for adults rearing small chicks and 0.475 kJ/g body weight for adults rearing large chicks. Double-crested Cormorants weighing 2089 g and housed in an environment of 11.4 °C had a daily energy requirement of 0.820 kJ/g body weight (Glahn et al., 1995). Double-crested Cormorant data was used to

hypothesize Great Cormorant energy requirement to be 0.643 kJ/g body weight (Derby and Lovvorn, 1997).

Dunn (1975) observed young Double-crested Cormorants fed eviscerated Pollack (*Pollachius virens*) fish three to four times a day. Gross energy was determined for fecal samples of young cormorants to calculate digestive efficiency. The digestive efficiency of young cormorants was 85 % when consuming Pollack fish and young cormorants averaged a caloric intake of 1.1 kcal/g fresh weight of fish (Dunn, 1975). Brugger (1993) reported three nitrogen corrected metabolizable energy co-efficients for adult Double-crested Cormorants consuming three different species of fish to be 75 % for bluegill (*Lepomis macrochirus*), 78 % for gizzard shad (*Dorosoma cepedianum*), and 79 % for channel catfish (*Ictalurus punctatus*). Both male and female cormorants supply feed to young offspring, affecting energetic needs of both parents. Cormorants raise approximately one to two chicks per year per breeding pair of adults and intake during chick rearing doubles (Kury, 1969; Snow, 1960; Vermeer, 1969). Wild adult cormorants may consume up to 25 % of their body weight (as-fed basis), requiring approximately 580 kcal/day of energy. Wild cormorants have been estimated to have 20 % to 50 % greater energy requirements than captive cormorants (Kale, 1965; Uramoto, 1961; Willson and Harmenson, 1973). Double-crested Cormorants basal metabolic rate was reported to be 545 kJ per/day by Henneman (1982). Using basal metabolic rate estimates, if metabolizable energy coefficients are known, then daily consumption can be calculated. Cormorants, like most avian specie, have elevated metabolisms compared to mammal species and metabolizable energy coefficients have been reported between 54 % (Cooper, 1978) and 90 % (Dunn, 1975).

Food Habits

Pelicans

Pelicans have been reported to travel distances of 96 to 240 km in order to forage (Johnson and Sloan, 1976; Knopf and Kennedy, 1980). Brown Pelicans and Dalmatian Pelicans may dive from air to water to actively pursue prey (Dinsmore, 1974 and Palmar, 1962), similar to most other Pelecaniformes; however, American White Pelicans are opportunistic feeders and often group together in order to trap prey in shallow water (Knopf and Kennedy, 1981). Other pelican species such as Dalmatian Pelicans, Pink-backed Pelicans and Spot-billed pelicans have also been reported to forage in groups (Marchant and Higgins, 1990). American White Pelicans consume many different species of fish and have been reported to occasionally consume crayfish and salamanders (Knopf and Evans, 2004). Although pelicans primarily consume shallow water fish, they have been reported to consume deep-water fish such as tui chub (*Bila bicolor*) when individuals of this species are present in shallow water (Knopf and Kennedy, 1980). Preferences of different species of fish have been reported for the American White Pelican. Derby and Lovvorn (1997) reported that American White Pelicans preferred to consume suckers (*Castostomus spp.*) compared to trout (*Oncorhynchus mykiss*) even when trout were much more abundant and readily available. Dalmatian pelicans have been observed having preferences for certain fish species in Cyprinidae: such as roach (*Rutilus*), bleak (*Alburnus*), rudd (*Scardinius*), and carp (*Cyprinus carpio*) (Crivelli and Vizi, 1981; Crivelli, 1987; Romashova, 1994).

Other factors affecting intake may relate to familiarity, social facilitation, and frequency of feeding (Brugger, 1993; Junor 1965, 1972). American White Pelicans may consume from 800 to 1500 g of fish daily, which is at least 10 % of their body weight (as-fed basis; Guillet and Furness, 1984; Johnsgard, 1993). Pelicans have been reported to feed from reservoirs, estuaries, rivers and fish ponds (King, 2002). While consuming a wide variety of fish, American White Pelicans may digest fish species differently, as reported for cormorants (Brugger, 1993). Pelicans may re-orient their prey in their gular pouch possibly because some fish, such as catfish, have spiny fins which may make it difficult to swallow. In captivity it is common to feed live fish to pelicans; however, pelicans may be trained to consume fresh dead, or frozen fish (Brugger, 1993; Jackson et al., 1987). This can be advantageous for zoos feeding pelicans because acquiring and storing frozen fish is easier than fresh live fish.

