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Short Note

Early reproduction onset in four species of Didelphimorphia in the Peruvian Amazonia

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Precise data about age of sexual maturity in didelphids are scarce, although knowledge on the reproductive patterns is well known from several publications (Tyndale-Biscoe and MacKenzie 1976, Tyndale-Biscoe and Renfree 1987, Harder 1992, McAllan 2003, Monteiro-Filho and Cáceres 2006). The limited knowledge published on sexual maturity is mainly due to the difficulties in establishing correlations between chronological and dental age; the latter is determined by the sequence of tooth replacement (Astúa and Geise 2006). Some published reports (e.g., Atramentowicz 1986, Gentile et al. 1995, Astúa and Geise 2006) revealed an early onset of the reproductive period in some species of didelphids, where young or subadult specimens (based on tooth replacement) were sexually mature. According to Astúa and Geise (2006), early sexual maturity is a strategy related to the capacity to produce more than one litter during the highest productive season.

During a project developed in northeastern Peru, 3-year intensive surveys (December 2002 to December 2005) were carried out along the highway from Iquitos to Nauta and some localities near Iquitos on tributaries of the Amazon River (Loreto Department, Figure 1, modified map from Kalliola and Flores Paitán 1998). The climate of the study area is tropical, warm (average temperature 27.5°C), humid (annual mean humidity 85%) and rainy (annual mean precipitation 2700 mm) (Tafur Rengifo 2001).

Trap lines (500 m in length) were placed in different habitats (primary forest, secondary forest and rural areas). Each line contained 50 stations (10 m spacing) and each station included a Sherman and a Tomahawk trap. Traps were baited with peanut butter and oats, and several fruits. The specimens collected will be deposited in part at the Museo de Historia Natural de San Marcos, Lima, Peru and in part at the Colección Mamíferos Lillo, Tucumán, Argentina. The records reported in this paper correspond to 11 localities (Appendix), representing three types of habitats, tropical humid forest, secondary forest and flooded grassland ("gramalotal").

Reproductive condition was determined by external examination (development of mammae, lactation, pregnancy or offspring presence); pups were measured (crown rump, CR), their sex determined (when possible) and were then preserved in a freezer (-4°C). Standard external measurements were taken in millimeters and body mass in grams.

Classification of dental age was according to Tyndale-Biscoe and MacKenzie (1976), as the four studied species have *Didelphis* eruption pattern. In total, seven dental classes were established based on tooth eruption, replacement and wear. Molars were numbered from 1 to 4 and the deciduous premolar was assigned as dP3 and the permanent premolar as P3. In dental class 5, four specimens with slightly erupted M4 were included.

The χ^2-test with Yates' continuity for correction was used, according to Preacher (2001) to determine dependence between reproducing females and dental age.

A total of 360 specimens of didelphids were collected, including 164 females, of which 16 (of four different species) were sexually mature, but with incomplete dentition, and thus classified as subadults or young (Table 1).

In 11 female *Didelphis marsupialis* Linnaeus 1758, of which 9 were not adults (81.8%), only 2 specimens of these with early reproduction onset were collected. The χ^2-test was not significant (Table 2), but the sample was too small. It is important to note that larger specimens of *Didelphis* were captured by hand, as they did not enter the traps because of their small size. One specimen was a juvenile (dental class age 3) with two offspring in the marsupium, and another was a lactating subadult with two well-developed mammae (dental class age 4), these were collected in February and March, respectively (see Table 1). Previous data on this species recorded this phenomenon in even younger specimens with dental class age 2 and age 3 (see Atramentowicz 1986, Julien-Laferrière and Atramentowicz 1990).

For *Philander opossum* (Linnaeus 1758), previous records of this phenomenon were also reported (see Atramentowicz 1986, Julien-Laferrière and Atramentowicz 1990). In this study, 63 specimens were collected, 27 of which (42.8%) were not adults and 10 were reproducing earlier than usual. The χ^2-test indicates that the differences were highly significant (Table 2), so reproduction in this species is dependent on dental age. These include one specimen of dental class age 2 collected in March (Figure 2A), five of dental class age 3 collected in February, June, August and December, three of dental class age 4 collected in February and November, and one of dental class age 5 collected in February, and all sexually active (see details in Table 1).

