Captive Amazon parrots and their diet: a study on reproductive success

Priam Psittaculture Centre
Research & Breeding

Daniel J. Gowland

2 Australis Place
Queanbeyan NSW 2620 Australia

daniel.gowland@priam.com.au

Abstract: **There are very few studies on reproductive parameters of Amazon parrots, either in the wild or in captivity, and many measurable aspects of psittacine reproduction may be affected by diet. In recent years there has been much debate in avicultural circles regarding the performance merits between extruded pellet diets, as well as extruded pellet diets compared with non-pellet diets. In this study, two pellet-based diets (Traditional and Organic) were fed to 22 pairs of mature captive Amazon parrots (*Amazona spp*) over 3 years. A variety of reproductive parameters were measured (egg production, fertility, egg/chick mortality, hatching and fledging percentages) to assess the performance of the diets in terms of breeding success. Pairs fed the Traditional diet laid an increased number of clutches per pair, and also showed trends towards more eggs (and more infertile eggs) laid per pair. There were no significant statistical differences recorded between the performances of the two diets with relation to embryonic and chick mortality, nor to hatching and fledging parameters.**

INTRODUCTION

Amazon parrots are medium to large sized parrots belonging to the genus *Amazona*. There are about 30 species in this genus (depending on the criteria used for classification), most with a predominately green body and variations in head, wing and tail colouration. Amazon parrots are native to South America, Central America, Mexico and the Caribbean, with loss of habitat and trapping threatening and endangering many populations. The factors determining productivity are important in evaluating the biological feasibility of sustainable harvest, in designing conservation strategies, and in modelling population viability (www.cites.org, www.iucn.org).

Amazon parrots are commonly kept as pets or aviary birds. Specialist captive breeding facilities provide birds to fulfil this demand, thereby reducing the pressures of trapping for trade on wild populations. Captive breeding can protect species under serious threat, providing research information that may help guide management decisions in wild populations, and may contribute to conservation by maintaining genetic and demographic reservoirs with appropriate numbers of animals for re-release programs in case of *in situ* population collapse (Juniper & Parr, 1998). Living populations are essential to preserve non-genetic learned behaviour patterns, for these may be crucial to species survival. Species involved in *ex situ* programs can also serve as 'flagships', raising considerable public interest in the conservation of the natural areas from which they originate (The World Zoo Conservation Strategy).

The importance of nutrition is evident throughout the reproductive cycle and has been studied in a range of birds (e.g. Ullrey *et al*, 1991, Bolton *et al*, 1992, Koutsos *et al*, 2001, Sancha *et al*, 2004). Diet may play a key role by keeping potential parent birds healthy so they are in an optimum condition to reproduce; by assisting in stimulating reproductive behaviour; and it is also essential for proper egg development, influencing clutch size and lay date (Arcese & Smith, 1988), and egg size and density (Bolton *et al*, 1992).

Unfortunately, it is next to impossible to replicate a wild bird's diet. Manufactured pellets are designed to provide as close to what is deemed to be a balanced diet for psittacines as possible. Extensive research at the Parrot Research Centre, University of California, on the Orange-winged Amazon during the breeding season indicated that the birds were more productive when fruits and vegetables were provided in addition to pellets.

The aim of this study was to compare the performance in terms of breeding success of 'Organic' and 'Traditional' pellet-based feeding regimes for parrots. A wide range of parameters was measured throughout the trial, while breeding success was determined by egg production and fertility, and hatching and fledging success rates.

METHODS AND MATERIALS

The study was conducted over three breeding seasons (2004-2007) at a research and conservation breeding facility ~30 km northeast of Canberra, Australia (~ 35º14'S, 149º27'E. The trials were conducted so that for each year there were 22 pairs of mature Amazon parrots aged three years or greater (12 pairs receiving Diet A and 10 pairs receiving Diet B). The trials included seven pairs of Blue-fronted Amazons (*Amazona aestiva*), nine pairs of Double Yellow-headed Amazons (*Amazona oratrix*), three pairs of Yellow-crowned Amazons (*Amazona o. ochrocephala*) and three pairs of Yellow-naped Amazons (*Amazona o. parvipes*). The majority of these birds were imported from the UK in 1995 and were chosen for this diet trial as they were well adapted to captivity and had been established in a breeding program for up to seven years.

EXPERIMENTAL DESIGN

The birds were housed in five banks of aviaries set amongst eucalypt woodland. The aviaries were orientated to the northeast so they received sunlight just after sunrise. A water sprinkling system was placed above the aviaries and activated in spring to stimulate the birds and to provide cooling during times of potential heat stress.

Each aviary contained six to 12 double wired, half sheltered Nogel style cages (1.2 x 1.2 x 3.6 m or 1.2 x 1.2 x 5.0 m, all made from mesh of $25mm^2$ square with a wire diameter of 2.0mm) elevated approximately 1.2 m above a bed of gravel, raked and hoed weekly. Each cage housed one pair of Amazon parrots and contained a minimum of two perches, a feed receptacle at the rear accessed by birds via a hole in the floor and an external nest box accessible for monitoring via a service area at the rear. During the non-breeding season (February to late August) the cages contained visual barriers at the rear sides to provide the birds with some privacy and seclusion but to also enable social interactions with adjoining neighbours at the front of the cage. During the breeding season, metal dividers were positioned at the front sides to prevent visual contact with neighbouring birds and at the back of the cages (service area) to prevent visual contact with feeders.