Cormorants

Cormorants often regurgitate bony pellets (Duke et al., 1975). It is believed that cormorants regurgitate these pellets to eject bulky, non-nutritious material consumed in the diet (Duke et al., 1975). Adult cormorants will often regurgitate larger bones; however, young chicks rarely regurgitate bone possibly to supply more minerals to their diet (Van Dobben, 1952), which may explain increased digestibility of dry matter in young cormorants (Brugger, 1993; Dunn, 1975). Results of a study conducted by Brugger (1993) showed that cormorants digest certain species of fish more efficiently. Brugger (1993) observed that when cormorants were fed gizzard shad (*Dorosoma cepedianum*) no bony indigestible material was regurgitated; however, cormorants

regurgitated bony material when they consumed catfish and bluegill. Much of the regurgitated material by cormorants was partially digested, indicating that adults may obtain energy from these fish before feeding the fish to their young (Dunn, 1975). Adult Great Cormorants and European Shags (*Phalacrocorax aristotelis*) regurgitated pellets on a daily basis at their nesting sites (Russel et al., 1995; Zijlstra and Van Erden, 1995). Cormorants that were consuming whole fish regurgitated more material than those that were consuming a ground or liquid diet (Dunn, 1975). In Brugger's (1993) study, frozen fish were unthawed prior to feeding; frozen fish may be digested differently than fresh fish due to tissue damage during freezing and(or) thawing (Brugger, 1993; Jackson et al., 1987). It is also important to take into account that consumption of feeds in captive settings may not mimic feed intake in the wild. Frequency of feeding influenced intake by Reed Cormorants (*Phalacrocorax africanus*; Junor, 1965, 1972). Brugger showed cormorants to have preferences for certain species of fish during different seasons, as cormorants refused to eat channel catfish during June. Dunn (1975) observed an altered preference of silverside fish during different seasons by cormorants.

Habitat

American White Pelicans can be very sensitive to human intrusion, especially during times of courtship and incubation of eggs (Johnsgard, 1993). Humans have also been a problem reproductively for Dalmatian Pelicans as Crivelli et al. (1996) reported disturbance even by birdwatchers and photographers to be a major threat; often causing increased stress in pelicans. This stress may cause the pelicans to leave their nests, which predisposes eggs to predation and potential hypothermia (Crivelli et al., 1996). Airplanes

and other loud noises may cause the same response by pelicans. According to Johnson and Sloan (1976) and Boellstorff et al. (1988), research activities should account for the sensitivity of pelicans to human interference. Not only has human disturbance (bird watching, research activities) negatively influenced pelican populations but there have been great losses of pelican habitat, due to soil erosion, flooding, drought and human encroachment (humans draining lakes, building homes) (Brugger, 1993; Guillet, 1985; Shmueli et al., 2000). Human use of water supplies has drained many lakes and wetlands, with expansion of agriculture coupled with changing weather conditions leading to drying lakes and loss of shorelines all contributing to the decrease of pelican habitat (Anderson and King, 2005; Minckley and Deacon, 1991). Long droughts occurred during 1988 through 1992 at Chase Lake, ND, and have been implicated as the cause of reduced pelican numbers in that area (Sovada et al., 2005). Traditional feeding sites for pelicans have diminished as human activities have increased (Shmueli et al., 2000). Humans have perceived pelicans as competitors for fish resulting in pelicans being persecuted (Keith, 2005). Farmers have shot and killed pelicans to reduce predation on fish ponds (Strait and Sloan, 1975; Stephney, 1987). Pelicans being caught in power lines have been identified as another cause of death (Shmueli et al., 2000). In an attempt to make power lines more noticeable, Crivelli et al. (1988) added plastic flags as markers to power lines or used thicker cables. Both of these mechanisms were successful for decreasing pelican collision with power lines.

Experiments conducted at Chase Lake, North Dakota have revealed disease to have a great impact on pelican survivability. Sovada et al. (2005) reported four major diseases impact pelican numbers; Newcastle's, West Nile, Clamdiosis and Avian

botulism all were observed in pelicans at Chase Lake for several years. Rocke et al. (2005) reviewed and summarized data from 183 dead pelicans at Chase Lake in an attempt to determine cause of pelican population decline from 1978 to 2003. These researchers identified several diseases including those previously mentioned by Sovada et al. (2005). Elevated concentrations of pesticides have been reported to reduce shell thickness of pelican eggs, causing a decreased hatchability (Crivelli et al., 1989). Eggshell thickness at Lake Prespa (northern Greece) was estimated to be reduced between 12 and 20 % due to heavy use of pesticides (Crivelli et al., 1989). Residue of some pesticides or organochlorine have also been reported to reduce eggshell thickness in Brown Pelicans, causing decreased reproductive success (Blus, 1970; Blus, 1982; Jehl, 1969; Mendenhall and Prouty, 1978).

Tagging

Brugger (1993) conducted a study using plastic flagging to evaluate digestibility of three different fish species; bluegill, gizzard shad and catfish. Cormorants were hand fed the fish that had been tagged with various colors to distinguish between species. The plastic tags from catfish and gizzard shad were regurgitated within 24 hours of feeding, and were collected on the ground and around the feeding bin of the holding pen. The tags placed in bluegill fish were regurgitated two days post-feeding along with material such as other bones or non-digestibles. Brugger (1993) hypothesized that as bones and other non-digestible material may accumulate in the proventriculus over several days, it is possible that tags from bluegill may have been collected along with this material. Bluegill was the least digestible of the three fish species, which may explain why tags

would have become trapped in the proventriculus along with the other indigestible material (Brugger, 1993). As indigestible material from the proventriculus may take days to accumulate before it is regurgitated, this would explain why the tags took time before being regurgitated along with the trapped indigestible material (Brugger, 1993).

