Concept

(Not for publication)

PELICAN & CORMORANT
HUSBANDRY MANUAL
NUTRITION SECTION – February 2003

Contributors: Roy McClements, Sue Crissey, Walter Jansen

For remarks and contributions please contact:
Walter Jansen
European Zoo Nutrition Centre
C/O EAZA office/Artis Zoo
P.O. Box 20164
NL-1000 HD Amsterdam
The Netherlands
Tel: +31(0)20 5200 750
Fax: + 31(0)20 5200 752
E-mail: info@eznc.org
Internet: www.eznc.org

Index of contents

EXECUTIVE SUMMARY

The pelican (*Pelecanus sp.*) is a large waterbird with a long heavy bill and voluminous distensible pouch. Living in all regions of the world from tropical to warm temperate zones, they forage in open waters, both fresh and saltwater. Morphologically, the largest species are the Dalmatian (*P. crispus*) and the Eastern great white (*P. onocrotalus*), which can grow to the weight of 15kg. The other five species are smaller at approximately 4-8kgs. Most pelican species are very gregarious, especially during breeding and foraging. The Brown pelican (*P. occidentalis*) is the only strict saltwater and "flight-dive" forager. The cormorant (*Phalacrocroax sp.*) genus contains 40 species, the largest within the order of Pelecaniformes. Medium to large-sized waterbirds with an elongated body, long neck and strong hooked bill. They live in many habitats of great diversity within tropical and temperate zones, in both fresh and saltwater. The Great (*P. carbo*), Double-crested (*P. auritus*) and Brandt's (*P. penicillatus*) range in size from 1.4 to 2.4kgs. The most commonly associated characteristic of the cormorant is the "wing-spread" posture that enables the cormorant to dry their water permeable wings.

There appears to be no significant difference in energy requirements between captive male and captive female pelicans. By determining basal metabolic rate (BMR), Shmueli *et al* (2000) calculated the roosting metabolism of captive great white pelicans as 2.478kcal/kg/h. BMR has been measured in many avian species and found to be highly correlated with body weight (Klasing, 1998). Using this information, energy values can be estimated for pelican species. Energy for exercise and non-breeding production was found to be ≥ 2.6 times the BMR (Shmueli *et al*, 2000). Given an energy digestibility of approximately 85% (Shumeli *et al* 2000), a 10.0kg great white pelican requires a gross energy intake of 1811kcal/day to maintain body weight. Fish on average contain 1.0 and 1.8kcal/g fresh weight. Therefore it is estimated that a 10kg Great penguin would require approximately 1.1kg food per day.

The major component of the diets of free-living pelicans and cormorants is fish. The most common varieties of fish consumed include; carp (*Cyprinius sp.*), perch (*Perca sp.*), anchovies (*Engraulis sp, Mordax sp.*), trout (*Oncorhynchus sp*) and sardines (*Sardinops sp.*). It the wild pelicans and cormorants will generally consume approximately 10% of their body weight per day. In captivity, the most common fish varieties offered are smelt (*Osmerus sp.*), capelin (*Mallotus sp.*) and herring (*Clupeidae sp.*). Fish are supplemented with a commercially available tablet containing vitamin E and thiamin.

References

- Johnsgard, P.A. (1993) Cormorants, Darters and Pelicans of the world, Smithsonian Institute, Washington & London, 343-397
- Brouwer, K, Hiddinga, B. & King, C.E. (1994) Management and breeding of pelicans *Pelecanus* sp. in captivity, Int. Zoo. Yb. 33: 24-39

1. FEEDING ECOLOGY

Composition of diet

Pelicans (*Pelecanus sp.*)

Pelecaniformes	Common Name	Scientific Name	Body Mass (kg)
Pelican	Dalmatian	*Pelecanus crispus*	10.0-13.0
	Eastern Great White	*Pelecanus onocrotalus*	5.4-15.0
	American White	*Pelecanus erythrorhynchos*	5.0-8.5
	Australian	*Pelecanus conspicillatus*	4.0-6.8
	Pink-backed	*Pelecanus rufescens*	3.9-7.0
	Spot-billed	*Pelecanus philippensis*	5.0
	Brown	*Pelecanus occidentalis*	3.5-5.0

There are seven species of pelican generally divided into three groups (Johnsgard, 1993). One group contains the Dalmatian (*Pelecanus crispus*) and the Eastern white (*P. onocrotalus*) of the Palaearctic region, the American white pelican (*P. erythrorhynchos*) of North and Central America and the Australian pelican (*P. conspicillatus*) of Australia. Another group contains two species, the Pink-backed pelican (*P. rufescens*) of Africa and Arabia and the Spot-billed pelican (*P. philippensis*) found in South and Southeast Asia. The brown pelican (*P. occidentalis*) is the single species of the final group. Similar in size and plumage to the group two birds, the brown pelican is given its own category because of its distinct foraging technique. The brown pelican plunges from flight into the water to grab fish. It is also the only strictly saltwater forager, whereas other pelican species maybe found foraging in either salt or freshwater wetlands. (del Hoyo *et al*, 1992). Classed as opportunistic feeders, many aquatic animals are part of the regular diet of many pelicans, but the major component of the free-ranging diets of all pelicans is fish. The most common varieties of fish consumed include; carp (*Cyprinius sp.*), perch (*Perca sp.*), anchovies (*Engraulis sp, Mordax sp.*), trout (*Oncorhynchus sp*) and sardines (*Sardinops sp.*) (McMahon & Evans 1992, Shmulei, Izhaki, Arieli & Arad, 2000, Anderson, Gress & Mais, 1982, del Hoyo *et al* 1992, Derby & Lovvorn, 1997) In addition to these common varieties, pelicans will consume numerous other fish species, crayfish, mice, lizards and tiger salamanders.