Three months before the commencement of the first breeding season of the trial the Amazon pairs were randomly allocated one of two trial diets so that there were approximately equal numbers of each species fed the diets.

The two trial diets were the **Traditional Diet: Diet B** (based on non-organic pellets), on which all birds were maintained prior to the trial, and a feeding regime based on organic pellets (hereafter referred to as the **Organic Diet: Diet A**). During the breeding season, the birds fed the Organic diet received 60g Harrison's Bird Diet pellets (High Potency, coarse) and approximately 120g chopped seasonal fruits and vegetables per pair daily. The birds fed the Traditional diet received approximately 60g Pretty Bird pellets (Breeder Select, medium), 120g chopped seasonal fruits and vegetables and 30g non-breeding sprouted seed mix (including millet, oats, safflower and corn) per pair daily (Table 1).

All birds received approximately 10g sprouted sunflower seed and 10g hard sunflower daily and six shelled almonds three times a week. During the non-breeding season sunflower was not offered and the diets were supplemented with Pretty Bird Daily Select Medium and Harrison's Bird Diet Adult Lifetime Coarse, respectively. Drinking water was supplied *ad lib* and bowls were flushed at least two to four times daily throughout the trial period.

	Traditional diet	Organic diet
Breeding season	60g Pretty Bird pellets (Breeder Select, medium) 120g chopped seasonal fruits and vegetables 30g non-breeding sprouted seed mix	60g HBD pellets (High Potency, coarse) 120g chopped seasonal fruit and vegetables
	10g sprouted sunflower + 10g hard sunflower per day plus 6 shelled almonds 3x a week	
Non-breeding season	Diet supplemented with Pretty Bird Daily Select medium	Diet supplemented with HBD Adult Lifetime Coarse
	No sunflower seed	

Table 1. The two diets used in the trial (amounts are approximate per pair per day)

Diets were prepared fresh each day and fed to the birds in the morning (excluding hard sunflower) between 0830 h and 0930 h. The birds were offered the hard sunflower in the afternoon between 1400 and 1600 and were also given approximately 30g of respective pellets if all other food had been consumed.

During the breeding season nest boxes were checked daily. All eggs were removed, replaced with artificial eggs, and artificially incubated. After all the eggs from the first clutch were laid, the artificial eggs were removed to stimulate a second clutch and in some instances, a third. Pairs that laid their first clutch after the end of November were not stimulated to double clutch.

In this study eggs were incubated at 37.2°C with varying humidity in AB Newlife 75 Mk6 incubators (AB Incubators: Suffolk, England). Eggs were positioned in a horizontal position on rollers. Each alternative roller had been fitted with "O" rings to control the precise turning of each egg, and the incubator was managed so that the eggs were turned 180° backwards and forwards 96 times per day. After full allantoic membrane development of an egg had been achieved, which was ideally 50-52% of the incubation period, the egg was candled and the air cell line on the egg was marked with a 2B pencil. The egg was then moved to an incubator with a gentle rocking movement (Octagon 20 incubator (Brinsea: Avon, UK) set at the same temperature) until external pipping occurred.

In the Octagon 20 incubator, the eggs were held by foam covered plastic dividers and the machine was set to rock the eggs backwards and forwards around 45° each way. The initial positioning of the egg was with the air cell at the most vertical position but with the horizontal axis of the egg positioned at 45° away from the vertical axis opposite to the greatest dip in the air cell line on the egg. As the egg approached the time of external pipping, the egg was positioned closer to the horizontal plane.

Humidity management of each egg was determined by weight loss trends and moving the eggs in to high or low humidity incubators as required from the results of the weight loss calculations. Management of each egg in this manner consistently gives greater hatching success and a very low incidence of malpositioning at hatching.

Externally pipped eggs were placed in a AB Newlife 75 Mk3 hatcher (AB Incubators: Suffolk, England) set at 36.5°C and 60% humidity until the chick hatched. Hatched chicks were moved to a AB Newlife 75 brooder (AB Incubators: Suffolk, England) set at 36.2°C and 70% humidity within six hours of hatching for hand-rearing.

Data collected from eggs during incubation included egg dimensions, initial fresh egg density, density changes over incubation period, weight loss trends, allantoic membrane development regime, embryonic mortalities (including blood ring), fertility, incubation period, hatching regimes and chick hatching weights. These data aided incubation management decisions.

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Incubation Management Techniques

ANALYSIS
Participation rate, number of clutches, eggs, eggs fertile/infertile/fertility unknown, eggs gone to blood ring, embryonic deaths, chicks hatched/died/fledged were recorded for each pair of Amazons. Data collected from hand-reared chicks, while not part of this trial, included weight, health, feeding regimes, fledging age and brooder environment.

Differences in the recorded measurements listed above were analysed by the Mann-Whitney *U*-test.