Agricultural Impact

Studies have been conducted to determine the amount of fish consumed by piscivorous birds and how they alter fish stocking rates (Derby and Lovvorn, 1997) and other impacts such as perpetuating the spread of internal parasites (Overstreet et al. 2002). Pelicans may prey on farm raised catfish; resulting in losses of fish production (Derby, 1995; Dunn, 1975; Keller, 1999; King, 1997). Cormorants, like pelicans, have become a concern of inland commercial fisheries (Bayer, 1989), as they often prey upon farm raised fish. As pelicans migrate south, re-plenishing energy reserves may be necessary and with traditional feeding sites diminishing, pelicans have resorted to feeding in alternative locations such as catfish ponds (King and Michot, 2002; Shmueli et al., 2000). American White Pelicans have been reported to consume on average 26 cm long (up to 63 cm long) farm raised catfish in Mississippi (Glahn and King, 2004). In Africa, it has been estimated that Great White Pelicans have reduced fish production by as little as 10 % or as much as 25 % (Guillet and Furness, 1984). As American White Pelicans continued to lose traditional habitat, they have been pushed to find alternative feeding sites such as readily stocked farmed fish. Additionally, pelicans may have a preference for certain species of fish (Derby and Lovvorn, 1997). Pelicans have traditionally been thought to consume a wide variety of fish species (Knopf and Evans, 2004). As pelicans

increase consumption of farmed fish their diet shifts to a mono-species, therefore, it is important to determine the effects of this change in diet. The overall objectives of this study were: 1) to determine the utilization of nutrients by American White Pelicans consuming channel catfish and (or) grass carp; 2) determine preference of American White Pelicans for (~350 g) channel catfish or (~75 g) grass carp; and 3) determine where and how long plastic tags may be retained in the body of American White Pelicans and how tags are affected by digestion.

CHAPTER II

TRIAL 1

Introduction

The daily feed requirement for maintaining American White Pelicans has been estimated to be 10 % of body weight (800 to 1500 g of fish on an as-fed basis; Guillet and Furness, 1984; Johnsgard, 1993). The energetic demands of wild pelicans increase during times of breeding (Gremillet et al., 1995) and migration (Shmueli et al., 2000). Pelicans in the wild consume a variety of fish species including channel catfish (*Ictalurus punctatus*) and grass carp (*Ctenopharyngodon idella*; Brugger, 1993; Johnsgard, 1993; Guillet and Furness, 1984; King, 2005; King et al., 2010; Shmueli et al., 2000). Pelican species have reported dry matter metabolism ranging from 70 to 90 % for multiple fish species calculated by Derby and Lovvorn (1997). Cormorants metabolized approximately 85 % of pollack with an average caloric intake of $1.1 \text{ kcal}\cdot\text{g}^{-1}\cdot\text{day}^{-1}$ fresh weight (Dunn, 1975). Metabolism of rockfish (*Clinus super-ciliatus*) by Great White Pelicans was reported at 73 % (Cooper, 1980). Metabolizable energy co-efficient of three different fish species when consumed by cormorants has been reported by Brugger (1993) to be 79 % for carp, 75 % for bluegill and 78 % for gizzard shad (on a nitrogen corrected basis). Cormorants have been reported to have relatively efficient

metabolizable energy co-efficient ranging from 54 % (Cooper, 1978) to 90 % (Dunn, 1975).

More recently, American White Pelicans have been reported to consume a large amount of farmed catfish (King, 2005). As American White Pelicans increase consumption of catfish (mono-species diet) opposed to a traditional diet (multi-species diet) the effects to the pelican of the dietary shift are unknown. Brugger (1993) suggested catfish may be less palatable due to spiny fins which may be metabolized less efficiently. As a result of decreased metabolism, pelicans may obtain fewer nutrients when consuming catfish, thus requiring an increased intake. Research conducted by Van Dobben (1952) reported young cormorant chicks had increased digestibility of bone material to allow increased absorption of nutrients and minerals; as he reported that young cormorant chicks rarely regurgitated bone material. Young cormorants may have increased nutrient requirements due to growth, supported by increased efficiency for metabolism. Dunn (1975) reported young cormorants consuming eviscerated Pollack to have metabolic efficiency of 85 %. When consumed material is not easily digested, pelicans will often regurgitate this material in bolus form (Dunn, 1975). Additionally, un-metabolized bone material may be excreted in feces. Therefore, the specific objective of this trial was to determine how American White Pelicans utilize nutrients when fed a diet of only channel catfish, grass carp, or a 50:50 mixture of channel catfish and grass carp.