Cormorants (*Phalacrocroax sp.*)

Pelecaniformes	Common Name	Scientific Name	Body Mass (kg)
Cormorant	Great	*Phalacrocroax carbo*	1.8-2.8
	Double-Crested	*Phalacrocroax auritus*	1.6-2.1
	Brandt's	*Phalacrocroax penicillatus*	2.4
	Neotropic	*Phalacrocroax olivaceus*	1.8
	Pelagic	*Phalacrocroax pelagicus*	1.4-2.4

The largest family of the Pelecaniformes, there are 40 species found with great diversity

throughout tropical and temperate zones world-wide (del Hoyo *et al* 1992). Of the 40 species, there are five species commonly found in North America. These five species include the Great cormorant (*P. carbo*), Double-crested (*P. auritus*), Brandt's (*P. penicillatus*), Neotropic (*P. olivaceus*), and the Pelagic (*P. pelagicus*). Fish is the main and sometimes only component of the cormorant diet (Cogswell, 1977). But similarly to the pelican, they can be opportunistic and will feed on marine invertebrates including crustaceans, cephalopods, mollusks, amphibians especially frogs, aquatic insects, water snakes, and turtles (del Hoyo *et al* 1992, Cogswell, 1977, Sibley, 2000).

Table 1 details the most commonly found Pelecaniformes in captivity and the dietary items that free-ranging pelicans consume. This table gives a good representation, but it does not take into account location variability. For example, over 90% of the diet of the brown pelican and Brandt's cormorant in the southern Californian bight was the northern anchovy (Anderson *et al* 1982).

FEEDING OF CAPTIVE PELICANS

The nutritional status of any captive animal feeding program relies heavily on the quality of the food and handling processes. Most captive fish-eating animals are fed thawed, frozen fish. Since daily food availability is crucial to any captive program, most fish purchases are made in bulk. This requires the items to be frozen and stored until use. Given the perishable nature of fish, appropriate fish-handling techniques are crucial to maintain the nutritive quality of the food and consequently the welfare of the animals. Guidelines for handling and storing fish can be found in *Handling Fish Fed to Fish-Eating Animals: A Manual of Standard Operating Procedures* (Crissey, 1998).

2. ZOO DIET SUMMARY

Information collected from institutions holding piscivorous birds in captivity can be a useful tool in proposing dietary guidelines. Recently a nutrition survey was conducted within institutions housing Pelecaniformes. There were eight U.S. zoological parks and aquaria that responded the survey, including Racine Zoo, Audubon Zoo, Baltimore Zoo, Columbus Zoo, Disney's Animal Kingdom, Smithsonian National Zoo, Dallas Zoo and Aquarium, and the Brookfield Zoo. The results of this survey showed that the captive diets of Pelecaniformes rely exclusively on whole, thawed, frozen fish of many varieties, supplemented with a multi-vitamin or vitamin/mineral supplement.

The most commonly fed whole fish were capelin (*Mallotus villosus*), smelt (*Osmerus mordaxl*) and herring (*Clupea harengus*). Other fish species included butterfish (*Perilus sp*), silversides (*Menidia menidia*), trout (*Oncorhychus sp*) and mullet (*Mullus sp*). Fish size ranged from three to eight inches in length depending on the species of fish. All responding zoos fed only whole fish and used some form of manufactured and commercially available supplement. Supplementing the fish was achieved using a variety of multivitamins, or vitamin E and thiamin in the forms of pastes and/or tablets from a number of commercial suppliers. In all cases, supplements are either injected or placed in the fish, normally behind the gills.

Table 2 is a summary of the suppliers, dietary ingredients, amounts fed per bird, and the supplements used at the named institutions.

Enrichment & Preference

Most reporting institutions did not use food for behavioural enrichment, although one institution released live fish into the exhibit during the summer as a form of ‘dietary’ enrichment. Bird preference, individual fish size and supplier availability were used in the selection of fish and fish species. In general, bird preference determines which fish species and sizes were fed. With the smaller fish being perceived to be preferred over larger fish. Supplier availability was a concern essentially due to fish availability and within preferential size categories

Feeding Schedule/Interval

In the majority of institutions, Pelecaniformes were fed twice daily, once in the morning and once in the evening. The first fish offered was the “supplemented” fish, which was given individually by hand. As a result of this hand feeding, all respondents were reasonably confident that the supplement was being ingested. Overall, hand feeding was the most common feeding practice. Once birds become satiated and disinterested in the hand feeding process, many institutions broadcast the diet within the exhibit, allowing the birds to forage. Consumption was measured visually but not necessarily recorded.

Determination of Nutrient Content of Diets

Over half of the institutions surveyed, had their fish analysed in a laboratory for protein, fat vitamins and minerals. These analyses were performed by the in-house nutritionist, a commercial laboratory or by the fish supplier. Dietary fish analysis was performed by these institutions at least once a year and in a few of the institutions more than once. Results from these tests were used when formulating the diet, often using a computer-based program (e.g. *Zootrition ä, Animal Nutritionist ä, Zoo Diet Analysis ä*).

Behaviour Associated with Feeding

Pelecaniformes in zoos across the U.S. are housed with many different varieties of birds and mammals in mixed species exhibits. Food related competition problems were only reported in a small percentage of these zoos. When problems were observed, they were essentially due to bird size differences, with the larger pelicans using their advantage to consume more fish over their smaller counterparts. The relatively low incidence of aggressive behaviour may be a consequence of hand feeding.

Alternative Diets

There were no specific dietary changes reported during reproduction. In the few institutions that were successfully breeding pelicans, parents are fed smaller fish to rear hatchlings.

3. TARGET NUTRIENT REQUIREMENTS

Specific nutrient requirements of Pelecaniformes have not been determined. Guidelines and target nutrient levels are given which are based on NRC requirements for domestic cats (carnivorous like Pelecaniformes) and poultry (NRC, 1986, NRC, 1994) similar to that recommended for penguins (Crissey & McGill, 1994). Table 3 gives the recommended nutrients for the adult pelicans expressed as quantity per unit dry matter.

3.1 Energy

Most birds will eat to meet their own energy needs and it is not recommended to limit feeding unless animals are unnaturally overweight. There appears to be no significant difference in energy requirements between captive male and captive female pelicans. By determining basal metabolic rate (BMR), Shmueli *et al* (2000) calculated the roosting metabolism of captive great white pelicans as 2.478kcal/kg/h. BMR has been measured in many avian species and found to be highly correlated with body weight (Klasing, 1998). Using this information, energy values can be estimated for pelican species. Energy for exercise and non-breeding production was found to be ≥ 2.6 times the BMR (Shmueli *et al*, 2000). Given energy digestibility of approximately 85%, a 10.0kg great white pelican requires a gross energy intake of 1811kcal/day to maintain body weight. Fish on average contain 1.0 and 1.8kcal/g fresh weight. (Using information from table 4 an average energy-value of 5.73 kcal/g fish can be calculated.) see table 5 for daily fishneed of pelican. Therefore it is estimated that a 10kg Great penguin would require approximately 1.1kg food per day. Kcal requirement is estimated to be in the range of 4-5kcal/g DM

3.2 Protein

The diets of piscivorous birds have the lowest carbohydrate consumption of any avian category (<2%). As a consequence the piscivorous bird has developed a metabolic adaptation to increase the rates of amino acid catabolism and the use of the carbon skeleton for gluconeogenesis in the absence of a high carbohydrate diet (Klasing, 1998). Specific crude protein and amino acid requirements of pelicans are unknown although they are estimated to be between 20-30 percent of the diet, DMB. Whole fish contains between 33-77% protein, DMB, thus protein and amino acid deficiency is unlikely. All of the fish sampled by Bernard & Ullrey (1997) well exceed target nutrient dietary requirements. A broad range of seasonally available fish will provide sufficient protein for both breeding and non-breeding captive birds.