Unless otherwise specified:

Participation rate	% of females laying eggs
Fertility rate	% fertile eggs (number fertile eggs/total number eggs laidx 100)
Hatching rate	% chicks hatched from fertile eggs (number chicks hatched/number fertile eggs x 100)
Fledging rate	% chicks fledged from all chicks hatched (number chicks fledged/number chicks hatched x 100)

RESULTS

During the 2004-2007 trial period, captive Amazon parrots laid 281 eggs (Table 2a). There were more fertile than infertile eggs (64.8% to 33.8%) with only 1.4% of the eggs assigned unknown fertility, predominately due to egg breakage before collection. Of the fertile eggs, 67% hatched as healthy chicks, while of the remaining 33%, 12% died as a result of blood ring, and 21% died further on during embryonic development. 14 chicks died following hatching (including 3 following bites from a mainland tiger snake (*Notechis scutatus*)), leaving 88.5% of all chicks hatched to ultimately fledge.

In October 2006, an incubator malfunction (turning problems, lasting an estimated 5 days) resulted in the loss of 12 fertile eggs (see Table 2a). The eggs that were not turned correctly failed to fully develop the allantoic membrane, resulting in the embryos dying up to 16 days after the incubator malfunction. Reduction in allantoic membrane leads to inhibition of embryo growth, with loss of 20% coverage of the inner shell surface usually leading to death of the embryo as it approaches hatching stage. Subsequently, the embryonic death rate was high (and the hatching and fledging rates low) for 2006. Statistical analyses showed that there was no difference in the number of deaths caused by human error/equipment failure between the two treatment groups. These data were included in the analyses to present results that are representative of breeding facilities.

	A: Organic diet				***B: Traditional diet***				*Total/ mean*
Breeding season	*2004*	*2005*	*2006*	*Total/ mean*	*200 4*	*200 5*	*2006*	*Total/ mean*	
Potential breeding pairs	12	12	12		10	10	10		66
Females producing eggs	9	10	9	9.3	8	9	10	9	55
Participation rate (females laying eggs %)	**75**	**83**	**75**	**77.6**	**80**	**90**	**100**	**90**	**83.8**
No. clutches laid (total)	11	13	11	35	12	12	16	40	75
Av. no. clutches laid per pair	.92	1.08	.92	.97	1.2	1.2	1.6	1.33	1.13
No. eggs laid (total)	**49**	**50**	**45**	**171**	**43**	**41**	**53**	**193**	**281**
Av. no. eggs laid per pair	4.08	4.16	3.75	3.11	4.3	4.1	5.3	4.49	4.2
Eggs per breeding female	5.4	5.0	5.0	5.1	5.4	4.6	5.3	5.0	**5.1**
No. infertile eggs (total)	18	17	14	49	11	15	20	46	95
Av. no. infertile eggs per pair	1.5	1.4	1.2	1.36	1.1	1.5	2.0	1.53	1.45
No. eggs fertility unknown (total)	0	1	2	3	1	0	0	1	4
Av. no. fertility unknown per pair	0	.08	.17	.08	0.1	0	0	.03	.06
No. fertile eggs (total)	**31**	**32**	**29**	**92**	**31**	**26**	**33**	**90**	**182**
Av. no. fertile eggs per pair	2.6	2.7	2.4	2.6	3.1	2.6	3.3	3.0	2.8
Fertility rate %	**63**	**64**	**64**	**63.7**	**72**	**63**	**62**	**65.7**	**64.7**
No. eggs to blood ring (total)	3	5	1	9	5	4	4	13	22
Av. no. eggs blood ring (per pair)	.25	.42	.08	.25	.5	.4	.4	.43	.34
No. embryonic deaths (total)	4	4	7	15	5	5	13	23	38
Av. no. embryonic deaths (per pair)	.33	.33	.58	.41	.5	.5	1.3	.77	.59
No. hatched chicks died (total)	2	4	2	8	2	1	3	6	14
Av. no. hatched chicks died (per pair)	.17	.33	.17	.22	.17	.08	.25	.17	.19
Embryonic mortality rate (total) – not including blood ring	.13	.13	.24	.16	.16	.19	.39	.26	.21
Embryonic mortality rate (per pair) – not including blood ring	.33	.33	.58	.41	.5	.5	1.3	.77	.59
No. chicks hatched (total)	**24**	**23**	**21**	**68**	**22**	**17**	**16**	**55**	**123**
Av. no. chicks hatched (per pair)	2	1.9	1.75	1.89	2.2	1.7	1.6	1.83	1.86
No. chicks fledged (total)	**22**	**19**	**19**	**60**	**20**	**16**	**13**	**49**	**109**
Av. no. chicks fledged (per pair laying eggs)	2.4	1.9	2.1	2.1	2.5	1.8	1.3	1.9	2.0
Hatching rate from fertile eggs %	**77**	**72**	**72**	**73**	**71**	**65**	**48**	**61.3**	**67**
Hatching rate from all eggs laid %	49	46	47	47	51	41	30	41	44
Fledging success from fertile eggs %	71	59	66	65	65	62	39	55	60
Fledglings per clutch	2.0	1.5	1.7	1.7	1.7	1.3	0.8	1.3	1.5
Fledglings per breeding pair	2.4	1.9	2.1	2.1	2.5	1.8	1.3	1.9	2.0
Fledging rate (from all chicks hatched) %	**92**	**83**	**90**	**88**	**91**	**94**	**81**	**89**	**88.5**

Table 2a. Breeding parameters from this study.