Sexually mature female young and subadult specimens of *Metachirus nudicaudatus* (É Geoffroy 1803) and

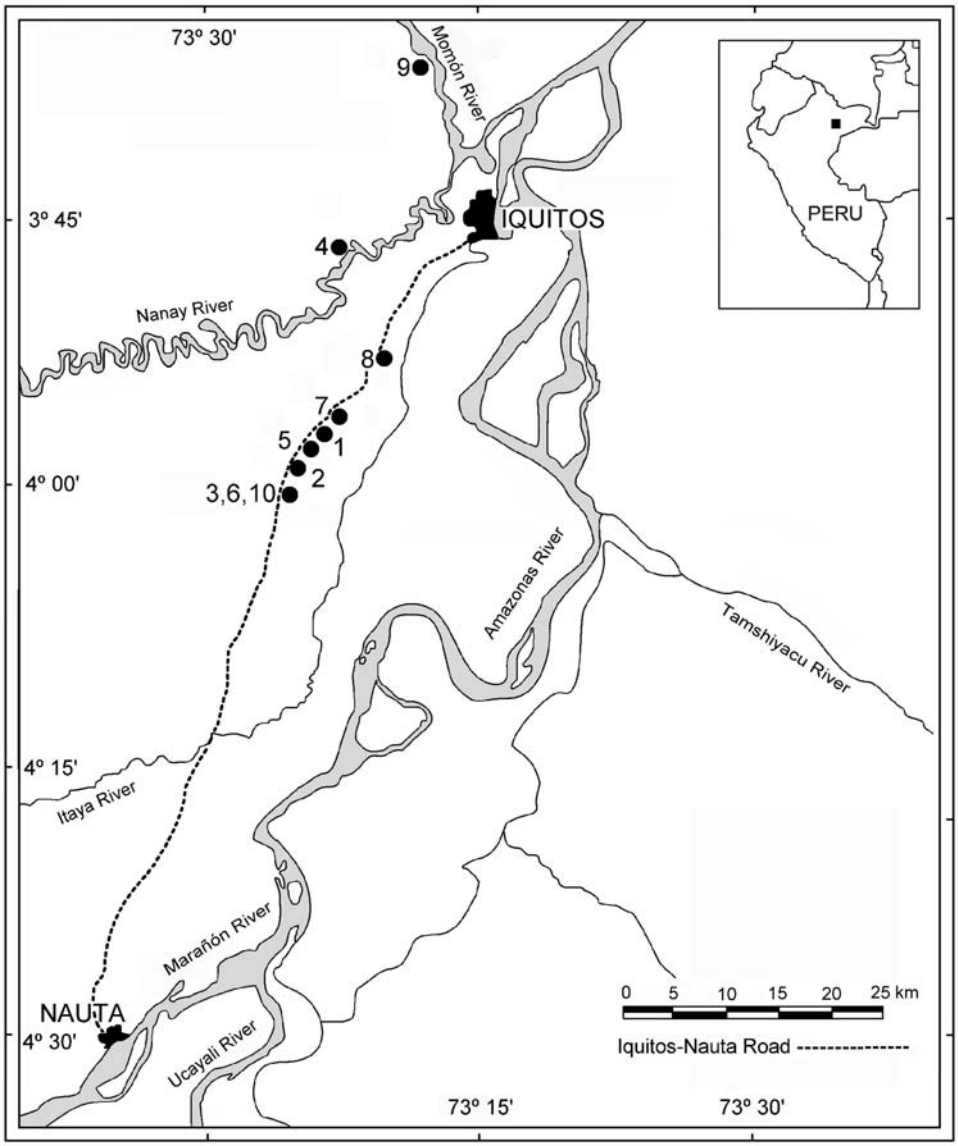

Figure 1 Map of the localities of the collected didelphids, see details of localities in Appendix A.

