The use of disturbed and undisturbed forest by masked titi monkeys *Callicebus personatus melanochir* is proportional to food availability

Stefanie Heiduck

Abstract The masked titi *Callicebus personatus melanochir* is a threatened primate, endemic to the Atlantic rainforest of eastern Brazil. The Atlantic rainforest has been reduced to only 5% of its former extent, and only 2% consists of undisturbed forest. The survival of the masked titi monkey is therefore dependent on its ability to utilise disturbed forest habitat. A group of four masked titi monkeys was observed for one year in a plot that contained both disturbed and undisturbed forest. The group used a home range of 22 ha, which comprised 58% undisturbed forest, 31% selectively logged forest and 11% forest that was regrowing after a clear-cut. The titi monkeys did not use the different forest types in proportion to the availability of each within their home range: undisturbed forest was used more than expected from its proportional availability, and disturbed forest was used less than expected. Use of forest types appeared to be determined by the availability of food resources. Undisturbed forest had the most food per unit area and regrowing forest had the least. This study shows that masked titi monkeys may be able to survive in disturbed forest habitats if these areas are of high enough quality to contain sufficient food and other resources.

Keywords Atlantic rainforest, Brazil, *Callicebus personatus melanochir*, disturbed forest, food resources, habitat use, masked titi monkey.

Introduction

Habitat disturbance is one of the main causes of the extinction of primate species living in tropical rainforests (Cowlishaw & Dunbar, 2000). The capacity of primates to adapt to disturbed habitats is therefore critical for their survival. Studies of the impact of forest disturbance on primates have focused mainly on population densities (Bernstein *et al*., 1976; Johns & Skorupa, 1987; Ganzhorn, 1995; Rosenbaum *et al*., 1998) rather than on comparisons of primate behaviour in disturbed and undisturbed habitat (Johns, 1986). Primate population densities are determined mainly by habitat quality (Oates *et al*., 1990; Peres, 1997), and one of the most important aspects of this in disturbed habitat appears to be the availability of food resources (Johns & Skorupa, 1987).

The masked titi monkey *Callicebus personatus* is endemic to the Atlantic rainforest of eastern Brazil, one of the world's most threatened ecosystems (Myers *et al*., 2000). Of the original 1,000,000 km^2 of forest only 5% remains, 2% is undisturbed and $<0.1\%$ is protected in parks and reserves (Myers, 1988). The Atlantic rainforest has extraordinarily high levels of biodiversity and endemism (Fonseca, 1985; Brown & Brown, 1992), but it is also the agricultural and industrial heart of Brazil, as well as its population centre (Mittermeier *et al*., 1989). Many of the primates in the Atlantic rainforest are threatened and endemic (Mittermeier *et al*., 1982; Santos *et al*., 1987; Rylands *et al*., 1995).

Titis, genus *Callicebus*, are medium sized monkeys weighing approximately 1.5 kg. They are territorial and live in groups of 2–5 individuals, consisting of a breeding pair and their non-reproductive offspring (Kinzey, 1981). Masked titi monkeys are mainly frugivorous (Kinzey & Becker, 1983; Heiduck, 1997). Four subspecies of *Callicebus personatus* (*C. p. barbarabrownae*, *C. p. melanochir*, *C. p. personatus* and *C. p. nigrifrons*) occur in the Atlantic forest (Hershkovitz, 1990). Recently a new member of the *personatus*-group, *Callicebus coimbrai*, was described by Kobayashi & Langguth (1999), who suggested that all taxa of the *personatus*-group should be given species status. However, in this paper I follow the classification of Hershkovitz (1990).

The subject of this study was the south-east Bahian subspecies *C. p. melanochir*. It ranges from the south of Rio Paraguaçu to the Rio Mucuri (Fonseca *et al*., 1994) (Fig. 1). It borders the range of *C. p. personatus* in the south and *C. p. barbarabrownae* in the north-west. The north-eastern area up to Rio São Francisco was formerly considered to be part of the range of *C. p. melanochir* but is now recognized to be the range of *C. coimbrai* (Fonseca *et al*., 1994).