	Year 1 2004	***Year 2 2005***	***Year 3 2006***	***mean***
Potential Breeding Pairs	22	22	22	22
Females produced eggs (participation rate %)	**17 (77)**	**19 (86)**	**19 (86)**	**18.3 (83)**
Total eggs laid	92	91	98	93.6 (281)
Fertile eggs	62	58	62	60.6 (182)
Fertility rate %	**67**	**64**	**63**	**64.7**
Total hatched	46	40	37	41 (123)
Hatching rate from fertile eggs %	**74**	**68.5**	**60**	**67.5**
Hatching rate from all eggs %	50	43.5	38.5	44
Infertile eggs	29	32	34	31.7 (95)
Chicks fledged	42	35	32	36.3 (109)
Fledging rate from all chicks hatched %	**91.5**	**88.5**	**85.5**	**88.5**
Fledging rate from all fertile eggs %	68	60.5	52.5	60.3
Fledglings per clutch	1.85	1.4	1.25	1.5
Fledglings per breeding pair	**2.5**	**1.85**	**1.7**	**2.0**

Table 2b. Comparison of breeding parameters for the three breeding seasons

EGG PRODUCTION AND FERTILITY

77.6% of the amazon pairs eating the Organic diet laid eggs (with a fertility rate of 63.7%), while 90% of the pairs eating the Traditional diet laid eggs (fertility 65.7%) (Figure 1).

When considering the results regarding egg production, the number of clutches per pair showed that those birds receiving the Traditional diet had statistically significant more clutches (1.37 per pair) than those birds receiving the Organic diet (0.94 clutches per pair; p=0.002, see table 4). Birds receiving the Traditional diet also showed a trend towards an increased number of eggs per pair (4.71), when compared to those birds receiving the organic diet (3.64 eggs per pair; p=0.086), along with a trend towards increased number of infertile eggs per pair (p=0.077). However, the diet had no affect on the number of fertile eggs produced or the fertility rate (Table 4).

HATCHING SUCCESS

There were no statistically significant differences detected in number of eggs blood ring, embryonic deaths, mortality rates or chick deaths observed between the two treatment groups (Table 5).

FLEDGING SUCCESS

There were no statistically significant differences detected in the number of chicks hatched, fledged or hatching and fledging rates (from all eggs laid and fertile eggs laid) observed between the two treatment groups (Table 6).

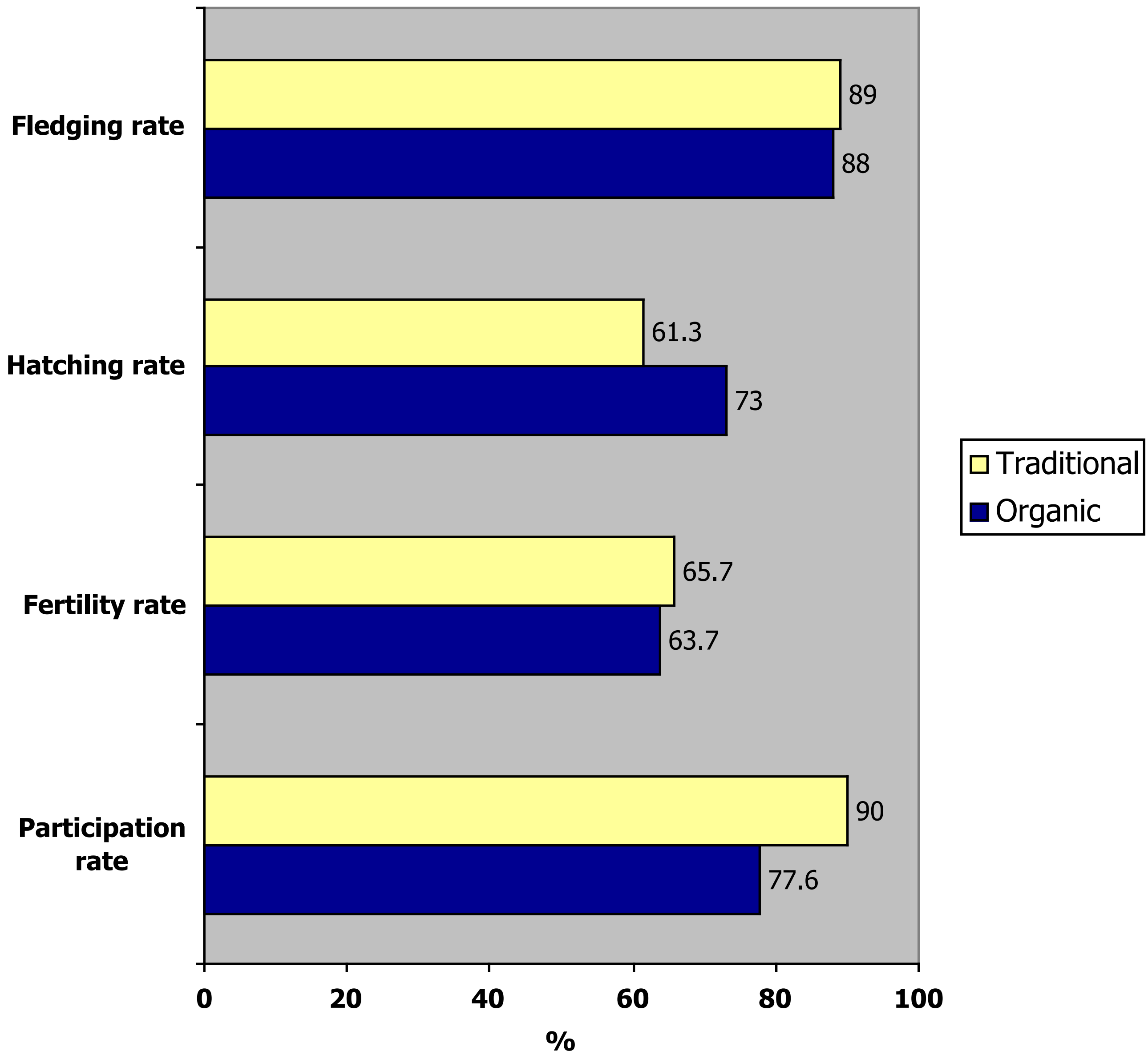

Figure 1. Comparison of breeding parameters between Organic (*n*=47) and Traditonal (*n*=41) diets.