Philander andersoni (Osgood 1913) are reported here for the first time. In *M. nudicaudatus*, 19 specimens were captured, of which 11 were not adults (57.9%), and of which 2 were reproducing subadult specimens (dental class age 5), both with 9 offspring, 1 was captured in February and the other in June (Figure 2B). The χ^2-test was highly significant (Table 2).

In *Philander andersoni*, 5 females were collected, of which 3 were not adults and 2 of these were showing an early reproductive onset, and 1 (dental class age 3) was carrying four offspring (collected in March), and another 1 (dental class age 5) with two litters was collected in July. The χ^2-test was not significant (Table 2), but the sample was too small.

Several studies indicated that the reproductive season in didelphids is activated either by photoperiod (Farris 1950, Cerqueira and Bergallo 1993, Bergallo and Cerqueira 1994, Regidor and Gorostiague 1996, Cerqueira 2005, Monteiro-Filho and Cáceres 2006) or by humid season, which is considered the highest productivity season (Cerqueira 1984, O'Connell 1989, Julien-Laferrière and Atramentowicz 1990, Fleck and Harder 1995); although, latitude and altitude are also considered as factors that cause the onset of the reproduction season (Cerqueira 2005, Monteiro-Filho and Cáceres 2006). According to this, in tropical low latitudes reproduction would be continuous [e.g., *Didelphis marsupialis*, in the Valle de Cauca, Colombia (Tyndale-Biscoe and MacKenzie 1976); and *Philander opossum* and *Caluromys philander* in the primary forest in French Guyana (Julien-Laferrière and Atramentowicz 1990)], whereas in populations of higher latitudes, the length of the reproductive period diminishes and its start is activated by changes in seasons [Fleming 1973, Cerqueira 2005 (*Didelphis*)]. In our study area (Amazon forest in northeastern Peru, a tropical area), there is no marked rainy season (minimum 100 mm monthly, maximum 355 mm monthly), and our data suggest similar results as in other studies in tropical areas.

The observations of Julien-Laferrière and Atramentowicz (1990) in the French Guiana indicated that repro-

Table 1 Species of didelphids with early reproductive onset.

n	Date	Genus	Species	Reproductive condition	Age[a]	Molariform eruption	W	Habitat
2842	02-Feb-04	*Didelphis*	*marsupialis*	Lactating, 2 offspring (CR=28 mm)	3	dP3, M3 erupting	590	P
4653	02-May-05	*Didelphis*	*marsupialis*	Two well developed mammae and lactating	4	P3 present, M3	1030	P
1662	21-Jun-03	*Metachirus*	*nudicaudatus*	Lactating, 9 offspring (CR=20 mm)	5	P3 erupting, M4 erupting	260	S
4316	22-Feb-05	*Metachirus*	*nudicaudatus*	Lactating, 9 offspring (CR=18 mm)	5	P3, M4 erupting	280	P
3492	05-Jul-04	*Philander*	*andersoni*	Lactating, 2 offspring (CR=35 mm)	5	P3, M4 erupting	273	P
4453	16-Mar-05	*Philander*	*andersoni*	Lactating, 4 offspring (CR=29 mm)	3	dP3, M3 erupting	220	S
2676	03-Dec-03	*Philander*	*opossum*	Pregnant (2 fetuses)	3	dP3, M3	250	S-CA
2971	28-Feb-04	*Philander*	*opossum*	Lactating, 4 offspring (CR=30 mm)	3	dP3, M3	310	S
3375	05-Jun-04	*Philander*	*opossum*	Lactating, 4 offspring (CR=10 mm)	3	dP3, M3 erupting	220	S
3396	08-Jun-04	*Philander*	*opossum*	Lactating, Pregnant (2 fetuses)	3	dP3, M3 erupting	214	S
3830	12-Nov-04	*Philander*	*opossum*	Lactating, 3 offspring: 2 M-1 H (TL: 104 mm, W: 7)	4	P3, M3	300	CA
4285	17-Feb-05	*Philander*	*opossum*	Lactating, 4 offspring: 3 M-1 H (TL: 102 mm, W: 7.1)	5	P3, M4 erupting	400	S
4291	18-Feb-05	*Philander*	*opossum*	Lactating, 4 offspring: 2 M-2 H (TL: 115 mm, W: 8.25)	4	P3, M3	410	S
4315	22-Feb-05	*Philander*	*opossum*	Lactating, 2 offspring: 2 M (TL:161, W: 16 g)	4	P3, not M3	360	S
4479	18-Mar-05	*Philander*	*opossum*	Lactating, 4 offspring (CR=12 mm)	2	dP3, M2	202	S
4956	20-Aug-05	*Philander*	*opossum*	Developed mammae	3	dP3, M3	249	S