C. p. melanochir is categorized as Vulnerable on the 2000 IUCN Red List (Hilton-Taylor, 2000), based on

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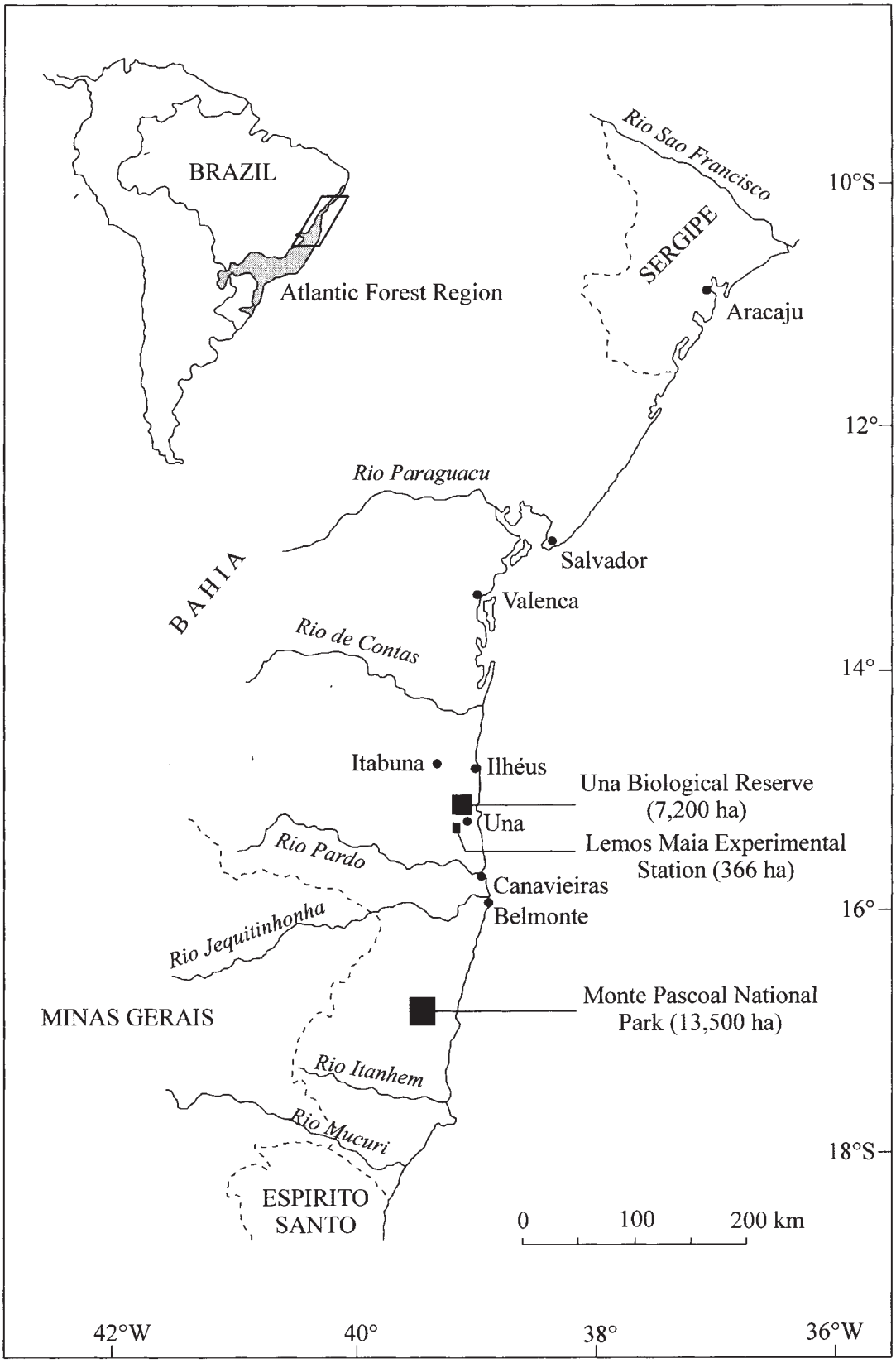

Fig. 1 The distribution of *Callicebus personatus melanochir*, which ranges from Rio Paraguacu to Rio Mucuri (see text for details), in the Atlantic rainforest of eastern Brazil (map modified from Oliver & Santos, 1991).