DISCUSSION

Studies of parrot breeding parameters, in this case the genus *Amazona,* may be important in establishing optimal captive and wild management guidelines, with potential extrapolations to the management of many other psittacines. Determining species differences within the same genus can help to guide management decisions.

There have been few intensive studies of *Amazona* parrots, in captivity or in the wild, and these have been mostly restricted to species inhabiting single islands, where populations are low either naturally or due to human effects (Snyder *et al*, 1987); and data are difficult to compare due to differences in habitat on different islands. Only fragmentary natural history accounts are available for many of the *Amazona* species.

This study is one of the few detailing captive Amazon breeding data. It is one of the very few comparative studies into the effects of dietary regimes on breeding success in captive birds. One of the challenges involved in the attempt at comparisons between different studies is the variety of 'breeding/productivity parameters' used. One of the advantages of studies on captive birds is that it enables daily, or hourly if necessary, data collection, for example, monitoring eggs for fertility and embryonic development.

Egg production/fertility

In this current study the participation rate (females producing eggs) was 77.6% for the Organic diet and 90% for the Traditional diet. In one other study involving captive amazons and diet, Hagen (1994) reported a participation rate of 43%. The mean clutch size was 3.6, and there was a significantly increased number of clutches per pair in the birds receiving the Traditional diet, with an average of 1.33 clutches per pair (compared to an average of 0.97 clutches per pair for the Organic diet). Double-clutching in wild amazons is uncommon, it has been reported in Puerto Rican and Hispaniolan Amazons, both island species, though has not been reliably documented for mainland *Amazona* species in the wild (Snyder et al, 1987).

Enkerlin-Hoeflich (1995) found, when researching three wild species of Amazon, that, especially for *A.oratrix*, the *proportion of non-reproductive pairs was high*. He also found that mean clutch size was inversely related to the typical body weight of the species. *A.viridigenalis* had the smallest body size (~305g) and the largest clutch size (3.4 eggs) and the largest species *A.oratrix* (~437g) had a mean clutch size of 2.6 eggs. In his wild study, nest inspections were a maximum every two days during egg laying and hatching.

Enkerlin-Hoefflich measured productivity using the "apparent success method" (nests fledging at least one young) and the "Mayfield Method" to estimate nesting success (avoids overestimates of nesting success that result when some nesting failures, especially those early in the nesting period, are undetected). In the wild, the problems in distinguishing among abandoned nests, infertility and embryonic mortality make comparisons difficult. Enkerlin-Hoefflich found that 'unhatched eggs' represented an average of 10% of the egg/chick mortality for the three species, with infertility and embryonic mortality considered together. In this captive study, the fertility rate was 51% (Traditional diet 48%, Organic diet 54%), and the embryonic mortality rate was 22%.

Low (1995) suggests that the captive breeding success of Amazon parrots is often considered to be lower than that of many other parrot species (Order *Psittaciformes*), particularly reflected by a high proportion of infertile eggs. The reduced breeding success of captive Amazon parrots may result from factors including that amazons have a shorter breeding season than other parrots (e.g. Macaws); and a low rate of double clutching. Low also suggests that amazons are less ready to accept their first partner than many other parrots, a factor which may also contribute to reduced breeding success. Flocking birds in the non-breeding season, even those 'successful' pairs, improves the chances for compatible pair formation.

The reduced fertility of captive birds may also involve seasonal factors. In a study done by Hagen (1994) on 56 pairs of amazons fed two different diets, the fertility rate was 38%. In Hagen's study, many of the amazons laid early in the season (compared to non-amazon parrots), and the first 10 pairs to breed laid infertile eggs. It is possible that males and females are not always in breeding condition simultaneously, leading to a higher percentage of infertile eggs, especially at the start and finish of the breeding season. Hagen postulated that the males may need more time to become sexually active before the female laid her eggs, maybe by going into breeding flights two weeks before the females (Hagen, 1994).

Hatching and Fledging rates

In this study, the hatching rate from fertile eggs was 68% (compared to 84% recorded in a 'survey' of mixed captive populations (Johnson, 1992)). The hatching rate from all eggs was 36%, which is low compared to some rates reported for wild birds, for example, 99% for *A.barbadensis* on Margarita Island, Venezuela (Sanz and Rodriguez-Ferraro, 2006) and 93% for *A.o.panamensis* (Rodriguez and Eberhard, 2006); however in the same study, the fledging rate for *A.o.panamensis* was 13%.

