NUTRITION OF ALLIGATORS

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Abstract

Various diets were tested during the past 15 years to develop an economical and nutritionally balanced feeding regimen; a practical one adaptable to large-scale alligator (Alligator mississippiensis) farming operations. Factors which determine choice of a feeding regimen include: cost considerations, annual availability of primary food source, storage quality, ease of handling, alligator acceptance, nutritional requirements, effects on growth rates and reproduction, and probably most importantly the objectives of propagation program, i.e., whether for grow-out and slaughter or primarily for breeding purposes. Sufficient information is just now becoming available to allow the study of basic alligator nutritional requirements.

Analyses of food habits in the wild revealed information regarding food preferences and provided an indication of basic life support requirements. Ecological studies provided further information about biological requirements of the alligator.

Our feeding program has evolved into three phases: Phase I (age 1 day to 3 years) - intensive culture under closely controlled environmental conditions, Phase II (age 3 to 6 years) - pen grow-out program, and Phase III (over age 6) - pen breeding program.

Introduction

The transition of the alligator from a native habitat, one literally occupied for millions of years, to an artificial environment offers tremendous challenges in terms of management and nutrition.

This paper describes the methods and feeds used in maintaining alligators in captivity at Rockefeller Refuge for the past 15 years. The feeding program was altered during this period, coinciding with advances in knowledge of the alligator in the wild and under controlled conditions. The first approach was to feed whatever was readily available at the least possible cost. Most times this involved a monodiet. Compounding dietary problems were inadequate pen design which resulted from our lack of understanding of environmental conditions required by adult alligators.

The second approach to feeding was to supply a diet similar to that consumed by the animal in its natural habitat. The natural approach takes into account the quality and quantity of food the wild animal eats (Morris, 1976). Cost and practicality of this method can be prohibitive depending upon location and objectives of individual farms.

The third approach to nutrition and the one under investigation involves refinement of pen design and nutritional and environmental requirements. Crocodilian nutrition is at best poorly understood. Specific nutritional requirements for alligators are based upon limited data of what the wild animal eats and since the alligator has no closely related domestic counterpart

we can only estimate what their nutritional requirements are. Tests of various diets, fed under varying den design and stocking rates, will hopefully result in proper dietary formulations.

In 1959 Louisiana's Department of Wildlife and Fisheries initiated an intensive alligator management program with the object of rebuilding, and maintaining the State's alligator population at a figure capable of sustaining a closely regulated annual harvest. It was diverse in scope and involved diligent enforcement and legislative efforts, restocking of depleted areas, and extensive research.

The research program was in two main parts: a field study segment investigating basic life history and a culture program which was based on the biological facts derived from field investigations. The culture program demonstarted the feasibility of rearing alligators in captivity and reinforced the concept of farming as a viable source of animals for commercial and conservation purposes. We were able to study captive alligators and make observations that were impossible under field conditions, e.g., reproductive activities, stocking densities, food requirements and social interactions (Joanen and McNease, 1979).

Materials and Methods - Background Research

Alligator food habits in the wild

Alligators eat a tremendous variety of native foods (Kellogg, 1929; McIlhenny, 1935, O'Neil, 1949; Giles and Childs, 1949; Valentine et al., 1972; McNease and Joanen, 1977; Chabreck, 1971; Fogarty and Albury, 1967). Large alligators (over 6' total length) preferred vertebrates although they ate nearly

all of the animals that small ones ate. Small alligators were limited to the size of the prey they can eat. Generally, small alligators prefer crustaceans, snails, insects, and small vertebrates. Large alligators exhibit opportunistic selectivity in their eating habits tempered by prey species vulnerability and availability. Large animals generally preferred mammals, arthropods, fish, birds, and reptiles. The fact that alligators tend to change (expand) their food habits prior to becoming sexually mature might hold special significance for reproductive events.

Observations in the wild

Information gathered from telemetric investigations added valuable insight into habitat requirements of adult alligators (Joanen and McNease, 1970, 1972), and brought to light differences in habitat requirements by sex and by season of the year. Both sexes tend to gather in courting groups in deep water areas during the spring. During courtship females were more social than males, but after mating males remained in the open water while females moved to dense cover and small isolated ponds in the interior marshes to begin nest construction. Females generally remained in isolation in the marshes until the following spring when courtship once again brought them into open water. Growth rates of wild alligators provided a basis for evaluating growth under captive conditions.