3.3 Crude Fat

The requirements for fat for many animals is between 3-5% dry matter basis, yet the fat content of most fish may range from 15-40%. Thus an appropriate range for fat for any piscivorous bird may be from 15-30%. Limiting fat to pelecaniformes is not recommended unless the animal is significantly overweight. Dietary fat provides energy, fat-soluble vitamin transport and essential fatty acids (Fowler, 1986). A dietary source of essential fatty acids (EFA) is vital, since animals are unable to synthesize them naturally. The presence of ω-3 and ω-6 polyunsaturated fatty acids

in the diets of piscivorous birds are considered vital for reproductive success (Surai *et al* 2001). Insufficient supply of these important fatty acids are known to be associated with late embryonic mortality, low sperm production, and low post-hatch survivability.

3.4 VITAMINS

In general, a mixed diet of whole fish should provide adequate levels of nutrients. Fish is considered a good source of vitamins A, D, K riboflavin, pyridoxine, pantothenic acid and B_{12} (Reiter & Crissey, 1991). Many factors may change the nutrient quality of this fish, including improper storage and handling, thawing techniques and fish processing. Irrespective of the handling of the fish, supplementation of fish-based diets with vitamins E and Thiamin (B_1) is considered essential (Geraci, 1986).

3.4.1 Vitamin E

The dietary requirement for vitamin E has not been specifically established for many captive exotic birds, but was extrapolated from domestic poultry models (NRC, 1994). Since vitamin E deficiency signs are similar for exotic and domestic birds. Vitamin E deficiency has been linked to fertility problems, muscular dystrophy, encephalomalacia, and lipid peroxidation of adipose tissue in birds (Crissey and Toddes, 1997, Dierenfeld, 1989). Within the adult tissues and eggs of the piscivorous bird, its antioxidant properties reduce the risk of perioxidative damage, as a result of free radicals and reactive oxygen (Surai *et al*, 2001). The presently accepted supplementation dose of vitamin E in captivity is 0.1 IU/g fish/day (0.4 IU/g DM) (Reiter & Crissey, 1991). Zollinger *et al* (2002) validated this rate of supplementation after post-mortems were taken on the Dallas Zoo's pelican population. The post-mortems showed that serum and tissue concentrations of vitamin E were at levels sufficient to maintain homeostasis, although tissues were damaged and unable to heal. Although they could not find a defining answer for the "vitaminosis" that the pelicans were exhibiting, they suggesting that providing a natural source of vitamin E and reducing environmental stressors might increase the bioavailability of the vitamin. (see – *Reported health problems associated with diet*)

On the other hand excessive supplementation of vitamin E can lead to coagulapathy; a state in which blood clotting is reduced which can lead to haemorrhages and even to dead. (Excessive amounts of vitamin A and D may also be involved in causing this process.) [179 - Nichols et al 1989]

3.4.2 Vitamin A

Vitamin A deficiency in piscivorous birds may not be of concern when feeding whole fish. The most concentration storage site for vitamin A in fish is the liver. If birds are fed eviscerated fish in captivity they could become susceptible to vitamin A deficiency (Robbins, 1993a). Signs of hypovitaminosis A include decreased growth, inappetance, ruffled feathers, lethargy, reduced disease resistance, abnormal ocular discharge, and corneal degeneration. It can also adversely affect egg production and hatchability. Similarly, vitamin toxicity should not be a concern since

piscivorous birds have a higher tolerance for vitamin A than domestic birds. Captive Humboldt penguins were fed 59.8 IU/g DM vitamin A long term, without signs of toxicity (Crissey and Toddes, 1997). The signs of vitamin A toxicity may include internal haemorrhage, steatites (yellow discoloration of liver and fat deposits), bone fractures, deformed embryos and reduced reproduction (Robbins, 1993a). Additionally, excess vitamin A can competitively inhibit absorption of vitamin E at the intestinal level (Dierenfeld, 1989). Presently the recommended minimum concentration of dietary vitamin A is 3.5 IU/g/day DM. Many fish contain up to twenty times this minimum recommended dosage. Birds may only be at a risk of hypervitaminosis if supplemented long term with vitamin A.

3.4.3 Thiamin (vitamin B1)

Thiamin is a coenzyme in carbohydrate metabolism and aids in synthesis of fatty acids. It may also play a role in nerve impulse transmission. Thiamin deficiency can be induced in a variety of animals by incorporating foods containing thiaminases into their diets. For feeder fish, at death and throughout processing, thiamin inactivation occurs as a result of the initiation of thiaminases (Geraci, 1986). Anchovy, mackerel, herring, smelt, and capelin have been identified as containing thiaminases (Robbins, 1983b, Geraci, 1974). Signs of thiamin deficiency include ataxia and awkward backward flexion “star gazing”, impaired digestion, diarrhoea, seizures and neurological disorders (Robbins, 1983b). Signs of deficiency can be treated with a single thiamin injection at a dose of up to 1mg/kg body weight. Diets supplemented with 25-30mg of thiamin/kg fish/day (100-120 mg/kg DM) will prevent thiamin deficiency (Geraci, 1986).