The fledging success rate of 88% is much higher than those rates reported in wild amazons (exceptionally, the colony breeder *Cyanoliseus patagonus* has a fledging rate of 91% (Masello and Quillfeldt, 2002)). There was an average of 1.53 juveniles fledged per breeding pair, compared to 0.45 per breeding pair of amazons (and 0.87 young per breeding pair of lorikeets) in the WWF/Traffic captive breeding survey done in the US (Allen and Johnson, 1991). There is no information regarding the dietary regimes in the survey.

Fledging rates in the wild are often considerably lower, though the colony breeder *Cyanoliseus patagonus* may fledge 3 juveniles per breeding pair (Masello and Quiilfeldt, 2002). For example, Seixas and Mourão (2002) found that 1.03 young fledged per nest in a study conducted on wild Blue-fronted Amazons (*Amazona aestiva*). The number of fledglings per breeding pair of *A.barbadensis* averaged 1.27, but varied greatly among years (Sanz and Rodriguez-Ferraro, 2006). The number of chicks per successful nest averaged 2.2 for the three species in Enkerlin-Hoeflich's study in NE Mexico (1995) but other measures such as fledglings produced per adult pair differed significantly; *A.viridigenalis*, *A.autumnalis* and *A.oratrix* had an average fledging rate of 45%, and average juveniles fledged per breeding pair of 0.57 (of which *A.oratrix* fledged 0.3 juveniles per breeding pair, lower than reported for any other study of Amazon parrots. *A.oratrix* also had a high proportion of non-reproductive pairs) (Enkerlin-Hoeflich, 1995).

Of 79 'active' nests in Enkerlin-Hoefflich's 1992-94 study, 47 nests experienced 'nest failure' (all eggs or chicks in a nest were not conspicuously damaged but cold or dead because of unidentified reasons that could include exposure, disease, cryptic predation, or lack of food deliveries) - of which 15 occurred before incubation and 20 occurred during the early nestling phase. 17 nests experienced 'brood reduction' (chicks that died after slow decline in condition in a clutch but siblings survived). *A.oratrix* initiated 23 nests, of which 18 'failed' (15 failing before incubation).

Enkerlin-Hoefflich commented that if management aims include increasing reproductive output and/or decreasing mortality, reduction of pre-fledgling mortality could be the most important factor to consider as the parrots do not commonly double clutch and do not seem to be limited by nest sites. It is difficult to ascertain whether large proportions of non-reproductive adult pairs were not breeding due to long term reproductive/environmental patterns or as a reflection of suboptimal reproductive conditions (for example, reduced chances for mate selection, inbreeding deterrence, young inexperienced pairs, lack of food).

Juvenile mortality generally appears to be high in Psittaciformes, and without taking into account diet, captive breeding situations will result in comparatively improved fledging success simply by the absence of predation (the three chicks lost to snake bite being an unusual occurrence), which is considered one of the biggest components of fledging mortality in wild populations. Enkerlin-Hoefflich (1995) found predation by snakes an important specific cause of juvenile mortality. In a study on Jamaica, predation was the primary cause of Black-billed parrot (*Amazona agilis*) nestling mortality, and many aspects of *A.agilis* and *A.collaria* (Yellow-billed parrot) nesting behaviour was thought to be related to predation (Koenig, 2001).

Interestingly, fledging success of 90%, with 3 juveniles fledged per breeding pair, was reported by Masello and Quillfeldt in a population of the Burrowing Parrot (*Cyanoliseus patagonus*) colony nesting on a largely inaccessible cliff, with no cases of nest predation detected (the high density of birds in some colonies is also thought to reduce predation). Seasonal variation could also play a role, with years of inclement weather/reduced food supply other than that observed in this 1999-2000 breeding season resulting in lower fledging success.

However improved parental nutrition may also be a factor, with all the birds in this study receiving diets aimed at maximising health and productivity, with seasonal influences also taken into account…

Study/Species of *Amazona*	Partici-pation Rate %	Mean clutch size (fertility %)	Hatching success (%) **from all eggs**	Fledging Rate %	Juveniles fledged per breeding pair	Young per successful nest	Successful attempts %	% of egg laying pairs successful	Reference
33 captive pairs mixed	**78**	**3.6** **(54)**	**36** (66% of fertile eggs)	**89**	**1.53**				**this study (2007)**
1294 captive pairs mixed				78	0.45				Allen and Johnson (1991)
1854 captive pairs mixed			(84% of fertile eggs)						Johnson (1992)
56 captive pairs mixed	43	(38)							Hagen (1994)
A. aestiva					1.03				Seixas and Mourao (2002)
A. barbadensis		3.4	99		1.27				Sanz and Rodriguez-Ferraro (2006)
A.leucocephala		3.6	56	54	0.8			42	Gnam and Rockwell (1991), cited in Masello and Quillfeldt (2002)
A.vittata		3	84	49	1.5		69		Snyder *et al* (1987)
A.autumnalis		2.6		56	0.94	2.61	48	42	Enkerlin-Hoeflich (1995)
A.oratrix		2.7		33	0.3	1.67	22	50	Enkerlin-Hoeflich (1995)
A.viridigenalis		3.4		47	1.4	2.22	48	57	Enkerlin-Hoeflich (1995)
A.o.panamensis		3.08	93	**13**	0.4				Rodriguez and Eberhard (2006)
A.ventralis		2.8				3.05		82	Snyder *et al*, 1987
Cyanoliseus patagonus *n*=29 nests		3.8	90	91	3		85		Masello and Quillfeldt (2002)

Table 7. Breeding parameters of captive and wild species of the genus *Amazona* (and a colony breeder *Cyanoliseus patagonus*) as reported in the literature.
Hatching rate: % of all eggs laid that hatched;
Successful attempts is the % of nests in which at least one chick fledged.