Materials and Methods

Animals

Twelve pelicans were captured on two separate occasions from estuaries near Belzona in northwest Mississippi (King et al., 1998). On the first day of capture, a rocket net was used to capture twelve pelicans. Two days later a second capture (in the same area) used modified foot-hold traps to capture an additional six birds. Thus ten pelicans from the first capture and two from the second capture allowed for 12 healthy pelicans to be used for the trials. Following capture birds were transported to the USDA/WS National Wildlife Research Center's research aviary on the Mississippi State University campus where the birds were placed into 12 individual three meters wide x three meters high x three meters long cages equipped with a 1000 L water tank equipped with a filtered re-circulation water system. Nine of 12 birds were immature (less than three years old) and the remaining three were adults (more than three years old). Although pelicans differed in age, pelicans were within 90 % of adult mass.

Acclimation

Approximately 1500 g of fish (five to ten whole, live fish) were fed to each pelican daily during the 10 day "taming" period (adjust to captivity, change of diet, human interaction). Following the 10 day "taming" period, pelicans were relocated to one meter wide x two meter long x one and a half meter high metabolism crates for nine days. Metabolism crates were equipped with a T-perch across the width of the crate to encourage birds to remain in the center of the crate. Pelicans were weighed before

placement into the metabolism crates. The first two days in the metabolism crates allowed acclimation of pelicans to the crates and respective diets. The remaining seven days in the crates were used for data collection during the metabolism trial. At the end of the trial the pelicans were weighed; and the average of the beginning and ending body weight was used for intake data.

Treatments

Twelve pelicans (nine male, three female) were separated into three dietary treatment groups with four birds per group (three male, one female). The three dietary treatments were: 1) catfish; 2) carp; 3) 50:50 mixture of catfish and carp. Regardless of differences in body size, each bird received 1500 g per day of their respective dietary treatment. Each day fresh fish were brought from holding tanks, located approximately 800 m from where the pelicans were maintained in metabolism crates. To decrease influence of gastrointestinal tract contents of the fish, fish were not fed for at least one day prior to being fed to the pelicans. Each pelican had a single bucket that they received their dietary treatment in once, daily.

Data Collection and Laboratory Analysis

Each day, before feeding, total fecal output for the previous 24 hours was collected and weighed. Each pelican was assigned two pre-weighed fecal collection pans. Individual fecal collection pans were placed underneath wire flooring of each metabolism crate daily. The following day, the fecal collection pan was removed, and the secondary fecal collection pan was placed under the metabolism crate. Feces were

collected by scraping fecal matter from the fecal collection pan into pre-weighed plastic bags. Fecal collection pans were then cleaned and left to air-dry in order to be used the following day. Any regurgitated fish and boluses were collected and labeled for each bird. A sample of each species of fish used (catfish and carp) was collected daily and weighed. Feces, orts and samples of catfish and carp were dried at 60 °C in a forced air oven. Dried fish, orts and excreta were ground to pass through a two mm screen in a Thomas Wiley Mill[®] (Author H. Thomas, Philadelphia, PA). All samples were analyzed for dry matter, organic matter, neutral detergent fiber, fat and crude protein (AOAC, 2003) and gross energy was determined using an isoperibol oxygen bomb calorimeter (Parr Instrument Co., Moline, IL).

Statistical Analysis

Data were subjected to an analysis of variance using the general linear model procedures of SAS (Version 9.2). Individual pelicans were considered the experimental unit. When means differed ($P < 0.05$) they were separated using Fisher's protected least significant difference.

Results and Discussion

Nutritional content of catfish and carp (Table 1) fed to American White pelicans was similar, except a minor variation in neutral detergent fiber (NDF), and gross energy content. The neutral detergent fiber content of catfish was twice the value of carp. Neutral detergent fiber indicates overall available carbohydrates and as animals (and fish) are composed of very little carbohydrate, this difference was not expected to have a large

biological impact on results. The greater gross energy in catfish was due to the greater fat content of catfish compared to carp. Previous exposure and consumption of catfish and carp by pelicans used was not known, and should not have affected the results of the current study.

Body weight and dry matter intake of pelicans in different treatments are reported in Table 2. Body weight was calculated as the average between pre- and post-metabolism trial body mass. The average weight before the trial was $5754 \text{ g} \pm 391.6$ and after the trial was conducted, the twelve pelicans averaged a weight of $6124 \text{ g} \pm 382.8$. There were no differences ($P > 0.05$) for body weights (average of pre- and post-trial body weight) among the three different treatments (Table 2). There were no differences between treatment groups for dry matter intake g/day, although data approached significance ($P = 0.10$). Consumption rates with respect to body mass differed ($P = 0.0107$). Pelicans consuming the treatment of catfish only, consumed less than pelicans receiving the treatments of carp only or both. Pelicans consuming the catfish only diet, in proportion to body weight ate the least amount of their respective treatment diet; showing pelicans may not favor consumption of catfish only. Pelicans offered the dietary treatment of carp only, consumed an increased amount of carp in addition to metabolizing carp more efficiently. On an as fed basis (not dry matter), pelicans consuming catfish ate 20.6 % of their body weight, pelicans consuming carp ate 24.3 % of their body weight and pelicans consuming the mixture of both ate 22.1 % of their body weight. Intake during this trial was higher than the previously reported consumption of approximately 10 % of body weight (Guillet and Furness, 1984; Johnsgard, 1993). However, during the time which Trial One was conducted (May) there may have been increased energetic