3.5 MINERALS

An important physiological adaptation of aquatic species is their ability to handle excess salt loading successfully. Specialised salt glands, functionally similar to renal tissue, are located in the cheek cavities of piscivorous birds. Dietary salt (NaCl) does not appear to be a requirement to maintain health. However, failure to provide salt to pelicans in a fresh water environment will cause atrophy of the glands by non-use (Klasing, 1998). If they have access to salt water this should not be a problem. In captive conditions, this atrophy of the salt glands is only a concern if the animals are housed in freshwater and then introduced into a saltwater environment (Fowler, 1986). The ash component of the common fish species fed to captive Pelecaniformes’ range from 4.8 - 24.5% DM (Bernard & Ullrey, 1997). Manganese and iron tend to be limiting nutrients in most fish species and therefore supplementation may be required. However analyses should be performed before deciding to supplement minerals. Bone deformation and/or reduced egg production and egg hatchability, are associated with manganese deficiency. Iron deficiency causes anaemia in poultry and loss of plumage coloration (NRC, 1994).

4. FORMULATION OF APPROPRIATE DIETS

When formulating appropriate diets for captive pelecaniformes, flexibility is needed to account for animal preference, environmental/seasonal conditions, bird weight & physical condition, and reproductive situation. The captive diets of pelecaniformes in the majority of institutions rely entirely on thawed, frozen fish for growth, maintenance and breeding. Table 4 briefly describes the nutrient content of some of the commonly used fish species. As a consequence of the limited available information on specific nutrient contents of whole fish and that nutrient content can vary radically within and among fish species. The following table should be used only for guideline reference. It is recommended that all zoos have laboratory analysis performed on their fish.

Because the fish species of table 4 all have similar energy-values, an average can be used to calculate the amount of fish that the pelican requires. Table 5 (enclosure 5) contains some amounts of fish fed to pelicans and a calculation of the average value of energy fed per metabolic kg bodyweight.

The outcome of this table is an average need of 1552 kCal per metabolic kg BW. Using the pelican requires to meet the energyneed of the pelican.

Requirements of vitamins can be calculated using table 3 and I the amount of fish does not meet the requirement nutrient, vitamin and mineral supplements can be an option.

Something else that should be taken into account is the size of the fish offered to the pelicans; next table shows the bill lengths of both males and females or general lengths for both sexes. Since pelicans swallow their prey whole, fishsize should not exceed the bottomlength of the pelicanbill.

Scientific Name	Bill length (mm) males	Bill length (mm) females	Literature	Maximum size of fish fed to pelican (mm)
P. crispus	390-425	335-370	114 (Grummt 1983)	335
P. onocrotalus	347-471	289-400	129 (del Hoyo et al 1992)	289
P. erythrorhynchos	320-365	265-320	129 (del Hoyo et al 1992)	265
P. conspicillatus	409-500	346-408	129 (del Hoyo et al 1992)	346
P. rufescens	290-380	290-380	129 (del Hoyo et al 1992)	290
P. philippensis	285-355	285-355	129 (del Hoyo et al 1992)	285
P. occidentalis	280-348	280-348	129 (del Hoyo et al 1992)	280

In order to avoid ultimate dependence on one particular food item, it is recommended that more than one species of fish be offered. Feeding many varieties of fish eliminates problems arising from supply difficulties and ensures a complete nutrient profile. When selecting fish and fish sources, quality should be the number one priority. Use only human quality items and insist upon the monitoring of freezing and storage conditions. Any evidence of degradation or thawing should not be accepted. Other considerations in fish selection could include fish species and size, availability, animal preference, and price.

Nutrient composition of fish

See Table 4 (enclosure 4): The nutrient composition of selected fish species.

Nutrient Supplementation

There are many commercially available thiamin, vitamin E supplements and multivitamins with or without minerals. Some are marketed directly for marine animals. Supplements are supplied in pastes, gel capsules, and tablets. They can be hidden in the fish and then hand fed to the bird.

5. HAND REARING

Pelicans are colonial breeders and at least a small group of birds are required for successful breeding (Brouwer *et al*, 1994). Nutrition information on the breeding of captive pelicans is scarce. Parental incubation and rearing should be encouraged over hand rearing (Brouwer *et al* 1994). Pelican species will lay either two or three eggs, but in general, both in captivity (Brouwer, *et al*, 1994) and the wild they will only raise one chick past fledgling (del Hoyo *et al* 1992). The published data suggest that the biggest constraints on successful breeding programs are that eggs are often infertile, broken or disappear during nesting (Ober & Verkade, 1998). Published information on hand rearing pelicans is very limited. Of the published data, institutions fed minced freshwater fish, mixed with mineral salts and vitamins (Dooley *et al*, 1969; Klos, 1969; Ober *et al*, 1998 & Wexler, 1997). Ober *et al* (1998) successfully raised four chicks, using a diet of minced smelt, Vitamine® and Salvikal®. The food was warmed prior to feeding and the mixture was fed using a syringe. The quantity of food was increased daily and at 14-days the chicks were given whole smelt. After unsuccessful attempts to feed the hatchling on the wet mixture, Wexler (1997) changed to a mash formula. After 10-days the pelican was feeding by itself.

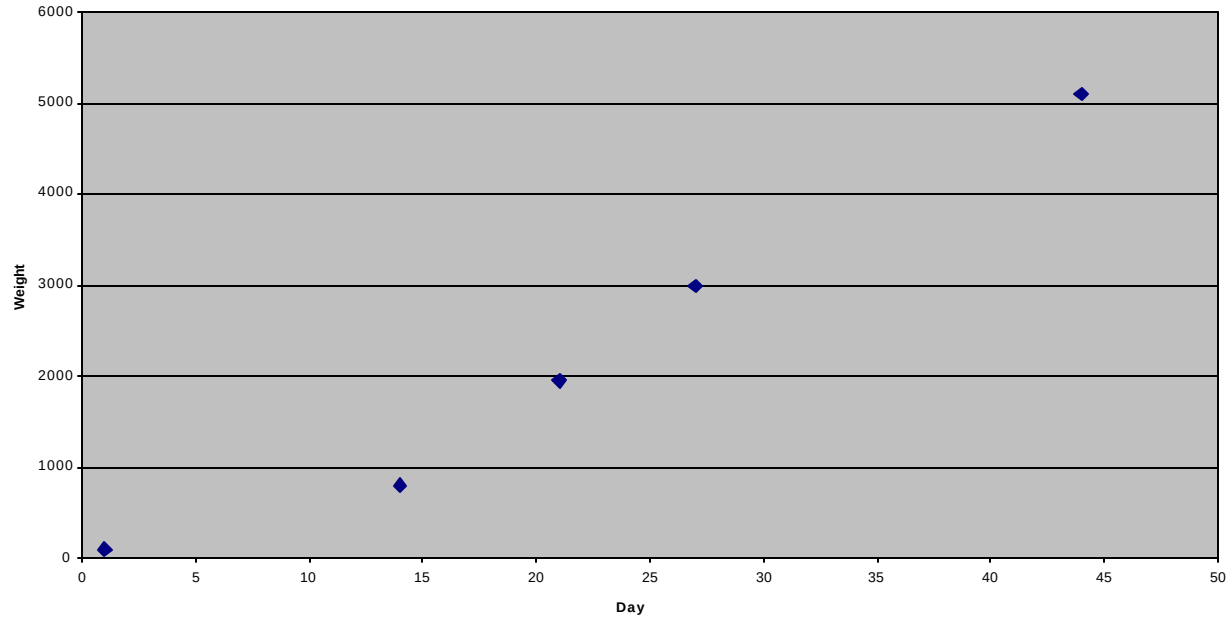
Of great use to the caretaker of the pelicans is information about the incubation period of the eggs; so the caretaker will know when to expect the young and he or she will know how much time there is to make all preparations concerning food and accommodation.