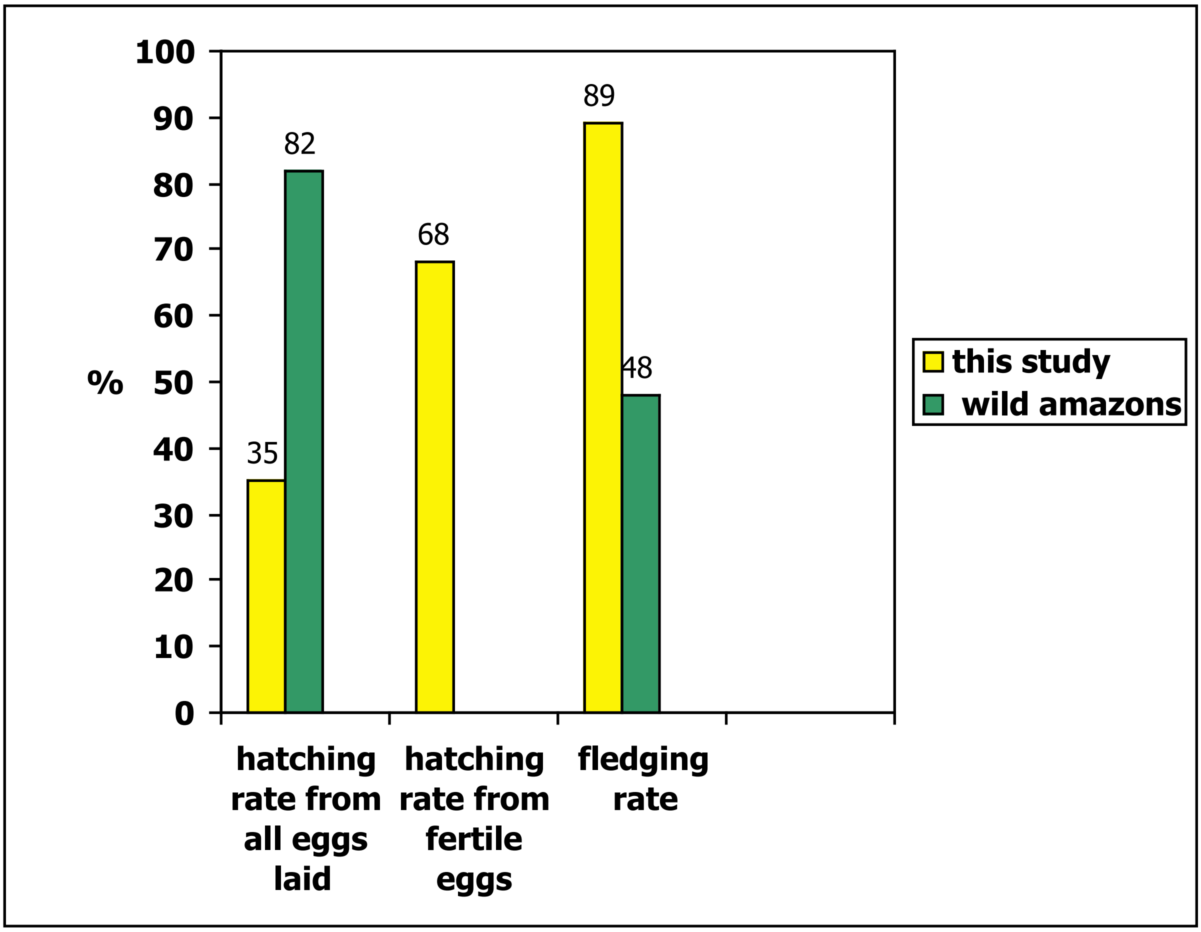

Figure 2. Comparison of hatching (% of all eggs/fertile eggs laid that hatched) and fledging (% of chicks hatched that fledged) rates of captive amazons in this study and an average for wild amazons as seen in the literature (table 7).

Table 4. Comparative results regarding egg production and fertility obtained from Amazon parrots fed an organic diet and a traditional diet. (total *n* =88)

Measure/pair	Organic diet *n* = 47	Traditional diet *n* = 41
No. clutches[a]		
Mean ± SD	0.94 ± 0.67	1.37 ± 0.66
Range	0 – 3	0 – 2
No. eggs[b]		
Mean ± SD	3.64 ± 2.85	4.71 ± 2.89
Range	0 – 10	0 – 12
No. fertile eggs		
Mean ± SD	1.96 ± 2.45	2.24 ± 2.28
Range	0 – 10	0 – 9
No. infertile eggs[b]		
Mean ± SD	1.6 0 ± 2.39	2.44 ± 3.03
Range	0 – 9	0 – 12
No. eggs fertility unknown		
Mean ± SD	0.09 ± 0.28	0.02 ± 0.16
Range	0 – 1	0 – 1
Fertility rate		
Mean ± SD	0.54 ± 0.43	0.48 ± 0.41

[a] Significant at $P < 0.05$ level, Mann-Whitney *U*-test.
[b] Trend at $0.05 > P < 0.10$ level, Mann-Whitney *U*-test.