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criteria A1c and B1 + 2c, i.e. a deline of ⩾20% over the last 10 years or 3 generations, and extent of occurrence <20,000 km² or area of occupancy <2,000 km², respectively. A reassessment to Endangered has been proposed because of the species's sporadic occurrence within its range (Oliver & Santos, 1991; Fonseca *et al*., 1994). At present the species occurs in only three reserves: Monte Pascoal National Park, Una Biological Reserve and Lemos Maia Experimental Station (Fig. 1).

Little is known of the population densities of masked titi monkeys, and data on the species obtained from transect censuses are highly variable and often unreliable (Stallings & Robinson, 1991; Pinto *et al*., 1993). Although several studies have shown that *C. personatus* occurs within disturbed forest (Rylands, 1982; Santos *et al*., 1987; Stallings & Robinson, 1991; Pinto *et al*., 1993), no detailed data are available on home range size and forest types used.

In this paper I present data from a study of a group of masked titi monkeys ranging in a mixed disturbed and undisturbed forest. I address the question of whether the use of different forest types is determined by the relative availability of each forest type or by the availability of food resources within the different forest types. I also discuss what other factors may influence habitat use and to what extent titi monkeys may be capable of utilising disturbed forest.

Methods

The study was conducted in the Lemos Maia Experimental Station (15°20′S, 39°05′W) in the south-eastern part of the state of Bahia, near the town of Una (Fig. 1) during 1994 and 1995. The study site was a forest fragment of *c.* 80 ha, owned by the local cocoa growing authority Commissão Executiva do Plano da Lavoura Cacaueira (CEPLAC), and part of a larger protected area of 366 ha. The fragment was surrounded by pasture. The northern border was a clearing in early succession that could serve as a future corridor for migration of animals between fragments. Oliver and Santos (1991) described four primate species still occurring in south-east Bahia: the golden headed lion tamarin *Leontopithecus chrysomelas*, Wied's tufted-ear marmoset *Callithrix kuhlii*, the masked titi monkey and the yellow breasted capuchin monkey *Cebus xanthosternos*. Only the three smaller species, the lion tamarin, the marmoset and the titi monkey, were seen in the study area.

From vocalisations it was evident that four groups of masked titi monkeys were living in the forest fragment at the time of this work. The study group consisted of one male, one female and two offspring (born in September 1993 and September 1994). The group was the subject of behavioural observations for two years prior to the beginning of this study (Müller, 1996), and was therefore well habituated. All animals could be identified individually.

The ranging area of the study group was accessible by a trail system, and included 1,500 labelled and mapped trees. Three forest types were found within this area: undisturbed, selectively logged and regrowing. The undisturbed forest showed no obvious signs of anthropogenic influence. The selectively logged forest had been formerly used for the extraction of building timber, and trees with diameters at breast height (dbh) of 3–20 cm had been removed. The regrowing forest was regenerating after a clear-cut carried out *c.* 15 years earlier. Three 20 × 20 m vegetation plots were set up in each forest type, nine vegetation plots in total, and each tree with dbh >3 cm was marked, measured and identified to at least family level.