Scientific Name	Incubation Period (days)	Literature
P. crispus	31-34	114 (Grummt 1983)
P. onocrotalus	28-31	114 (Grummt 1983), 118 (Grummt 1992)
P. erythrorhynchos	28-30	114 (Grummt 1983), 118 (Grummt 1992)
P. conspicillatus	34	118 (Grummt 1992)
P. rufescens	30	129 (del Hoyo et al 1992)
P. philippensis	30	129 (del Hoyo et al 1992)
P. occidentalis	30-31	114 (Grummt 1983), 118 (Grummt 1992)

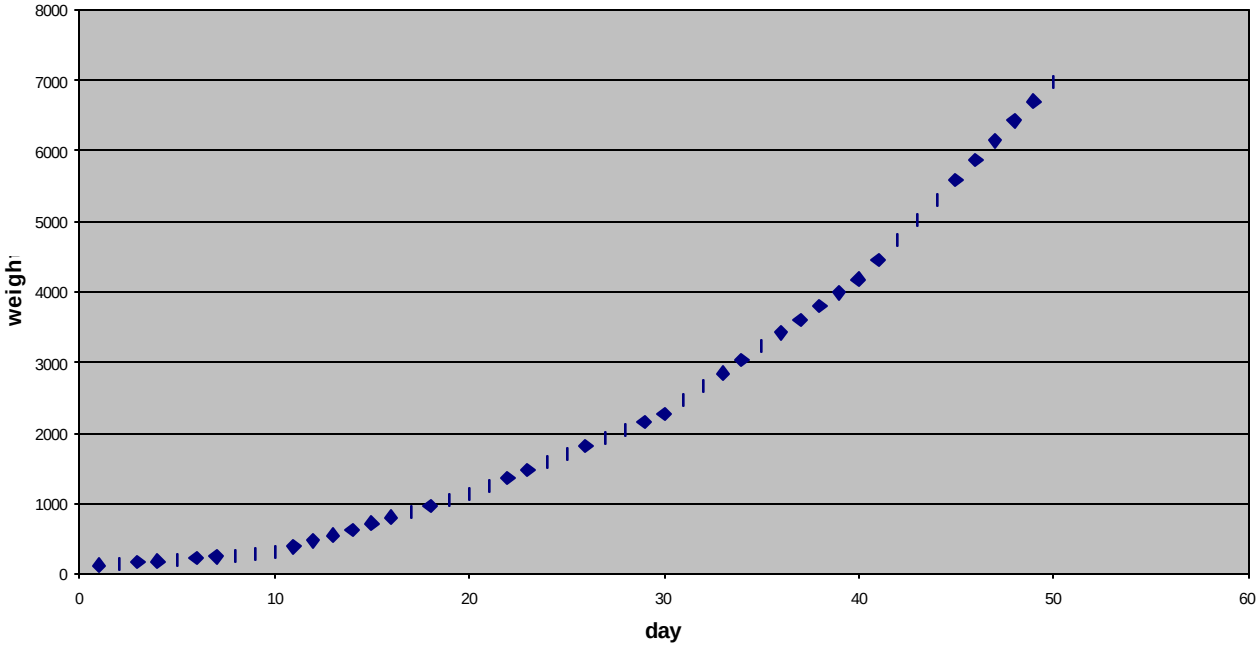
The growth of the young chick should be closely monitored and any normal BW increases or losses should be documented, as well as the daily amount of food fed to the chick (and the consumed amount of food) in relation to these changes in BW.
The BW of the chick increases fast (in every species), but it should be taken care of that the BW does not increase too fast, because this may lead to health problems concerning bones which are not strong enough to carry that much weight.

Subjoined are two graphics containing growthcurves of two different species of pelicans.

P. rufencens, [241] Wexler 1997



P. onocrotalus, [123] Hanhart et al 1972



6. REPORTED HEALTH PROBLEMS ASSOCIATED WITH DIET

In the late 1980's, a study on captive pink-backed pelicans fed 270-1250 IU/kg/fish (1080-5000 IU/kg DM) reported death in three birds from subcutaneous, intramuscular and internal haemorrhage. Initially thought to be a vitamin K deficiency, it was later discovered to be a result of competitive inhibition between vitamins K and E (Nichols *et al* 1989). The Dallas Zoo recently reported similar problems in a pelican flock that was considered appropriately supplemented. Between December 2001 and January 2002, three Eastern white pelicans (*Pelecanus onocrotalus*) and two pink-backed pelicans (*Pelecanus rufescens*) died due to concurrent rhabdomyolysis, steatites, and coagulopathy. Explanations to define a single source for the sudden death of the birds could not be established. Documented evidence showed that hypovitaminosis E causes rhabdomyolysis but coagulopathy can be caused by hypervitaminosis E. The combination of both conditions had never been documented in avian piscivores, especially in the face of daily supplementation of vitamin E. Zollinger *et al* (2002), proposed many potential sources for this "vitaminopathy" including: a fat soluble/vitamin A imbalance; an interaction between the fat-soluble vitamins and the gastrointestinal tract; the quantity and quality of the fish fed; and the stress on the birds. Post-mortem analysis of the birds showed normal serum and tissue concentrations of vitamin E and indicated that it should have been available. However, the tissues were damaged and unable to utilise the antioxidant capabilities of vitamin E. The recommendation was to supplement pelican species with a vitamin E source, preferably natural, at 100 IU/kg fresh weight fish and decrease environmental stressors. In time of apparent stress, it may be wise to analyse the diet and monitor the α-tocopherol serum levels in the birds.