n, Field number (MMD); collection date; CR, crown-rump in mm; TL, total length in mm; W, weight in g; P, primary forest; S, secondary forest; CA, cultivated areas.
[a]According to Tyndale-Biscoe and MacKenzie (1976).

duction activity coincides with the period of food abundance. In fact, only 7 reproductive females of *Philander opossum* were captured in primary forest, while all other reproductive females (adult and not adults) were collected in secondary forest (Tables 1 and 2). This habitat has higher food availability than the primary forest for terrestrial forms, because there are more understory and pioneer plants, such as *Cecropia* and *Piper*, fruits that typically *P. opossum* consume (Castro-Arellano et al. 2000).

According to Astúa and Geise (2006), early reproduction onset is a strategy to maximize the number of litter in habitats with marked seasonality, *D. albiventris* being capable of producing two litters and two generations in one reproductive season. However, our data indicate that this phenomenon occurs independently of the seasonal weather, as sexually mature young or subadult females according to dental age are registered all year through (at least in *Philander opossum*, see Table 1) in the tropical forests. The early reproductive onset seems to be more frequent than previously reported for Didelphidae, and here two new species (*Metachirus nudicaudatus* and *Philander andersoni*) are added to the list of species where this phenomenon occurs. Our data confirm that sexual maturity can be reached before the completion of tooth replacement in females of several species of didelphid, having the possibility to produce more than one litter and more than one generation in the same reproductive season.

There is also a relationship between weight, dental age and sexual maturity. According to Cerqueira (1984), there is no minimum body size for females to start reproducing except age, as Cerqueira reported only pregnant females of dental class age 5 in *Didelphis albiventris* (of which one had a weight of 207 g). Tyndale-Biscoe and Mackenzie (1976) revealed a correlation between weight and dental classes 1 to 5 for *Didelphis marsupialis*, although they reported one female with pouch young weighing 240 g, and another weighing more than 500 g, both of dental class 4. In *Didelphis albiventris*, Astúa and Geise (2006) reported a pregnant female of age 2 weighing 320 g, and Regidor and Gorostiague (1996) described a pregnant female of age 3 weighing 740 g. On the other hand, our data show that reproducing females of different ages in *Philander andersoni* have similar weights (Table 1). These data demonstrate a high variation of weight not related to age and/or sexual maturity, as stated by Reynolds (1952) for *D. virginiana*. In addition, the fact that early reproduction onset had been recorded only in large opossums could be related to the body size of young or subadult females, allowing them to be more successful when breeding a litter.

Finally, our data confirm that females of didelphid maximize their reproductive capacity in areas with continuous optimal conditions, as in the Iquitos region, an equatorial zone with no marked seasonal rain. Thus, the females' strategy resides in a continuous reproductive period at low latitudes, whereas early reproductive onset occurs independently of latitude and seasonality. The correct determination of reproductive age in didelphid females, as well as the knowledge of variation on the reproductive patterns, is significant in order to analyze population parameters, which are important for ecological and conservation studies.

Table 2 Reproductive female of each species (χ^2 between adult and not adult reproductive (R) and not reproductive).