Behavioural data were obtained from April 1994 to April 1995, except for July 1994. The study group was observed for one day each week from dawn to dusk, for a total of 47 days over the 12 months, using the instantaneous scan sampling method (Altmann, 1974). Every 5 minutes the activity of each group member was recorded as one of the following behavioural categories: locomotion, rest, feeding, play and social behaviour. Only the feeding data are analysed here. Feeding was defined as manipulation and ingestion of food items. Following the scan the location of the study group was determined relative to the labelled and mapped trees. The study area was divided into a 50 × 50 m grid and each square was assigned to a forest type based on the vegetation at its centre. The home range of the group was considered to include all squares in which the group was recorded at least once.

Residence and feeding times were used to estimate the relative use of the different forest types by the masked titi monkeys. Residence time, calculated from the 5-minute instantaneous scan samples of group location, was the percentage of daily active time the group spent within a forest type, regardless of the specific behaviour of individuals. Feeding time was the group mean time spent feeding in each forest type, calculated from the scan samples of individual activity. Some of the behavioural data were missing because individuals were sometimes obscured by vegetation at the moment of the instantaneous samples. These missing values comprised 21.8% of the observations in undisturbed forest, 15.1% in selectively logged forest and 21.9% in regrowing forest. The total number of feeding events in each forest type per individual per observation day was estimated by assuming that the activity categories of missing values were distributed in the same way as the behaviour actually observed within each forest type. There were no missing values for the location of the

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group because the titis did not move very fast and the 50×50 m square in which they were located could always be determined.

Total residence time in each forest type was calculated from group location records summed over the year, and total feeding time was calculated from the sum of the group mean feeding times. In the latter case group means were calculated before the yearly totals because group size changed as the result of the birth of an infant. This new individual was included in the observations when it ceased breastfeeding.

The availability of the three forest types was determined by calculating the proportion of 50×50 m squares of each forest type within the home range. The basal area ($A = \pi(dbh/2)^2$) of trees from plant families known to be used by the study group was taken as an indication of food availability. Basal area was correlated with crown volume in the nine vegetation plots ($r = 0.75$, $n = 917$, $P < 0.01$) and a similar correlation has been shown in other studies (Chapman *et al.*, 1992). The proportional contribution of each forest type to the total food resources in the home range (i.e. food availability) was calculated using the total basal area of potential food trees in the three vegetation plots of each forest type (1,200 m^2) and the proportion of each forest type in the home range.

Differences between food availability and observed use were explored with χ^2 tests, using the proportional availability of the forest types and the proportion of food resources occurring in each forest type as expected values. Statistics were performed with Statistica 5.0 (Stat. Soft Inc., 1996).

Results

The study group used a home range of 22 ha during the 12 months. Fifty eight per cent consisted of undisturbed forest, 31% of selectively logged forest and 11% of regrowing forest (Fig. 2). The characteristics of the forest types and the size distribution of trees by dbh class are given in Table 1 and Figure 3, respectively.

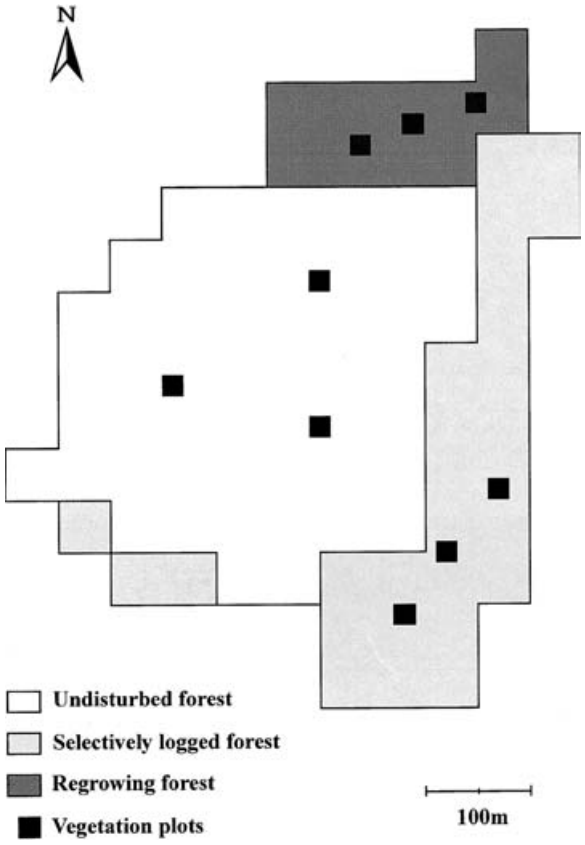

Fig. 2 Home range of the study group, with distribution of forest types and locations of the nine 20×20 m vegetation plots.