demands in preparation for migration and breeding. These results are similar to those reported by Gremillet et al. (1995) and Shumeli et al. (2000) during breeding and migration (respectively) with fish consumption exceeding 20 % of body weight (as fed basis). Brugger (1993) saw a decreased metabolism of catfish in relation to other fish species (bluegill and gizzard shad), due to the increased difficulty of consuming catfish; as catfish have sharp spiny fins. During Trial One it was observed that pelicans consuming catfish had increased difficulty swallowing than pelicans consuming carp. Another factor which may contribute to the increased difficulty of swallowing catfish may have been due to the larger size of the fish species, as pelicans would often be seen struggling to swallow.

Several studies have been conducted which evaluated food consumption by wild cormorants and pelicans. Much of the reported metabolism by these birds of different fish species may not account for what the fish had eaten prior to consumption. During Trial One, fish went unfed for 24 hours prior to being fed to pelicans which may explain why apparent dry matter metabolism was less than previously reported (metabolism efficiencies) by cormorants and pelicans; 77.9 to 89.9 % for bluegill, gizzard shad and channel catfish (Brugger, 1993; Dunn, 1975) by cormorants, 73 % for rockfish (Cooper, 1980) and 70 to 90 % for several species (Derby and Lovvorn, 1997). This explanation is supported by organic matter values reported in Table 3. Bones (as indicated by organic matter) of catfish and carp used in the present trial were a larger portion of body composition because of an empty gastro intestine. The decreased consumption of catfish may be a result of decreased metabolism and increased regurgitation of bony non-nutritious material, which may explain why pelicans metabolized less dry matter of fish

in Trial One. Regurgitation of bony non-nutritious material has also been reported by Dunn (1975), which also may have resulted in decreased metabolism. While apparent protein metabolism of catfish and(or) carp was not different it approached significance. When the pelicans consumed catfish, they metabolized less protein than pelicans consuming carp. Pelicans consuming the 50:50 mixture were intermediate to catfish only and carp only. There were no differences ($P = 0.1731$) for apparent neutral detergent fiber metabolism among the three treatment diets. Apparent metabolism of fat and energy followed the same general trend as dry matter and organic matter metabolism. Apparent fat metabolism ($P = 0.0611$) for pelicans consuming the catfish only diet tended to be less than for pelicans receiving the other treatment diets of both and carp only. In Trial One the proportion of diets that were actually consumed by pelicans were 55 % carp and 45 % catfish. Pelicans consuming catfish metabolized less energy than birds consuming the 50:50 mixture and carp diets ($P = 0.0193$).

Physical properties were different between catfish and carp used in the present study. The carp were smaller (approximately 75 g) compared to the catfish (approximately 350 g). Catfish may have been difficult for pelicans to swallow because of being larger which resulted in a decreased consumption rate of the catfish diet. Pelicans appeared to consume carp with greater ease than catfish when observed during feeding. Carp were smaller but may have been harder to catch. Catfish and carp were of similar maturity which accounts for different body weight. Carp being smaller in size and therefore more surface area per mass, may metabolize with increased efficiency. Catfish have spiny fins and a mucus layer over the skin's surface. Pelicans would often re-orient catfish in their gular pouch prior to swallowing which was similarly observed by

Brugger (1993) who reported catfish to have spiny fins, which may have complicated consumption. Furthermore, catfish had a thicker epidermis which may have been more difficult for enzymatic digestion. The mucus layer that coated the catfish may have enhanced enzymatic breakdown, there by affecting nutrient metabolism by the pelicans. The mucus layer which coats the catfish is composed of various components to aid in digestions and protection from infection (Maki and Dickerson, 2003). There is also an unknown function of the mucus layer surrounding catfish, which may have other enzymatic properties. Carp which were not covered with a mucus layer do have much thinner skin that is protected by scales; unlike catfish who have no scales. The scales on the outside of the carp may have reduced digestibility.

Some pelicans were better adapted to human presence during the trial; however, most remained highly sensitive to human intrusion. Increased regurgitation and agitation of pelicans were attributed to the presence of humans (Boellstorff et al., 1988; Johnsgard, 1993; Johnson and Sloan, 1976). Increased stress may have decreased intake compared to wild pelicans and cormorants where greater intake has been reported (Kale, 1965; Uramoto, 1961; Willson and Harmenson, 1973). In addition to decreased energy needs in confined birds, other factors such as frequency of feeding may have affected intake (Brugger, 1993; Junor 1965, 1972).

Conclusion

American White Pelicans ate a larger portion of dry matter when consuming carp as a percentage of their body weight. Differences in consumption may be a result of differing physical properties of catfish compared to carp, as well as the size difference

between the fish species; catfish have bony fins which may make it hard to swallow and were also much larger in size. Although there were minor differences in fish composition when comparing catfish and carp, pelicans metabolized less dry matter, organic matter, and energy when consuming catfish only. Pelicans apparently metabolized less crude protein and fat from the catfish only diet. Apparent metabolism differences may also be a result of differing physical properties between the fish as catfish contain a mucus layer which may inhibit enzymatic breakdown as it protects the fish from foreign objects.