Species	Total	Adult	R	Not adult	R (% not adult)	χ^2	p
Didelphis marsupialis	11	2	2	9 (81.8%)	2 (22.2%)	1.577	0.209
Metachirus nudicaudatus	19	8	8	11 (57.9%)	2 (18.2%)	9.37**	0.0069
Philander andersoni	5	2	2	3 (60%)	2 (66.6%)	0.052	0.819
Philander opossum	63	36	35	27 (42.8%)	10 (37%)	24.515**	<0.0001

**Differences are highly significant. The Yates' correction was used in all cases.

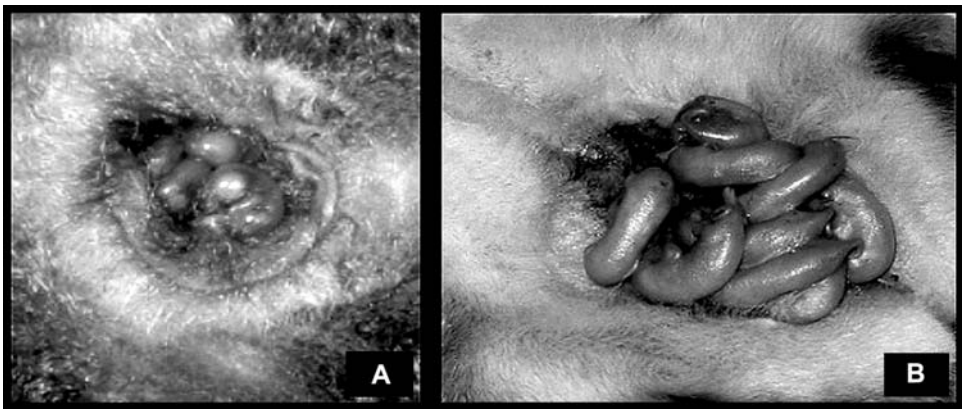

Figure 2 (A) Pouch young (CR=12 mm) in a juvenile female of *Philander andersoni* (MMD 4479). (B) Subadult female of *Metachirus nudicaudatus* (MMD 4316) with nine offspring (CR=18 mm).

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Appendix A

Collected localities (district in parentheses), geographic coordinates and type of habitat.

1. 1 km E km 25.3 de la carretera Iquitos-Nauta, Fundo San Martín (San Juan) 3° 57.954′ S 73° 24.259′ W – Tropical humid forest.
2. ca. 500 m E km 28.8 de la carretera Iquitos-Nauta (San Juan) 3° 59.227′ S 73° 24.920′ W – Secondary forest.
3. Camino a El Paujil, 1.8 km al W del km 35 de la carretera Iquitos-Nauta (San Juan) 4° 01.217′ S 73° 26.787′ W – Tropical humid forest.
4. Caserío Santa Sofía, 500 m W (San Juan) 3° 46.642′ S 73° 21.516′ W – Secondary forest.
5. El Dorado, km 25 de la carretera Iquitos-Nauta, ca. 1.5 km al E (San Juan) 3° 58.010′ S 73° 23.620′ W – Secondary forest.
6. Ex Petroleros, 300 m W km 39.8 de la carretera Iquitos-Nauta (San Juan) 4° 04.740′ S 73° 27.180′ W – Tropical humid forest and secondary forest.
7. km 22.7 de la carretera Iquitos-Nauta (San Juan) 3° 56.371′ S 73° 23.710′ W – Ecotonal area between secondary forest and cultivated fields.
8. Ninarumi, 7.4 km al W y 1 km al SE del km 6 de la carretera Iquitos-Nauta (San Juan) 3° 50.990′ S 73° 22.436′ W – Tropical humid forest.
9. Padrecocha (Punchana) 3° 41.490′ S 73° 17.120′ W – Secondary forest.
10. Paujil, W km 37.45 de la carretera Iquitos-Nauta (San Juan) 4° 03.527′ S 73° 26.535′ W – Flooded grassland.
11. Santo Tomás, 6 km al W del km 1 de la carretera Iquitos-Nauta (San Juan) 3° 48.581′ S 73° 20.288′ W – Secondary forest.

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