Design of enclosures for adults

An important finding from our pen culture study was the relationship between pen design and productivity. Early pen

design was inadequate because of lack of habitat diversification to achieve the level of production necessary for a large-scale farm operation (Joanen and McNease, 1971, 1975). Inadequate pen features caused competition between both sexes, resulting in fighting and mortality. Using data collected in field studies on habitat requirements, we altered pen construction so that social and environmental considerations could be incorporated into the design. Thus, stocking densities could be much higher (Joanen and McNease, 1979).

Pen culture studies

Stocking rates: As in any farming operation, quality stock is a prerequisite to a productive program. In our early farming endeavours wild-captured adults were the only stock available and were used until they were replaced with a group of pen reared alligators; raised entirely in captivity.

Wild-captured alligators need approximately ten times more space than captive-bred alligators. Under the best pen conditions we were able to maintain five wild alligators per 0.4 ha. A commercial alligator farm in Louisiana was able to maintain 45 adult domesticated alligators per 0.4 ha with a nesting success ranging from 18-90% over a 13 year period (Joanen and McNease, 1979).

Housing for juveniles

Environmental chambers were used as brooders for alligators up to three years of age. Water capacity for three chambers was 530 liters with 10.4 m^2 surface area in each tank. Six chambers were later constructed with the following alterations:

solid concrete walls instead of concrete blocks, water capacity of 1,136 liters and 14.9 m^2 surface area per tank. A tin-roofed shed with skylights provided overhead protection for the chambers (Joanen and McNease, 1974).

All nine tanks were heated by thermostatically controlled electrical thermal conductors. Water was supplied through a network of plastic and galvanized pipes from a 5 cm water well. Temperature recorders were used to monitor outside air temperature, and air and water temperatures inside the chambers.

Disease and other problems

Care was exercised to reduce crowding and pile-ups, the best method being to partition each chamber into smaller units. Pile-ups caused suffocation, fighting, and physical abuse. Overcrowding was our most easily diagnosed and simplest problem to correct.

Gout was caused by overfeeding; however, fasting for one week to ten days usually corrected the problem.

No serious disease problems were encountered during the study. Occasionally animals went off feed for some unexplained reason, perhaps due to changes in fish composition or to minor bacterial or viral infections. Tetracycline, a broad-spectrum antibiotic, provided protection against infection.

The environmental chambers must be 'climb proof'. Hatchlings were especially agile and readily climbed out of the chambers.

Fighting occurred occasionally, resulting in cuts on the tail, back and limbs, but was not considered a serious problem.

High stocking densities increased fighting.

Feeds and feeding

Various diets were tested during the past 15 years to develop an economical and nutritionally balanced feeding regimen, a practical one adaptable to large scale farming operations. Factors which determined choice of a feeding regime included: cost considerations, annual availability of primary food source, storage quality, ease of handling, alligator acceptance, nutritional requirements, effects on growth rates and reproduction, and very importantly, the objectives of propagation program, i.e., whether for grow-out or primarily for breeding purposes. Sufficient information is just now becoming available to allow the study of basic alligator nutritional requirements.

Our feeding program has evolved into three distinct phases: Phase I (age 1 day to 3 years) - intensive culture under closely controlled environmental conditions, Phase II (age 3 to 6 years) - pen grow-out program, and Phase III (over age 6) - pen breeding program.

Our food habit investigations of wild alligators demonstrated that all age classes depend heavily upon a wide variety of animal material in their diets.

Coastal Louisiana produces an abundant and ready supply of high quality and reasonably priced fish, nutria and in some cases domestic chickens. All of these require freezing. Whole fish and nutria (Myocastor coypus) carcasses are available as by-products of commercial operations and cost less than 44¢ per kilogram packaged and frozen. Nutria is only available for 3

months during winter, which requires long periods of freezing, whereas fish is available anytime during the year. Nutritional analyses revealed that nutria contained 14.9% crude protein, 2.1% crude fat, 0.5% crude fiber, and 45% moisture; whereas fish contained 9.9% protein, 4.0% fat, 1.0% fiber and 60.6% moisture. Table 1 gives percent of occurrence by species of fish used as alligator feed.