Table 1. Nutrient composition (DM basis) of catfish and carp fed to American White Pelicans

	DM¹, %	OM¹, %	CP¹, %	NDF¹, %	FAT, %	Gross Energy, kcal/g
Catfish	21.4	83.5	68.9	11.9	23.3	4694.1
Carp	24.9	86.2	67.1	4.6	25.4	5044.6

¹DM= dry matter, OM= organic matter, CP= crude protein, NDF= neutral detergent fiber.

Table 2. Dry matter intake and body weights of American White Pelicans consuming catfish and(or) carp

Treatment	Body Weight, g	DM¹ Intake, g/day	DM¹ Intake, % body weight/day
Catfish	6008	264.4	4.41 ^a
Both²	5995	307.0	5.10 ^a
Carp	5689	341.7	6.06 ^b
SEM³	384.2	22.45	0.296
P =	0.8065	0.1022	0.0107

¹ DM= dry matter

² Both= diet offered consisted of 50 % catfish and 50 % carp

³ SEM= Standard error of the mean

^{ab} Means with different superscripts within column differ (P < 0.05)

Table 3. Nutrient metabolism by American White Pelicans consuming catfish and(or) carp

Treatment	DM¹, %	OM¹, %	CP¹, %	NDF¹, %	FAT, %	Energy, %
Catfish	42.2 ^a	52.0 ^a	2.5 ^a	93.9	71.9 ^a	74.4 ^a
Both²	54.8 ^b	64.1 ^b	22.5 ^{ab}	93.1	82.6 ^b	81.2 ^b
Carp	60.0 ^b	68.0 ^b	28.1 ^b	90.1	83.7 ^b	83.4 ^b
SEM³	3.84	3.12	6.76	1.38	3.31	1.86
P =	0.0260	0.0137	0.0579	0.1731	0.0611	0.0193

¹ DM = dry matter, OM= organic matter, CP= crude protein, NDF= neutral detergent fiber

² Both = diet offered consisted of 50 % catfish and 50 % carp

³ SEM = Standard error of the mean

^{ab}Means with different superscripts within column differ (P < 0.05)

CHAPTER III

TRIAL 2

Introduction

American White Pelicans consume a variety of fish species and also have occasionally been reported to consume crayfish and salamanders (Knopf and Evans, 2004). Pelicans primarily consume shallow water fish (one to two meters deep) but have been observed consuming deep-water fish such as tui chub (*Bila bicolor*) when they are present in shallow water (Knopf and Kennedy, 1980). Preferences for different species of fish have been reported for the American White Pelican. Derby and Lovvorn (1997) reported that American White Pelicans preferred to consume suckers (*Castostomus spp.*) compared to trout (*Oncorhynchus mykiss*) even when trout were much more abundant and readily available. Dunn (1975) also observed an increased preference for silverside fish during different seasons by cormorants. Brugger (1993) showed cormorants had preferences for certain fish during different seasons, as cormorants refused to eat channel catfish during June. Brugger (1993) showed cormorants to metabolize certain species of fish more efficiently; channel catfish 79 %, gizzard shad 78 % and bluegill 75 % metabolized, which may affect preference. Therefore, the objective for Trial Two was to determine if American White Pelicans had preferences for (~ 350 g) channel catfish or (~75 g) grass carp.

Materials and Methods

Animals and Acclimation

For determination of preference by American White Pelicans, the same four birds that received the 50:50 mixture of catfish and carp during Trial One were used for Trial Two. The birds were placed into four individual three meter wide x three meter high x three meter long tanks equipped with a 1000 L water tanks at the USDA/WS National Wildlife Research Center's research aviary on the Mississippi State University campus. These birds had been previously acclimated (see Trial One: Acclimation) to their surroundings and had been receiving their treatment diet for a total of 1500 g/day for nine days prior to being used to determine their preference for catfish or carp.

Feeding Practices

Each pelican was provided with 2000 g of live catfish and 2000 g of live carp daily. Also individual catfish (~350 g) used in the current study weighed more than the individual carp (~75 g). Size difference between the two fish species may be accounted for selection of fish at the same level of maturity to obtain similar nutritional compositions. Typically pelicans weighing six kg would be expected to consume 1500 g of fish. Therefore, providing 2000 g of each species of fish should have allowed complete consumption of either fish species if pelicans chose to eat only one species. Each pelican had a single bucket that they received their dietary treatment in once, daily.

Data Collection

Each day, dead and any uneaten fish were collected and weighed for each of the four birds, and then were separated by species, catfish or carp. Fish types were weighed separately to determine amount eaten and refused of each species. The preference trial (Trial 2) was conducted on two consecutive days (May, 2009).