Residence time in undisturbed forest was greater than expected from the availability of forest types, and lower in selectively logged and regrowing forest ($\chi^2 = 15.01$, df = 2, $P < 0.001$; Fig. 4). Time spent feeding within the individual forest types also differed from the availability of the forest types ($\chi^2 = 10.97$, df = 2, $P < 0.01$) but in a way that was expected from residence time ($\chi^2 = 0.68$, df = 2, $P < 0.71$).

The masked titi monkeys fed from trees of 26 plant families during the study period. Twenty-five of these families were found within the vegetation plots. The

Table 1 Characteristics of the three forest types found within the home range of the study group.

	Undisturbed forest	Selectively logged forest	Regrowing forest
Predominant vegetation	trees	trees and shrubs	shrubs and small trees
Canopy	relatively closed	open	none
Maximum height of vegetation	20–30 m	up to 25 m	5–10 m
Density of undergrowth	low	medium	high
Density of epiphytes	high	medium	low
Mean no. of trees ha^{-1} (dbh > 3 cm)	3,316	2,216	3,432
No. of tree families	40	40	37
Predominant tree families	Myrtaceae, Sapotaceae, Arecaceae	Moraceae, Sapotaceae, Nyctaginaceae	Melastomataceae, Euphorbiaceae, Arecaceae

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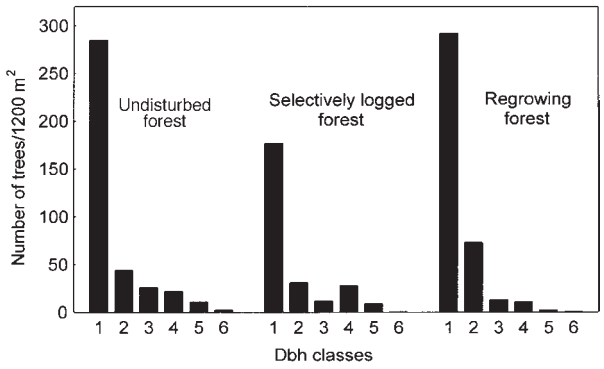

Fig. 3 Density of trees of six dbh classes in the vegetation plots (see Fig. 2) in the three forest types. Dbh classes: 1 = 3–9.9 cm, 2 = 10–14.9 cm, 3 = 15–19.9 cm, 4 = 20–29.9 cm, 5 = 30–49.9 cm, 6 >50 cm.

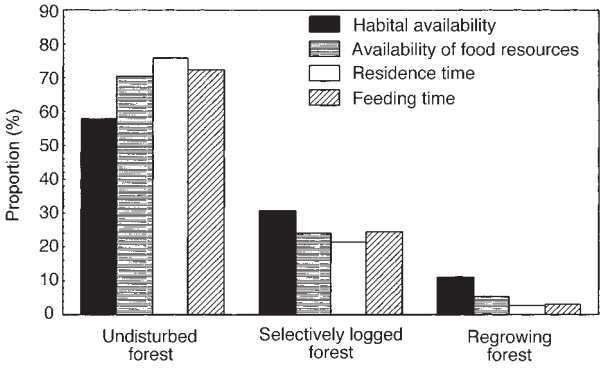

Fig. 4 Proportional habitat availability, availability of food resources, and residence and feeding times of the study group in undisturbed, selectively logged and regrowing forest.

highest basal area of potential food trees was in the undisturbed forest (34.0 m^2 ha^{-1}), followed by selectively logged (23.1 m^2 ha^{-1}) and regrowing forest (15.4 m^2 ha^{-1}). Residence time ($\chi^2 = 1.99$, df = 2, $P < 0.37$) and feeding time ($\chi^2 = 1.06$, df = 2, $P < 0.59$) were proportional to the relative food availability within each forest type (Fig. 4).