A special vitamin premix is added to the diets, a maximum rate of 1% by weight, of all age classes of farm alligators. The concentration of vitamins A and D3 were doubled during the last two years of feeding in an attempt to increase reproductive productivity. The specifications for the premix presently in use are (manufactured by Dawe's Laboratories Ltd., Chicago Heights, Illinois 60411):

SPECIFICATIONS	PER 1 LB.
VITAMIN A	1,800,000.00 USP U
VITAMIN D3	200,000.00 IC U
VITAMIN E	5,000.00 IU
RIBOFLAVIN	1,000.00 MG.
d-PANTOTHENIC ACID	2,760.00 MG.
NIACIN	4.50 GM.
CHOLINE CHLORIDE	86.43 GM.
VITAMIN B12	1.35 MG.
FOLIC ACID	90.00 MG.
BIOTIN	20.00 MG.
PYRIDOXINE HYDROCHLORIDE	1,000.00 MG.
MENADIONE SODIUM BISULFITE	4,283.00 MG.
THIAMINE MONONITRATE	1,000.00 MG.
INOSITOL	5,000.00 MG.
PARA-AMINO BENZOIC ACID	5,000.00 MG.
ASCORBIC ACID	45,000.00 MG.
ETHOXYQUIN	5.00 GM.

Results and Discussion

Feeds and feeding for controlled environmental chamber culture (age 1 day to 3 years)

Four diets have been tested for young alligators (Joanen and McNease, 1976). Two altered commercial rations, catfish and turtle feeds, proved totally ineffective and were quickly discontinued. Alligators seem to be unable to synthesize vegetable based proteins in their feeds (Dr. R. A. Coulson, per. comm. 1974).

Nutria carcasses and fish were most acceptable as foods. Growth of nutria fed alligators was superior to those fed fish. Nutria meat caused storage problems because of its seasonal availability and was more expensive than fish. Disadvantages of fish were: high percent moisture, overfeeding tended to produce gout, required freezing for storage, must be purchased in large enough quantities to make delivery economically feasible, must be ground for feeding small alligators, and was found deficient in vitamins, hence the addition of a vitamin premix to the fish diet (Joanen and McNease, 1976).

Ideally young alligators should be separated into size groups with special care taken to keep the smaller and weaker individuals segregated. Environmental chambers should be kept thoroughly clean to avoid infections and to reduce pathogens. Mortality was low during the first ten days after hatching, ranging from 2-5% during eight years of study. Careful attention must be given to keeping stocking densities at a safe level, i.e., no more than one alligator per 0.1 m^2. Overcrowding tended

to induce pile-ups and cause suffocations. After hatching temperatures were held at 32° C in order to speed up body functions with the result that hatchlings began to feed by the ninth or tenth day after hatching. Feeding was not initiated until the eighth day of life to allow for absorption of the egg yolk. Initially food consumption was low, less than 5% of body weight per week, but the important consideration was to get the young regimented to a feeding scheme as quickly as possible.

After the tenth day of life environmental chamber culture was basically one of maintaining clean tanks and providing proper diets for maximum yield. Maximum stocking density remained at 0.1 m^2 until one year of age when it was decreased to a minimum of 0.3 m^2 per animal. This allowed ample space for later growth. For maximum growth the temperatures of the environmental chambers were maintained at 30° C.

Feeding was carried out five days per week for the first year and three days per week thereafter (for example; Monday, Wednesday and Friday). A feeding rate corresponding to 25% body weight per week was adhered to for approximately the first year and thereafter was progressively decreased to about 18% at the end of the third year. Feeding rates were adjusted on a monthly basis. Fish or nutria which had been finely ground was given until the alligators were around one year old when they had attained sufficient size to handle and digest chopped food. Later, as soon as the animals were large enough to handle it, whole fish or larger pieces of nutria were given. After 36 consecutive months of feeding, the young outgrew their brooder facilities

and were stocked into outside pens.

Alligators fed fish converted 49.5% of the food consumed (dry weight) into body mass over a two-and-a-half year period. Coulson et al. (1973) reported conversion rates of 40% up to one year of age and 25% from one to three years but this was probably based on wet weights. At 33 months (i.e., after 26 months of intensive feeding) all animals averaged 19.4 kg and 160 cm with 10% of the alligators measuring more than 180 cm. The longest individual was 193 cm. After 12 months feeding (19 months of age) alligators fed fish averaged 106 cm total length and 4.02 kg body weight - a mean gain of 67.8 cm and 3.85 kg. Length-weight relationships (Joanen and McNease, 1976) were comparable with the findings of Coulson et al. (1973). Captive-reared alligators had a superior body condition to wild alligators being 10% heavier per given length and twice the length of wild alligators of the same age (Coulson et al., 1973).