Statistical Analysis

Data were subjected to an analysis of variance using the general linear model procedures of SAS (Version 9.2). Individual pelican was considered the experimental unit. Means were considered different when $P < 0.05$.

Results and Discussion

During the preference trial pelicans selected more ($P = 0.0001$) carp (~ 75 g) than catfish (~ 350 g; Table 4). Although pelicans are considered opportunistic feeders, they have been reported to have preferences for certain fish species, especially in different seasons (Derby and Lovvorn, 1997; Dunn, 1975). Previous exposure and consumption of catfish and carp by pelicans used was not known, and should not have affected the results of the current study. Pelicans preferred the (~ 75 g) carp, but larger catfish were consumed, although much less compared to carp. This consumption of catfish even though less preferred, may demonstrate the opportunistic nature of pelicans. Pelicans may consume a wide variety of readily available fish to meet energetic demands even when there is significant preference. The amount of catfish consumed by pelicans was 246 g/day compared to 1708 g/day of carp. Pelicans chose to consume 85 % of the

smaller carp provided to them and 12 % of the larger catfish provided to them. Finally, diet composition was calculated to reveal that when allowed to choose between ad libitum large catfish and small carp, pelicans consumed a diet of 89 % carp and 11 % catfish. In Trial One, these pelicans were fed the mixture diet of approximately 750 g of catfish and 750 g of carp. For Trial One, pelicans which received both large catfish and smaller carp, selected a diet that consisted of 45 % catfish and 55 % carp. The ratio of consumption may be the result of not being provided enough of either species to consume only that species. The physical attributes of catfish may have discouraged pelicans from selecting consumption of catfish. Catfish had sharp, bony fins compared to carp. Many times undigested catfish were fully or partially regurgitated, as seen by Brugger (1993). Also individual catfish (~350 g) used in the current study weighed more than the individual carp (~75 g). Additionally a preference of carp may have resulted from the ease of swallowing the smaller size.

Conclusion

American White Pelicans do have preferences for certain fish species. These preferences may exist due to physical properties of fish such as size, lubrication, or rigid bony structure. Pelicans may also metabolize some species of fish more efficiently leading to preferences. Preferences for American White Pelicans may also change with season. Lastly, although pelicans do have preferences for certain species of fish, they are still highly opportunistic and will consume other types of less preferred fish if readily available to fulfill energetic demands.

Table 4. Consumption of catfish and carp when both were offered to American White Pelicans

Treatment	Consumed¹, g/day	% offered¹, %	% of diet¹, %
Catfish	246	12.26	10.76
Carp	1708	84.82	89.24
SEM²	109.1	5.453	4.846
P =	0.0001	0.0001	0.0001

¹Consumed = amount of fish consumed, wet basis; % offered = g specie consumed/g specie offered (i.e. g catfish consumed/2000 g catfish offered); % of diet = g specie consumed/g total consumption

²SEM = standard error of the mean

CHAPTER IV

TRIAL 3

Introduction

In addition to determining preference of American White Pelicans for catfish or carp this trial also assessed the digestibility of plastic Floy tags commonly used to identify fish by wildlife biologists. Retention of integrated transponder tags has been seen in flathead catfish (Daugherty and Buckmeier, 2009). Tagging has also been used as a management strategy to track the movement of common carp (Stuart and Jones, 2006). Plastic tagging allowed Brugger (1993) to monitor regurgitation using colored tags in different species of fish. Brugger intended to look at the metabolism of three different fish species; gizzard shad, channel catfish and bluegill. Plastic tags used by Brugger (1993) were reported undigested by cormorant species. These tags were additionally retrieved in the cages from the floor and feeding bins often days after feeding. Brugger (1993) suspected that tags would collect in the proventriculus along with other indigestible material and be later regurgitated with this bulky material explaining its regurgitation days later. As indigestible material is often regurgitated, Brugger (1993) expected the tags would not pass through to the fecal material.

If length of retention can be determined and different fish species can be flagged with various colors or numbers, feeding sites and migratory patterns may be tracked.

From a wildlife perspective, feeding locations and types of fish consumed may be valuable information used for restoration of habitat or deterrence of fish predation. Therefore the objective for this experiment was to determine where and how long plastic tags may be retained in the body of a pelican in addition to how tags may be affected by digestion.

Materials and Methods

Animals and Acclimation

The plastic tagging of fish occurred during the preference trial (Trial Two). Birds were acclimated in Trial Two. In addition to determining preference, pelicans were fed tagged fish during consumption of their respective dietary treatments.

Feeding Practices

While holding the fish firmly, Floy tags were pierced through the skin using a tagging gun for three catfish and five carp as part of each bird's daily allotments of fish (approximately 2000 g of carp, 2000 g of catfish). Prior to feeding, fish were tagged on the left side of their dorsal fin, approximately two cm deep. Often tags placed in carp would have to be punched deeper into the fish in order to stay in place (due to carp having a thinner outside skin layer). Tags were orange and labeled with four digit numbers for specific identification between birds (Figure 1). Tags were approximately one inch in length and were cylindrical with a diameter of two mm.