Table 5. Comparative results regarding embryonic and chick mortality obtained from Amazon parrots fed an organic diet and a traditional diet. (total *n* =88)

Measure/pair	Organic diet *n* = 47	Traditional diet *n* = 41
No. eggs blood ring		
Mean ± SD	0.19 ± 0.40	0.29 ± 0.75
Range	0 – 1	0 – 4
No. embryonic deaths		
Mean ± SD	0.32 ± 0.69	0.56 ± 0.84
Range	0 – 3	0 – 3
No. eggs blood ring + embryonic deaths		
Mean ± SD	0.51 ± 0.83	0.85 ± 1.17
Range	0 – 3	0 – 4
Embryonic mortality rate (exc. blood ring)		
Mean ± SD	0.16 ± 0.25	0.25 ± 0.33
Embryonic mortality rate (inc. blood ring)		
Mean ± SD	0.28 ± 0.30	0.41 ± 0.38
No. hatched chicks died		
Mean ± SD	0.17 ± 0.48	0.15 ± 0.42
Range	0 – 2	0 – 2

*No significant statistical tests, Mann-Whitney *U*-test.

Table 6. Comparative results regarding chicks hatching and fledging obtained from Amazon parrots fed an organic diet and a traditional diet (total *n*=88).

Measure/pair	Organic diet *n* = 47	Traditional diet *n* = 41
No. chicks hatched		
Mean ± SD	1.45 ± 2.0	1.39 ± 1.84
Range	0 – 9	0 – 7
Hatching rate (from fertile eggs)		
Mean ± SD	0.73 ± 0.30	0.62 ± 0.38
Hatching rate (from all eggs)		
Mean ± SD	0.40 ± 0.36	0.30 ± 0.36
No. chicks fledged		
Mean ± SD	1.28 ± 1.70	1.24 ± 1.59
Range	0 – 7	0 – 5
Fledging rate (from fertile eggs)		
Mean ± SD	0.65 ± 0.33	0.55 ± 0.35
Fledging rate (from all eggs)		
Mean ± SD	0.35 ± 0.34	0.29 ± 0.33

*No significant statistical tests, Mann-Whitney *U*-test.

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REFERENCES

Allen, C.M. and Johnson, K.A. (1991) 1990 Psittacine Captive Breeding Survey. A Survey of Private Aviculture in the United States. Traffic/World Wildlife Fund, U.S.A.

Arcese, P. & Smith, J. N. M. (1988) Effects of population density and supplemental food on reproduction in song sparrow. *Journal of Animal Ecology*, 57, 119-136.

Bolton, M., Houston, D. & Monaghan, P. (1992) Nutritional constraints on egg formation in the Lesser Black-backed Gull: an experimental study. *Journal of Animal Ecology*, 61, 521-532.

Hagen, M. (1994) Comparing two feeding methods in an outdoor aviary. *Canadian Parrot Sumporium 1994.*

Hamilton, E. C., Hunter, D. B., Smith, D. A.. & Michel, P. (1999) Artificial incubation of trumpeter swan eggs: selected factors affecting hatchability. *Zoo Biology*, 18, 403-414.

Johnson, K.A. (1992) 1991 Psittacine Captive Breeding Survey. A Survey of Private Aviculture in the United States. Traffic/World Wildife Fund, U.S.A.

Juniper, T. & Parr, M. (1998) *Parrots: a guide to parrots of the world*. East Sussex, Pica Press.

Koutsos, , E. A., Matson, K. D. & Klasing, K. C. (2001) Nutrtition of birds in the order Psittaciformes: a review. *Journal of Avian Medicine and Surgery*, 15, 257-275.

Low, R. (2005) *Amazon parrots: aviculture, trade and conservation*. Mansfield, Insignis Publications.

Masello, J.F. and Quillfeldt, P. (2002) Chick growth and breeding success of the burrowing parrot. *The Condor*, 104:574-586.

Richards, M. P. (1997) Trace mineral metabolism in the avian embryo. *Poultry Science*, 76, 52-64.

Rodriguez Castillo, A.M. and Eberhard, J.R. (2006). Reproductive Behaviour of the Yellow-crowned Parrot (*Amazona ochrocephala*) in Western Panama. Wilson Journal of Ornithology 118(2): 225-236.

Sancha, E. van Heesik, Y., Maloney, Y., Alley, M. & Seddon, P. (2004) Iodine deficiency affects hatchability of endangered captive kaki (Black Stilt, *Himantopus novaezelandiae*). *Zoo Biology*, 23, 1-13.

Sanz, V. and Rodriquez-Feraro, A. (2006) Reproductive Parameters and Productivity of the Yellow-shouldered Parrot on Margarita island, Venezuela: a Long-term Study. *The Condor*, 108:178-192.

Seixas G. H. F. & Mourão G. M. (2002) nesting success and hatching survival of the Blue-fronted Amazon (*Amazona aestiva*) in the Pantanal of Mato Grosso do Sul, Brazil. *Journal of Field Ornithology*, 73, 399-409.

Snyder et al 1987

Ullrey, D. E., Allen, M. E. & Baer, D. J. (1991) Formulated diets verses seed mixtures for Psittacines. *Journal of Nutrition*, 121, S193-S205.