A comparison of body condition factors for fish fed vs. nutria fed showed the nutria diet contributed to the production of alligators that were heavier than those on the fish diet for a given age class. Increases were 20% heavier and 3% longer for nutria fed alligators.

Operating costs averaged about $20.00 per alligator up to 33 months of age. However, at today's inflated prices costs would be greater. This figure included costs of electricity, feed, vitamins, medicines, and miscellaneous supplies. Capital outlay and labor were not included because of the experimental design of our study (Joanen and McNease, 1979).

Feeds and feeding of alligators under pen conditions

Joanen and McNease (1971, 1975, 1979) described feeding methods and rations for wild caught, captive alligators. Feeding began in March and terminated in October, corresponding to the warmer months of the year. A feeding rate corresponding to about 7% body weight was given each week. Various types of foods were fed; trawl remnant marine fish (Table 1), mammals, and beef by-products. Fish was used as the basic dietary component because of availability and minimal cost. Nutria meat was substituted for fish in some of the pens during 1980. Vitamins and trace elements (approximately 0.5% by weight) are used and seem beneficial. The vitamin supplement was altered to increase vitamins A and D_3 in 1979 and is used for all age classes of alligators.

Our cultured alligators have exhibited suspected dietary problems, especially those animals on a fish monodiet, that were not observed with wild caught stock. Growth rates were excellent but problems with egg fertility and hatchability could be influenced by inadequate nutrition. Problems with reproduction deserve further study.

Most alligator farms in the United States rely heavily upon fish as their primary food source. We strongly recommend that farmers take a close look at the feeding programs, especially for brood stock animals. Culture of our artificially incubated and hand-reared stock has raised serious questions about the effectiveness of traditional feeding programs with respect to an efficient, self-sustaining program.

Growth rates under pen conditions

1972 hatched alligators which were raised in controlled environmental chambers were stocked into pens in June, 1975 at the age of 3 years. Average size at stocking into pens was 1.60 m total length and 19.41 kg. A sample of 19 female alligators in the spring of 1980 showed them to average 37.51 kg ±2.23 kg (n=7) and 2.13 m ±3.18 cm (n=19) total body length (range 29.48-46.27 kg and 1.97-2.43 m). The only male captured in 1980 was 2.92 m total length and about 136 kg. These animals were fed a monodiet of fish and vitamin supplement all of their lives.

1973 hatchlings were stocked into grow-out pens in 1976 at a size comparable to the 1972 age class. A sample of 49 alligators in the spring of 1980 showed females averaged 36.83 kg ±5.58 kg (n=5) and 2.06 m ±1.9 cm (n=32) (range of 28.58-56.70 kg and 1.89-2.32 m) and males averaged 52.25 kg ±3.03 kg (n=6) and 2.37 m ±1.3 cm (n=17) total body length (range of 42.18-61.24 kg and 2.27-2.49 m). Larger males were evident but were not captured for measurements. The 1973 year class were fed fish all of their lives except in 1980 when nutria and vitamin supplements were substituted.

The behavior of fish fed vs. nutria fed animals was obviously different. Animals on fish were shy and very wary whereas nutria eaters were aggressive at the feeding site and overall a much more active animal.

Reproductive success under pen conditions

Age at first nesting for alligators raised in environmental chambers for three years and then pen reared was 5 years 10

months as compared to 9 years 10 months for animals raised in outside enclosures (McIlhenny, 1935; Joanen and McNease, 1975). Wild alligators probably first breed at 10 years of age also.

Egg deposition generally occurred from 12 June to the end of the first week of July. However, for any given year, nesting occurred within a two-week period and the time of nesting was directly related to air temperature, higher temperatures inducing earlier laying (Joanen, 1969; Joanen and McNease, 1979). Hatching was in late August and early September, after artificial incubation for about 65 days. Pen reared alligators frequently lay multiple clutches of eggs per nest; whereas, wild females are solitary nesters.

Stocking rates for the 1972 age class were 1 male:7.7 females and 60 alligators:0.74 ha. The low incidence of males was due to our hatching process favoring females but nevertheless should give useful information relative to number of females a male can service.