REFERENCES

- Anderson, D.W., Gress, F. & Mais, K.F. (1982) Brown pelicans: influence of food supply on reproduction, Oikos 39: 23-31
- Bernard, J.B. & Allen, M.E. (1997) Feeding captive piscivorous animals: Nutritional aspects of fish as food, Nutrition advisory group handbook, Fact sheet 5, Chicago Zoological Society, Brookfield Zoo
- Bernard, J.B. & Ullrey D.E.(1989) Proximate analysis and energy content of whole fish and marine invertebrates (DMB), In: Feeding captive piscivorous animals: Nutritional aspects of fish as food, NAG handbook, Fact sheet 5, Chicago Zoological Society Brookfield Zoo. eds: Bernard & Allen.
- Brouwer, K, Hiddinga, B. & King, C.E. (1994) Management and breeding of pelicans *Pelecanus* sp. in captivity, Int. Zoo. Yb. 33: 24-39
- Carl, R.A. (1987) Age-class variation in foraging techniques by brown pelicans, The Condor 89: 525-533
- Cogswell, H.L (1977) Cormorants, *In:* Water birds of California, University of California Press, Berkeley, Los Angeles, USA, 85-89
- Crissey, S.D. (1998) Handling fish fed to fish-eating Animals: A manual of standard operating procedures. U.S. Dept of Agriculture, Agricultural research service, National Agricultural library, http://www.nal.usda.gov/awic/pubs/fshndl.htm
- Crissey, S.D. McGill, P. (1994) Penguin Nutrition, In: Penguin Husbandry Manual, Chapter 5, AZA publication, 1st edition, *eds*: Ellis, S. & Branch, S.
- Crissey, S.D., Slifka, K.E. & McGill, P. (2001) Penguins: Nutrition and dietary husbandry, Nutrition advisory group handbook, Chicago Zoological Society, Brookfield Zoo
- Crissey, S.D.& Toddes, B. (1997). Diets for Micronesian Kingfisher, *Halcyon c. cinnamomina*. In: Micronesian Kingfisher Species Survival Plan, chapter 9, AZA publication, eds: Bahner, B., Baltz, A., Diebold, E.
- Cordonnier, P. (1982) Note on the successful breeding of the Dalmatian pelican *Pelecanus crispus* at the Park of Villars-les-Dombes, France, Avicult. Mag 88: 33-35
- del Hoyo, J. Elliott, A. & Sargatal, J. eds. (1992) Handbook of the birds of the World. Vol. 1. Lynx Edicions, Barcelona, 290-311
- Derby, C.E. & Lovvorn, J.R. (1997) Predation on fish by cormorants and pelicans in cold-water river: a field and modeling study, Can J Fish Aquat. Sci. 54 1480-1493
- Dierenfeld, E.S. (1989) Vitamin E deficiency in zoo reptiles, birds and ungulates, J Zoo. Wild. Med. 20(1): 3-11
- Dierenfeld, E.S. & Traber, M.G. (1992) Vitamin E status of exotic animals compared with livestock and domestics" *in* Vitamin E in Health and Disease. Packer, L. and Fuchs, J, eds. Marcel Dekker, Inc., New York, 345-370
- Dooley, R.E. & Heyland, O. (1969) Notes on breeding brown pelicans *Pelicanus occidentalis* at Houston Zoo. Int. Zoo. Yb 9: 120-121

- Duffy, D.C. (1983) The foraging ecology of Peruvian seabirds, The Auk 100: 800-810
- Geraci, J.R. (1974) Thiamine deficiency in seals and recommendations for its prevention, J. Am. Vet. Med. Assoc. 145(9): 861-863
- Geraci, J.R. (1986) Nutrition and nutritional disorders, 760-764 *In*: Zoo and Wild Animal Medicine, 2nd edition, W.B. Saunders Company, Philadelphia, USA, eds: Fowler, M.E.
- Greichus, Y.A, Greichus, A & Call, D.J. (1976) Care and growth of captive white pelicans. Avicult. Mag. 82: 139-142
- Grummt, W. (1983) Breeding Pelicans at Tierpark Berlin, Proceedings: Intl. Found Conservation of Birds? Jean Delacour Symposium
- Grummt, W. (1984) Beitrage zur Biologie, speziell zur Fortpflanzungsbiologie der Pelikane. Zool. Garten N. F., Jena (1984) 4/5, S. 225-312
- Grummt, W. (1992) Mehr als drei Jarhzehnte erfolgreiche pelikanbruten im Tierpark Berlin-Fredrichsfelde, Zool. Garten N.F., 62, (19929 4, S. 249-265
- Hanhart, E., Kleinpeter, R., Steiner, M. (1972), Kunstliche Aufzucht eines Rosenpelikans, Zolli 29
- Johnsgard, P.A. (1993) Cormorants, Darters and Pelicans of the world, Smithsonian Institute, Washington & London, 343-397
- Klasing, K.C. (1998) Comparative Avian Nutrition, chapter 9, p214-216, Cambridge University Press, CAB international, UK,
- Klos, U (1966) Notes on breeding of pelicans at the West Berlin Zoo. Int. Zoo Yb, 6: 121-122
- March, B.E (1992) Essential fatty acids in fish physiology, Can. J. Physiol. Pharmacol. 71: 684-689
- McMahon, B.F. & Evans, R.M. (1992) Nocturnal foraging in the American White pelican, The Condor 94: 101-109
- Nichols, D.K., Wolff, M.J., Phillips, L.G. & Montali, R.J. (1989) Coagulopathy in pink-backed pelicans (*Pelecanus rufescens*) associated with hypervitaminosis E, J. Zoo. Wild. Med. 20:1 57-61
- NRC (1994) Nutrient requirements of poultry, 9th Edition, Nutrient Requirements of Domestic Animals, National Academy Press, Washington DC
- NRC (1986) Nutrient requirements of Cats, Revised edition, Nutrient Requirements of Domestic Animals, National Academy Press, Washington DC
- Nyunt, K.M., Lim H., Ng K.M. (1993) Pelican breeding-suggestions and problems, Australian birdkeeper 1993, pages 385-390
- Ober, S.H. & Verkade, R. (1998) Hand rearing the Eastern or Great white pelican *Pelecanus onocrotalus* at Vogelpark Avifauna, Alphen. Int Zoo Yb 36: 171-173
- Reiter, J.L. & Crissey, S.D. (1991) Nutrient considerations of diets for fish eating animals, Nat. Wildlife Rehab. Assoc. Conference, 20-24 Feb 1991.