Data Collection

The tagging of fish occurred during the preference trial (Trial 2), conducted two consecutive days (May, 2009). Tags were recovered from remaining fish and regurgitate. Water tanks and feces on the ground were examined to retrieve plastic tags.

Three days after the trial had ended, tags were still collected. One pelican necropsy was conducted to determine the possibility of pelicans retaining tags within the body.

Results and Discussion

Regurgitated material from pelicans did contain plastic tags. Other plastic tags were found remaining in fish or found at the bottom of the water tank/feeding bins. There is also speculation that tags may have fallen out while fish were inside the feeding bin. This may be due to increased activity while pelicans were trying to catch the fish, or perhaps the tags were too loosely attached. Tags were also collected from the stomach of bird 3 during necropsy. Unlike Brugger (1993), tags were not collected in the proventriculus but rather in the ventriculus, although this cannot rule out tags being regurgitated from the proventriculus. Plastic tags retrieved during this trial seemed to be unaffected, and therefore undigested by the pelicans (Figure 1). There may also be differences between fish as catfish that were tagged had a thicker skin which seemingly kept the tag in place. Only five carp and three catfish were tagged for each bird each day as there were a limited number of tags and catfish seemed to better retain tags.

Tracking the digestion of catfish and carp using plastic tagging seemed quite inefficient. Tags were, however, collected more than 48 hours after feeding when regurgitated. These tags may have been regurgitated from the proventriculus, as other

tags may have been retained in the ventriculus. None of the collected tags were found in fecal material suggesting none of the tags passed through the digestive system and excreted through the cloaca. Tags unaccounted for may have been retained within the ventriculus of birds; 1, 10 and 12 (Table 5 and Table 6). As these birds did not undergo necropsy, it is hypothesized a portion of the tags were, in fact, retained. Other tags may have been lost between the cracks in the flooring used in the cages or perhaps had been washed away, or pushed far outside the cages.

Conclusion

It can be summarized that tags can be retained by American White Pelicans for several days after consumption. Tags are unaffected by digestion, but may collect in the proventriculus and be regurgitated, or collect in the ventriculus. As no tags were recovered in fecal matter, further research is required to determine if consumed tags may affect pelican digestion as tags may continually be collected in the ventriculus.

Table 5. Consumption of carp containing plastic tags offered to American White Pelicans

Bird ID	Carp # tags	Tags in Stomach	Tags in regurgitate	Uneaten tags	Missing Tags
1	15	n/a	0	1	14
3	15	7	3	5	0
10	15	n/a	6	5	4
12	15	n/a	5	7	3

Table 6. Consumption of catfish containing plastic tags offered to American White Pelicans

Bird ID	Catfish # tags	Tags in Stomach	Tags in regurgitate	Uneaten tags	Missing Tags
1	6	n/a	0	3	3
3	6	n/a	0	1	5
10	6	n/a	0	3	3
12	6	n/a	2	1	3



Figure 1. Example of plastic tag used in Trial 3.

CHAPTER V

SUMMARY

The overall objectives of this study were: 1) to determine the utilization of nutrients by American White Pelicans consuming channel catfish and (or) grass carp; 2) determine preference of American White Pelicans for (~ 350 g) channel catfish or (~ 75 g) grass carp; and 3) determine where and how long Floy plastic tags may be retained in the body of American White Pelicans and how tags are affected by digestion. American White Pelicans did metabolize more nutrients from carp than catfish or a mixture of catfish and carp. This indicates that a mono-species diet may be efficiently utilized and furthermore, certain species of fish are metabolized differently by American White Pelicans. This trial indicated that American White Pelicans preferred smaller carp compared to larger catfish. Whether this preference is due to pelicans enhanced nutrient metabolism of carp compared to catfish is not known. Pelicans may also regurgitate pellets of non-digestible fish as they may prefer species of fish that are more digestible in an attempt to acquire nutrients more efficiently. Plastic Floy tagging of carp and catfish indicated that pelicans may retain plastic tags for several days within the ventriculus, but may not excrete tags in fecal matter. Visual observation of tags collected from the ventriculus of bird 3 indicated tags were not affected by digestive processes in the pelican.

CHAPTER VI

IMPLICATIONS

While pelicans preferred carp and utilized nutrients more readily from carp, catfish can effectively be fed to pelicans in captivity, but further research is needed to evaluate a need for supplementing additional nutrients. Additionally, with increased concentration of farm raised catfish in areas where pelicans spend winter months, nutrients available to wild pelicans may be reduced compared to traditional diets. However, little is known regarding the nutrient requirements of pelicans. Therefore, further research to determine nutrient and energetic needs of pelicans, especially during migration and breeding, is warranted. Because American White Pelicans prefer carp compared to catfish, catfish farmers may be able to reduce predation of catfish by enticing pelican consumption of an economically feasible and preferred fish species. Through the use of tagging fish, migration patterns and fish preference may also be monitored. From a wildlife/habitat management perspective, this data may allow restoration of habitat to attract American White Pelicans with desired fish species, and at the same time may provide pelicans a diet with more available nutrients.

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