Stocking rate for the 1973 age class were 1 male:2 females and 50 alligators:0.3 ha. The reason for the ultrahigh stocking rate was to determine maximum stocking densities for cultured alligators and to investigate unusual stress/social conditions which arose.

The 1972 age class group (fish fed) produced 12 clutches of eggs in 1978, an 18.2% nesting rate. This age cohort was represented by 66 females. Nineteen clutches were laid in 1979 for a 28.8% nesting success. Nesting success in 1980 dropped-off to 18.2% the same as for their very first nesting effort.

The 1973 age class group (fish fed through 1979; changed over to nutria in 1980) produced 20 clutches of eggs in 1979, a 25% nesting rate in their very first year. Eighty females were in this group. In 1980, the 1973 class showed a 36.2% nesting effort (29 clutches), corresponding to the change in diet to whole nutria carcasses. Table 2 presents information on nesting and hatching success for 1979 and 1980.

One pen which contained three males and seven females hatched in 1964 and raised in outside enclosures produced no nests in 1980. These animals were stocked at very low densities; 1 alligator:0.08 ha and subsisted wholly on a fish diet.

Chabreck (1966) determined that 68 percent of wild females nested each year. The average nesting rate of 26.3 percent for our young alligators during their first three years of sexual maturity was considerably below the 48-50 percent reported for wild captured-pen cultured alligators (Joanen and McNease, 1971, 1975).

Hatchability in 1979 was a very low 34 percent and in 1980 44 percent, excluding infertile eggs. This is much below the 50.3 percent reported by Joanen and McNease (1975) for wild captured alligators under pen conditions and the 58 percent reported by Joanen (1969) in the wild. The average clutch size over two nesting seasons was 27.6 eggs for very young captive reared alligators compared to 39 eggs per clutch for alligators in the wild (Joanen, 1969) and wild-captured pen stock (Joanen and McNease, 1979). Egg fertility for young captive reared brood stock averaged 39.5% for two years, much lower than the 87.5% determined

for wild alligators and 75.4% for wild alligators held in pens.

Summary

Recent feed and feeding studies have resulted in more unanswered questions than answered ones. We feel that a variety of quality foods in the diet are better than a monodiet. Excellent growth was achieved with fish and nutria diets; however, fish may not be suitable for a high degree of reproductive success.

The very young age at sexual maturity further complicants comparison of data. Stocking rates, stress, artificial incubation techniques and grow-out procedure may also affect reproductive potential. These factors require long-term study.

Our pen culture program is just now reaching the point where the very basic nutritional requirements of alligators can be studied. We have only begun blood work in the past year (Dr. Valentine Lance, unpublished 1979-80 field data). Dr. Mark Ferguson's ongoing alligator egg and hatchling research should assist in answering reproductive related questions.

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TABLE 1. Percent of occurrence by species of trawl remnant fish used as alligator food.

Fish Feed	Percent of Occurrence
Sciaenidae	
Micropogon undulatus (Atlantic Croaker)	80
Leiostomus xanthurus (Spot)	4
Bairdiella chrysura (Silver Perch)	2
Cynoscion arenarius (Sand Seatrout)	2
Menticirrhus americanus (Southern Kingfish)	2
Polynemidae	
Polydactylus octonemus (Atlantic Threadfin)	7
Stromateidae	
Poronotus triacanthus (Butterfish)	2
Trichiuridae	
Trichiurus lepturus (Atlantic Cutlassfish)	Tr.*
Clupeidae	
Brevoortia patronus (Largescale Menhaden)	Tr.
Carangidae	
Chloroscombrus chrysurus (Bumper)	Tr.
Ephippidae	
Chaetodipterus faber (Atlantic Spadefish)	Tr.
Engraulidae	
Anchoa sp. (Anchovy)	Tr.
Lutjanidae	
Lutjanus synagris (Lane Snapper)	Tr.

*Trace - less than 1 percent.

TABLE 2. Nesting effort and hatching success for 1979 and 1980.

Year of Nesting	Hatching Year of Brood Stock	Average Number Eggs/Clutch	Percent of Females Nesting	Percent Fertile Eggs that Hatched	Percent of Eggs that were Infertile
1979*	1972	28.8	28.8	32	80
1979*	1973	25.3	25.0	36	71
1980	1972	24.2	18.2	37	64
1980**	1973	32.0	36.2	50	27

*Began using a more 'potent' vitamin supplement.

**Diet changed to whole, eviscerated nutria.