- Robbins, C.T. (1993a). Fat Soluble Vitamins, *in* Wildlife Feeding and Nutrition, 2nd edition. Academic Press, San Diego, 81-95
- Robbins, C.T. (1993b). Water Soluble Vitamins, *in* Wildlife Feeding and Nutrition, 2nd edition. Academic Press, San Diego, 95-100
- Saino, N., Fasola, M. & Waiyaki, E. (1994) Do white pelicans *Pelecanus onocrotalus* benefit from foraging in flocks using synchronous feeding?, Ibis 137: 227-230
- Schwarrz, F.J. (1996) Influence of dietary fatty acid composition and vitamin E on fatty acids and α-tocopherol in carp *Cyprinus carpoi* L. Arch. Anim. Nutr. 49: 66-71
- Shmueli, M., Izhaki, I., Arieli, A. & Arad, Z. (2000) Energy requirements of migrating Great White pelicans *Pelecanus onocrotalus*, Ibis 142, 208-216
- Sibley, D.A. (2000) Pelecaniformes, *In*: The Sibley guide to birds, National Audubon Society, Chanticleer Press Inc, 50-51
- Surai, P.F. Bortolotti, G.R. Fidgett, A.L. Blount, J.D. & Speake, B.K. (2001) Effects of piscivory on the fatty acid profiles and antioxidants of avian yolk: studies on eggs of the gannet, skua, pelican and comorant. J. Zool. Lond. 255: 305-312
- Wexler, P. (1997) Breeding the pink-backed pelican *Pelicanus rufescens*, Avicult. Mag. 103(2): 80-84
- Zollinger, T.J., Gamble, K.C., Alvarado, T.P., Levens, G., Garner, M.M. & Raymond, J.T. (2002) Rhabdomyolysis, steatitis, coagulopathy in East Africa white pelicans (*Pelecanus onocrotalus*) and Pink-backed pelicans (*Pelecanus rufescens*)

Enclosure 1: Table 1 - Common prey items of free-ranging pelecaniformes

Species	Pelicans							Cormorants		
	Dalmatiain *(P. crispus)*	Eastern Great White *(P. onocrotalus)*	American White *(P. erythrorhynchos)*	Australian *(P. conspicillatus)*	Pink-backed *(P. rufescens)*	Spot-billed *(P. philippensis)*	Brown *(P. occidentalis)*	Great *(P. carbo)*	Double-crested *(P. auritu)*	Brandt's *(P. penicillatus)*
Carp	X	X	X	X	X					
Perch	X		X	X				X	X	
Anchovies							X			X
Trout			X				X			
Cichlids		X			X		X			
Sardines							X			
Other – fish species	X pike	X mullet, catfish	X chub sunfish suckers	X goldfish whitebait	X mackerel		X menhaden mullet spard herring	X flatfish cod, eel herring	X sandeels catfish chub	X rockfish sanddabs
Other – Marine	X eels	X frogs	X salamander crayfish	X shrimp, crayfish		X frogs	X shrimp, carrion	X frogs		
Other	X vegetable matter	X eggs & chicks		X gulls, teal, reptile, amphibian, eggs, chicks		X lizards, snakes	X Offal from fishing boats	X reptiles		X squid

Carp: *Cyprinus, Alburnus, Hypophthalmichthys, Scardinus*
Perch: *Perca*
Anchovy: *Engraulis*
Trout: *Otolithidae, Onocorhynchus*
Chicilid: *Tilapia, Oreochromis, Hapliochromis*
Sardines: *Sardinops*

Other – fish species: *Clarias* (catfish), *Brevoorita* (menhaden), *Mugil* (mullet), *Clupeidae* (herring), *Scomber* (mackerel), *Anguilla* (Eel) *Galaxias* (whitebait), *centrarchidae* (sunfish), *sebastes* (rockfish), *Citharichthys* (sanddabs), *Ammodytidae* (sandeels), *Zoarces* (flatfish), *Gila* (chub).
Other – marine species: *Bufo* (frog), *Crustacia* (prawn), *Cherax* (crayfish), *Loligo* (squid).

Enclosure 2: Table 2 - Results from the dietary survey.

		Racine Zoo	Audubon Zoo	Baltimore Zoo	Columbus Zoo	Disney's Animal Kingdom	Smithsonian National Zoo	Dallas zoo and aquarium	Brookfield Zoo
BIRD SPECIES		American White pelicans	Great White pelican Pink-backed pelican Great cormorant	Pink-backed pelican White breasted cormorant Double crested cormorant	Brown Pelican	[1]Great White pelican [2]Pink-backed pelican	Brown Pelican Double crested cormorant	[1]Eastern White pelican [2] Pink-backed pelican [3]White breasted cormorant	[1]Brown pelican [2]Double crested cormorant
SUPPLIER / **DIETARY ITEMS**		Packers Pride	McRoberts Sales Co.	McRoberts Sales Co.	Atlantic – Pacific	McRoberts Sales Co.	Atlantic – Pacific	McRoberts + Packers	Atlantic – Pacific
Herring	Fish Size	7-8 in.		6 in.					6 in & 180g
	Quantity/bird	12 fish		336g					[2]30g
Smelt	Fish Size		All sizes		3-5 in.	1.5in. & 10g			2 in. & 10g
	Quantity/bird				634g	[1]400g [2]200g			[1]206g [2]66g
Capelin	Fish Size		All sizes	6 in.	5-7 in.		6 in. & 35-36g	28g	3 in & 25g
	Quantity/bird			112g	157g		600-700g	[1]906-1,359g [2]680-793g	[1]206g [2]66g
Butterfish	Fish Size						6 in. & 50-60g		
	Quantity/bird						500-600g		
Silverside	Fish Size				3-5 in.				1-2 in.
	Quantity/bird				184g				[1]137g [2]75g
Trout	Fish Size				3-5 in.	3in. & 30g			
	Quantity/bird				15g	[1]450g [2]225g			
Mullet	Fish Size					3in & 30g			
	Quantity/bird					[1]150g [2]75g			
TOTAL QUANTITY OF DIET OFFERED PER BIRD (Wt)		~1200g		448g	990g	[1]1000g [2]500g	1100-1300g	[1]906-1,359g [2]680-793g	[1]550g [2]220g
SUPPLEMENTS									
Seatab – Pacific Research Labs		1 tablet/day		½tablet – every 2nd day				[1]3-tablets/day [2]1.5-tablets/day	
Mazuri - 5M25 – Purina Mills, Inc.					0.19g / 250g of fish				
Vitamin E – Windmill products									[1]0.165g

Enclosure 2: Table 2 - Results from the dietary survey.