Discussion

The group of masked titi monkeys used two types of disturbed forest: a selectively logged forest and a forest that was regrowing 15 years after a clear-cut. The majority of their home range, however, consisted of undisturbed forest. The use of forest types, both for feeding and for general residence, was not determined by the proportional availability of these forest types within the home range. Rather, it seemed to be determined by the availability of food resources, which was lower in selectively logged than in undisturbed forest and lowest in regrowing forest. Use of undisturbed forest was therefore higher than expected from its extent in the home range, and the use of disturbed forest was lower.

Many primates are threatened by habitat loss and disturbance, and their response to these changes will be essential for their survival (Cowlishaw & Dunbar, 2000). Johns & Skorupa (1987) demonstrated that species' survival in disturbed habitats is negatively correlated with a high degree of frugivory. The densities of folivorous primates, however, may increase with moderate forest disturbance (Ganzhorn, 1995). The responses of primates to disturbance are influenced by species specific characteristics, as well as the nature and level of disturbance (Marsh *et al.*, 1987). The masked titi monkeys in this study used the two disturbed forest types according to the availability of food resources. The results of this study suggest that if masked titi monkeys were to range only in selectively logged forest their home range would need to be *c.* 28 ha if it were to contain similar levels of potential food resources as the 22 ha of territory in mixed disturbed and undisturbed forest. In regrowing forest the titi monkeys would need >40 ha. The selectively logged forest may therefore serve as a suitable habitat for this species, but a territory of 40 ha of regrowing forest is likely to exceed the energy budget of the titi monkeys for food searching and territorial defence. However, only small trees were removed during the selective logging operation; the removal of larger trees would have a greater effect on the availability of food resources and affect the ability of the titi monkeys to utilise selectively logged forest. Similarly there is no information available about the tree species that had been removed from the study area, but 14 of the tree species used as food by the masked titi monkeys in this study are commercial timber species in south-east Bahia. The titi monkeys in this study spent 19% of their feeding time over the year on these particular species (Heiduck *et al.*, 1996).

Although food availability appears to be the major factor influencing habitat use by masked titi monkeys, other habitat variables may also be important. Firstly, the structure of the vegetation may be important for locomotion (Ganzhorn, 1993). Tree density in the selectively logged forest was lower than in undisturbed forest and there was an open canopy, probably resulting in higher energetic demands for travelling. Secondly, the vegetation is important as a shelter against predators, especially the availability of suitable sleeping trees. The masked titi monkeys of this study were highly selective in their choice of sleeping trees: they used only six individual trees, five of which were located in the undisturbed forest and one in the selectively logged forest. The sleeping trees were taller than the average canopy and had dense foliage. Trees of this form may

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be scarcer in the selectively logged forest, and there were no trees with these characteristics in the regrowing forest.

Sustainable selective logging has often been cited as a way to maintain habitat for threatened species while satisfying the economic needs of human populations, especially where protected areas are of insufficient size to ensure the survival of many species (van Schaik & Terborgh, 1993; Johns, 1997; Kramer *et al*., 1997). However, this study showed that not all kinds of disturbed forest are useful as conservation areas for masked titi monkeys because nutritional or other needs may not always be satisfied. It appears that the capacity of masked titi monkeys to use disturbed forest depends on the level of disturbance and/or the quality of remaining forest. Forest quality is therefore a crucial factor for the conservation of masked titi monkeys, and their capacity to survive in disturbed forests will be crucial for the survival of the species.

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Biographical sketch

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