	Racine Zoo	Audubon Zoo	Baltimore Zoo	Columbus Zoo	Disney's Animal Kingdom	Smithsonian National Zoo	Dallas zoo and aquarium	Brookfield Zoo
Thiamin – Windmill products								[1]0.165g
Multi vitamin + mineral – Windmill products								[1]0.11g
Thiamin E – Stuart products					1 gram/kg food			
Vitamin E – lifesfinast		400IU / dose						

Enclosure 3: Table 3 - Target nutrient ranges on for adult pelicans in their daily diet (dry matter basis)

ITEM	*Target nutrient range
Energy (kcal/g)	4 – 6**
Crude protein (%)	20-30
Fat (%)	15 – 30***
Linoleic acid (%)	1.1
Vitamin A (IU/g)	3.5
Vitamin D (IU/g)	0.22 – 0.5
Vitamin E (IU/g)	0.3 – 1.2
Thiamin (mg/kg)	100 – 120
Riboflavin (mg/kg)	2.0 – 4.4
Pantothenic acid (mg/kg)	11.1
Niacin (mg/kg)	12.2 – 61.2
Pyridoxine (mg/kg)	2.9 – 3.3
Folic acid (mg/kg)	0.28 – 0.8
Vitamin B12 (mg/kg)	0.003
Choline (mg/kg)	1000 – 3000
Calcium (%)	0.778 – 0.8
Phosphorus (%)	0.33 – 0.44
Potassium (%)	0.33
Sodium (%)	0.167
Magnesium (%)	0.056
Zinc (mg/kg)	38.9 – 50
Copper (mg/kg)	6.67
Manganese (mg/kg)	33.3 – 44.4
Iron (mg/kg)	66.7 – 80.0
Iodine (mg/kg)	0.389

*Recommendations are based on requirements for domestic poultry and carnivorous mammals, except as noted below.

**Energy requirements based on the 2.6 times the BMR resulting from research by Shmueli *et al* (2000) with apparent energy digestible of 85%

***The fat content of many commercially available fish are in the range of 5-40%, so appropriate levels may fall at 15-30%

Table 4: Nutrient content of selected whole fish. All values are presented on dry matter basis (DMB)

Nutrient	Capelin *Mallotus sp.*	Herring *Clupeidae sp.*	Smelt *Osmerus sp.*	Trout *Oncorhychus sp*	Silversides *Menidia sp.*	Averages	SD
Dry Matter % fresh weight	14.6 – 22.8	23.9 – 32.1	15.8 – 33.4	27.7 – 30.7	26.7 – 29.3	25.7	3.82
Energy (kcal/g)	4.94 – 5.92	5.13 – 6.73	5.45 – 6.05	5.68 – 6.15	5.48 – 5.80	5.73	0.19
Protein (%)	56.0 – 76.5	46.8 – 69.0	56.2 – 73.2	54.7 – 68.5	53.5 – 57.3	61.17	4.06
Fat (%)	7.0 – 23.3	13.3 – 43.0	15.9 – 73.2	8.30 – 11.4	23.5 – 28.3	24.72	11.99
Calcium (%)	1.19 – 2.20	1.62 – 6.41	1.64 – 2.56	1.54 – 1.82	2.29 – 2.89	2.42	0.87
Phosphorus (%)	1.34 – 2.33	1.29 – 2.34	1.62 – 2.01	1.54 – 1.78	1.69 – 2.36	1.83	0.12
Vitamin A (IU/g)	8.9 – 189	10.7 – 31.8	9.2 – 75.0	---	---	54.1	32.84
Vitamin E (IU/g)	0.02– 0.36	0.02 – 0.12	0.08 – 0.28	---	---	0.15	0.05

Analysis from J.B. Bernard and D.E. Ullrey (1997), *In*: Feeding captive piscivorous animals: Nutritional aspects of fish for food, NAG Handbook, Fact sheet 005

Enclosure 5: Table 5 – Energyneed per kg metabolic BW

Scientific Name	Estimated daily Fish-intake (gr)	Energy-value fish-intake (fish-intake * average energyvalue)[1]	Body weight pelican	Metabolic body weight pelican ($BW^{0,75}$)	Energy/metabolic body weight (kCal) *[average][3]*
P. crispus	1200 [129]	6880	10.0 - 13.0 [129]	5.62 - 6.85	1224 - 1004 *[1114]*
P. onocrotalus	900-1200 [129]	5160-6880	5.4 - 15.0 [129]	3.54 - 7.62	1457 - 902 *[1180]*
P. erythrorhynchos	1000 [115]	5730	5.0 - 8.5 [129]	3.34 - 4.98	1715 - 1150 *[1432]*
P. conspicillatus	1000 [115]	5730	4.0 - 6.8 [129]	2.83 - 4.21	2024 - 1361 *[1692]*
P. rufescens	800 [181]	4585	3.9 - 7.0 [129]	2.78 - 4.30	1649 - 1066 *[1358]*
P. philippensis	1000 [129]	5730	5.0 [129]	3.34	1715 *[1715]*
P. occidentalis	600 [181]	3440	3.5 - 5.0 [129]	2.56 - 3.34	1344 - 1030 *[2374]*

[1] For all energy values see table 4

[2] [ ] literature source:
115: Grummt
129: del Hoyo et al 1992
181: Nyunt et al 1993

[3] Using the averages a guideline can be made for the amount of energy that can be given to a pelican on base of its body weight.
Average:
1552 kCal per kg Metabolic Body Weight
E.g.: A pelican with a BW of 10.0 kg has a metabolic BW of 5.62 ($10.0^{0,75}$)
5.62 x 1552= 8722 kCal per day
8722/5.73 (energy value per gr)= 1522 gr of fish (from table 4)